

DESIGNING THE

FUTURE

DESIGNING THE



ECONOMIC, SOCIETAL AND POLITICAL DIMENSIONS OF INNOVATION

**AUSTRIAN COUNCIL FOR RESEARCH
AND TECHNOLOGY DEVELOPMENT**

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INTRODUCTION: DESIGNING THE FUTURE

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The Council for Research and Technology Development is the central advisory body of the Austrian Government for education, science, research and innovation policy affairs. On a legal basis, it works out precise, implementation-oriented recommendations for specific policy areas in its scope of responsibility, and, as commissioned by the Austrian Council of Ministers, compiles an annual report on Austria's scientific and technological performance. The Council, however, does not see its role merely as an incentive provider for the specified policy fields. Far more to the point it also wishes to deal with topics and issues from its work area that transcend daily policy requirements, which increase the understanding of historical developments, current processes, and future requirements. This aim was also the background basis for the genesis of this book.

The book is entitled *Designing the Future: Economic, Societal and Political Dimensions of Innovation*. It is designed as a collected volume and its objective is to illustrate 'innovation' from the most diverse perspectives. The key role in particular of technical innovations for the constitution of human societies – as outlined by the technology researcher Ernest Braun in his essay, 'From Need to Greed' (2010) – is expressed to this day by the fact that entire ages and eras of the history of humanity are defined by the prevailing technologies applied in them (Braun, 2010, 6).

These *General Purpose Technologies* not only dominate the economy at a national or global level, but also influence social and political structures in particular (Lipsey et al., 2006, 93ff.). According to the economist Richard Lipsey (2006, 85ff.), 24 of these *General Purpose Technologies* can be defined over the course of history. The list ranges from the emergence of writing to printing and the steam engine through to

electricity, computer technology or the internet.¹ It is not always entirely clear here whether technical innovations cause social changes, or whether social innovations are first required so that technical innovations can succeed. In most cases, both are arguably conditional on each other. The individual contributions of this book aim to discuss the different dimensions of innovation in the past, the present and their relevance for the world in the 21st century. The first part of the book begins with the Enlightenment in Europe, the 'invention' of invention and progress, and the development of the key institutions of the knowledge society, and consequently the 'Unbound Prometheus' (Landes, 1986). The second part focuses on the modern development conditions of innovations as we know them today. And in the third part an attempt is made to hazard a look into the future and sound out possibilities, and to examine what role research and innovation might have in the future for the economy and society, and how the future can be rethought and restructured.

The objective of the book is to provide food for thought and promote debate on the topic of innovation beyond the strict boundaries of the politics of the day. The fact that this is not merely a purpose-free, intellectual discussion is evidenced by the specific implications for RTI issues included in all contributions. Secondly, it is also illustrated here that only a sound examination of the emergence conditions of innovation in history and in today's world will provide the basis for future-oriented political decision-making. The focus of a large part of these contributions is therefore on the future requirements of and for innovation. Let us begin with a brief look back at history.

¹ Not mentioned here are the innumerable small innovations used every day, from needles and screws through zips to paper clips or punchers. Small innovations find their way into everyday life not through dramatic and spectacular events, but mostly through gradual and inconspicuous processes (see also Glatzer, 1999, 178ff.).

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BRIEF OUTLINE OF THE HISTORY OF INNOVATION, FROM THE DAWN OF HUMANITY TO THE MODERN AGE

In his essay 'All Life is Problem Solving' (1991), the British-Austrian philosopher Sir Karl Popper argues that inventions and technical aids are an essential feature of living organisms – for humans and animals alike. Different organisms are, of course, better or worse at this and more successful or less successful. At any rate, in its attempt to meet challenges and solve problems with the invention of technical aids, humankind has achieved a certain perfection. This is why the history of human civilisation is at the same time the history of a chain of ever quicker successive and mostly technical innovations, which also have social, economic or political consequences (see Braun, 2010; Harari, 2013).

Necessity and want are responsible for this on one hand. 'Necessity is the mother of invention', as we say with good reason. Already at the dawn of the *Homo sapiens*, the need to satisfy basic human requirements – such as food, protection against the cold or security and therefore ultimately the assurance of survival – led to the discovery of the usefulness of simple technical aids and tools (Braun 2010, 9ff.). In all probability, coincidence and the trial-and-error principle played an important role here (Diamond, 1997, 245ff.).

On the other hand, there is a basic instinct of humankind, which has characterised and defined it from the very beginning, and which drives the innovation spirals further and further – curiosity. Astonishment of the unknown or amazement 'of the closest unexplained' as Aristotle describes it in his *Metaphysics* (see Liessmann, 1997, 25ff.), has spurred the human on since time immemorial. Eagerness for knowledge and striving to achieve the 'new' are therefore at the root of humankind's cultural development (see Nowotny, 2005, 35ff.).

This striving has accompanied humanity since, as related to us in Greek mythology, Prometheus brought fire from Olympus, although forbidden to do so, and taught

man how to use it. As we know, Zeus severely punished Prometheus for his actions.² Along with curiosity, another basic constant of human behaviour also played a significant role in the emergence of innovations: aggression and violent confrontations (see Harari, 2013, 80ff.; Lorenz, 1981, 30ff.). Since day one, war has clearly been part of human societies, as proven by archaeological and anthropological findings (Harris, 1990, 46ff., Morris, 2013, 14ff.). Whether or not war is truly the 'father of all things', as related by Heraclitus, is anyone's guess. The fact is, however, that a plethora of technical innovations have been developed for the purpose of waging war, or used after their development for military purposes (Diamond, 1997; 250f.; Harris, 1990, 107; Morris, 2013, 105ff.). And as we will see, it was the 'scientific-military-industrial complex' (Harari, 2013, 342) which ultimately brought about the industrial revolution and its consequences in a significant way. Little wonder then that the emergence of Silicon Valley, which today stands as a global, model region for innovation culture, was and is immediately connected with military-technological research (Leslie, 2000; 48ff.; Sturgeon, 2000, 15ff.), or that the Pentagon continues to be by far the greatest promoter of research and development in the USA (see AAAS, 2015, 61).

British historian Ian Morris has another explanation for the motor of history: in his epochal work 'Why the West Rules – for Now' (2010) he argues that technical innovation and accompanying social change have always been and always will be motivated by an essentially lazy human searching for easier and more convenient solutions. The consequences of this were and are still mostly unforeseeable, and occasionally also led to unintended developments, the nuclei of which are installed in every innovation, because the solution of specific problems can release forces that undermine this solution and in turn cause entirely new problems (Morris, 2010,

² See also the detailed illustration in *Reclams Lexikon der antiken Mythologie*, 1991, 455f.

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28, 560). At any rate, the sum of all these changes, of the erection and conversion of even more new complex structures, is what we today describe as the history of our global civilisation.

In his work *Eine kurze Geschichte der Menschheit* ('A Brief History of Humanity', 2013), Israeli historian Yuval Harari illustrates the profound changes, revolutions indeed, that (technical) innovations have occasionally effected. Three major revolutions in particular were of eminent importance here (the first of which admittedly was not due to any technical innovation, but rather owed its existence more to a coincidental gene mutation): the cognitive revolution, which around 70,000 years ago led to the development of language and with it the rise of *Homo sapiens*, and ultimately marked the beginning of 'our' history; the agricultural revolution, which approximately 10,000 years ago radically changed mankind's way of life, and the consequences of which are still being felt today – because to date the global calorie requirement can be covered more than ninety per cent by the plant types domesticated at that time (see Harari 2013, 102; Diamond 1997, 128) and, finally, the scientific revolution, whose foundation was laid approximately 500 years ago, and whose continued course through the industrial revolution into the digital revolution has provided us with today's knowledge society.

For some time human inventions were attributed to coincidence or arose from direct needs and requirements. Innovations were therefore quasi by-products of human behaviour, such as the taming of fire, the discovery of bones or stones as technical aids, from which, over time, flints, knives or needles were produced, or the invention of the wheel (see Diamond, 1997, 246f.; Lipsey et al., 2006, 55ff.). The development of the basis for the agricultural revolution in the Neolithic Age (i.e. the domestication of plants and animals) appears to have emerged in all probability in a gradual and coincidental way (see Diamond, 1997, 93ff., 105f.; Harari, 2013, 37; Lipsey et al., 2006, 137ff.). The main factors responsible for this were global climate warming after the

end of the Ice Age, the extinction of large animal stocks in the Mesolithic Age and the resulting pressure to adjust, which necessitated a nutritional shift to compensate for the falloff in the production of animal proteins with plant proteins (Harris, 1990, 32ff.; Morris, 2010, 81ff.).

As humanity had lived through the greatest part of its history up to that point in smaller groups of hunters/gatherers, the agricultural revolution effected the most radical transformation in the human way of life with the change in production conditions and the resulting sedentarism. The cultivation of plants meant more calories per surface area, which caused a genuine population explosion. While before the beginning of the Neolithic revolution, over millennia approx. one to maximum five million people lived on the earth, the number rose to some 250 million by the beginning of the modern calendar (Diamond, 1997, 92; see Harari, 2013, 126; Harris, 1990, 26, 45). This swift population growth was, however, also accompanied by a deterioration in nutritional quality and an increase in disease and the emergence of epidemics (see Diamond, 1997, 203f.; Harari, 2013, 104f.; Harris, 1990, 25, 37ff.).³

The rise in population numbers led to the gradual formation of larger social structures, which in turn necessitated an entirely new type of information and its dissemination: data and numbers (see Harari, 2013, 155). The old Mesopotamian cultures were the first to begin developing a system to make bookkeeping easier and to document harvest yields (see Lipsey et al., 2006, 144ff.). Over the course of time, this developed into the first known form of writing. At the beginning of the development of writing we consequently see a specific practical benefit as one of the most important

³ Compared to later eras, Stone Age man obviously enjoyed far better food and living standards (Harari, 2013, 104; Harris, 1990, 18f.; Sahlin, 1972, 35). Archaeological evidence proves that Stone Age hunter/gatherers lived healthier, were ill less and showed higher levels of healthiness than following generations. Clear proof of this is the fact that the average growth of people of the Palaeolithic Age was only reached again in the 1960s (Harris, 1990, 25).

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innovations of all time (see Fara, 2010, 10f.; Morris, 2010, 181): The oldest texts of humanity include, as Harari writes, neither profound philosophical knowledge nor poems, legends, laws or heroic epics. Rather, they are entirely everyday recordings of business life, such as tax payments, debt securities and deeds of ownership (Harari, 2013, 158).

With the development of writing, the foundation was laid for the development and organisation of more complex, stratified societies (Diamond, 1997, 234ff.). Once established, this innovation led, however, to an (at first unintended) recording of myths, religious stories, medicinal knowledge or observations of the skies. At the same time, mathematical, astronomical and other knowledge, which defines our worldview right up to the present day, could now also be recorded. Many of our current ways of thinking, and also the sciences, are based – as illustrated by the English science historian Patricia Fara in her book *Science: A Four Thousand Year History* (2010) – on technologies and ideas that have their origin in antiquity and are passed on in writing. Our current division of time into weeks with seven days or hours with sixty minutes, each with sixty seconds originates in Babylon. Mathematical or geometrical principles – such as the idea that a circle has 360 degrees – go back to a millennia-old system developed by Babylonian land surveyors and bookkeepers (see Fara, 2010, 13).

Unlike the development of writing, the discovery of bronze did not evolve on the basis of a specific problem. It is seen as a coincidental but logical step in a longer history of incremental improvements of a metal already used since the Stone Age (Lipsey et al., 2006, 151). The development of steel and iron, on the other hand, was the result of necessity. Important centres of advanced Bronze Age cultures collapsed during the transition to the Iron Age, which resulted in the collapse of existing trade networks. The very rare tin required for bronze production was therefore no longer available in many places. Iron ore was indeed known earlier, but its processing only became

interesting with the absence of tin and the resulting search for alternatives (Morris, 2010, 233; Lipsey et al., 2006, 155). Extremely differentiated work processes were already required for the production of bronze and iron. The establishment of entirely new occupational groups followed, for mining, transport and processing in continuously further developed furnaces. The social, economic or political changes that accompanied the establishment of these new (cultural) technologies were also correspondingly great – even if their dissemination in places ranged across centuries, as in the case of iron (see Lipsey et al., 2006, 151ff.). The rise of the Persian Empire in the 6th century BCE coincides more or less with the consistent use of iron for the development of a superior weaponry technology (Morris, 2010, 245ff.). The swift expansion of the Persian Empire was first arrested by the Greeks at the beginning of the 5th century Before Common Era. They had developed higher performance furnaces and innovatively further developed the skill of iron forging (Lipsey et al., 159f.). Combined with an improved weaponry and war technology (Meier 2009, 184, ff.) and supported by an unprecedented social and political reorientation, the allied Greek city-states defied the far superior Persian forces (Meier 2009, 36ff.) Subsequently it was, among other factors, ever newer, increasingly innovative weapons and accompanying military combat techniques that effected the emergence and the downfall of empires (see Diamond, 1997, 241; Harris, 1990, 45ff.; Morris, 2013, 144ff.). During the last two and a half millennia, the empire that secured its power through military dominance was the dominating system of government, and most people lived in one of these 'global empires' (Harari 2013, 235ff, Morris 2013, 85ff.).

There were also technological innovations in periods which we today usually consider not particularly innovative historical eras. Agrarian production, for example, was innovatively revolutionised in the Middle Ages with the further development of the plough and the introduction of three-field crop rotation (Braun, 2010, 47f.; Lipsey et al., 2006, 161; Landes, 1999, 41). The widespread use of the water wheel, introduced

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especially for the operation of mills – originally already invented by the Romans, but never used in numbers worth mentioning – was one of the foundation stones for the road to mechanisation and therefore also one of the basic requirements for the later industrial revolution (Diamond, 1997, 359; Landes, 1999, 45f.; Lipsey et al., 2006, 167). These innovations were primarily developed to compensate for the absence of workers, which had been replaced in the Roman Empire by slaves (Braun, 2010, 61; Lipsey et al., 2006, 161, 165).

In addition to a number of other inventions, such as windmills, glasses, the sextant, the compass or three-mast sailing ships, the European Middle Ages also for the first time saw the development of firearms (Braun, 2010, 61; Landes, 1999, 52f.). In the 14th century, an important foundation stone was consequently laid for the conquests of the conquistadors and Europe's later global dominance (Diamond, 1997, 74ff.; Harari, 2013, 340ff.; Landes, 1999, 29ff.). This far-reaching innovation was not a genuine European innovation but merely the further development of an invention that had reached Europe from China on the trade routes across Mongolia and Arabia (see Morris 2010, 396). The Arabs had made use of the Chinese invention of black powder, which in its country of origin had, despite some attempts, never been used for war-ring purposes until then (Diamond, 1997, 247).

FROM COINCIDENCE TO SYSTEM:

THE EMERGENCE OF THE KNOWLEDGE SOCIETY

All these innovations up to this point were all completely pragmatic, based on absolutely no theories and had been developed with trial and error (Braun, 2010, 61). In his scientific manifest entitled *Novum organum scientiarum*, or 'new information or knowledge tool', in 1620 the English philosopher Francis Bacon issued not only the renowned sentence, 'Knowledge is power', but also proposed a then revolutionary concept – the unification of science and technology. The book therefore constitutes a

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landmark point between medieval thinking and modern systematic research, which is oriented towards scientific and technological progress for the benefit of humanity in general (see Fara, 2010, 149ff.; Fischer, 2001, 52f.; Harari, 2013, 317f.).

While, therefore, earlier innovations were very heavily characterised by the element of coincidence or direct requirements, over the centuries a more systematic approach pushed to the fore (see Fara, 2010, 103ff.; Fischer, 2001, 49; Morris, 2010, 510f.). This 'Invention of Invention' (Landes, 1999, 45) was to have far-reaching consequences for European thinking and action. With the Renaissance and the Enlightenment in Europe came the first individual mind-sets, structures and institutions, whose purpose increasingly served the systematic production of knowledge (Burke, 2001, 45ff.; Fara, 2010, 165ff.; Harari, 2013, 299ff.). In particular the universities that had already existed since the Middle Ages subsequently experienced a massive upsurge, and in the future formed a foundation stone for the scientific and industrial revolutions (Braun, 2006, 64f.; Burke, 2001, 52ff.).

At their core was a new thinking that was committed to progress and steeped in the conviction that certainty cannot be achieved by belief but through reason and systematic trials alone (Fara, 2010, 225ff.; Fischer, 2001, 48ff.).⁴ This was a genuinely

⁴ The belief in constant progress has been accompanied by criticism since its emergence. Towards the end of the Renaissance, in his *Essays* (1572–1587), Michel de Montaigne was one of the first to doubt the belief in progress that had established itself in Europe. Jean-Jacques Rousseau addresses a key thought of Montaigne, according to which culture continually destroys nature, and in his *Discourse on Inequality* (1755), essentially promotes a call 'back to nature'. In this tradition, Friedrich Nietzsche, who in his, *The Gay Science* (1887) explores the freedom of thinking beyond scientific-methodical constraints, in *The Antichrist* (1888) praises the sceptic as the only decent type in history, and in *Twilight of the Idols* (1889) expresses his mistrust for all systematists. Nietzsche was also a role model for the philosopher of culture Oswald Spengler, whose masterpiece, *The Decline of the West* (1918) formulates a rather pessimistic prognosis of the future development of Europe in light of the experiences of the First World War. With his *Civilisation and Its Discontents* (1930), Sigmund Freud ultimately delivers one of the most influential culture-critical pieces of the 20th century. More recently social and cultural anthropology has questioned the concept of a teleological progression of history through to a constantly improved future (see Harris, 1990, 7f.; Sahlins, 1972, 1ff.).

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European way of thinking; there is no specific place at which it emerged in isolation. Europe itself is this place: Nicolaus Copernicus, for example, was Polish, Francis Bacon and Isaac Newton were English, Paracelsus, Johannes Kepler and Gottfried Wilhelm Leibniz were German, Galileo Galilei and Evangelista Torricelli were Italian and René Descartes and Blaise Pascal were French (see Rossi, 1997).

Indicative of this development is also the increasing promotion of the sciences by the European royal houses, ambitious patrons or scientific societies (see Burke, 2001, 55f., 58ff, 149ff.). International trade was also extremely important for the progress of the sciences. On one hand, it stimulated the global exchange of raw materials, products, animals and plants, as well as technical skills and knowledge; on the other hand, it financed international voyages of discovery, whose findings were invaluable for scientific research (Fara, 2010, 103).

A key innovation that marked the beginning of the developing knowledge society was printing (Burke, 2001, 20; Landes, 1999, 51f.; Lipsey et al., 2006, 175ff.). This revolutionised the way knowledge could be documented and diversified. However, it also changed the ability to spread knowledge (Burke, 2001, 96f.). And this was one of the fundamental requirements for the 'explosion of knowledge' in our time (Burke, 2014) and the establishment of today's scientific knowledge system. It is based on previously acquired knowledge, on which it can build and further develop. This principle leads to a more consistent progress than the earlier unsystematic approach and to this day forms one of the key requirements of the modern sciences and the knowledge society (see Acemoğlu/Robinson, 2012, 215; Burke, 2001, 20ff.; Lipsey et al., 2006, 181).

The interdependencies between innovations and political power and the use and control of knowledge can be seen clearly when we use printing as our example (see Burke, 2001, 139ff.). It also illustrates the interdependence between sciences, economy and government, which ultimately resulted in an all-out contest for the promotion of scientific knowledge and technological innovation between the European nation

states (see Harari, 2013, 330ff.). The interactions between the sciences, capitalistic economy structures and the European systems of rule were the motor of history in the centuries that followed (Harari, 2013, 334). The successful colonial empires of the 19th century in particular supported scientific research in massive and specific ways in the hope of producing useful technological innovations (Harari, 2013, 432).

Today the sciences form the backbone of the modern world, but they could only fully exercise their role in the interaction with industry, economy, the military, government and healthcare system, as Fara writes (Fara, 2010, 165). She goes on to argue that decisive for this was the transition period from the private experiments of some wealthy and distinguished men, to the public research institutes, the state financing and industrialisation of the 19th century (ib.).

The scientific and subsequently the industrial revolution changed the life of humankind in a way previously unknown. With the use of fossil fuels, muscle power was gradually replaced by machine power (Braun, 2010, 63). The social transformations that resulted from the invention of the steam engine in an increasing mechanisation of all production processes, the enabling of mass production in factories, increased goods transport with the railroad and ultimately electrification, are, in the dynamics of their development, unique in the history of humanity, and at best comparable with the radical changes of living conditions after the Neolithic Revolution (see Hobsbawm, 1996, 38ff.; Landes, 1999, 186ff.).

In particular the replacement of the old energy systems based on human and animal muscle power with new fossil, later nuclear and today increasingly renewable ones, effected an energy landmark and a fundamental restructuring of economy and society. Our civilisation today is entirely based on the use of energy. From agriculture through the manufacturing sector or mobility to appliances for daily requirements, such as fridges, washing machines or dishwashers, we depend on 'energy slaves' (Dürr, 2010, 72ff.), which convert energy fed from outside in order to reduce our work-

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load. While the energy use of pre-industrial agrarian societies was approximately 600 watts per person annually, today it has risen in our industrial countries to 4,750 watts (Glaser, 2013, 33). As Glaser writes, the global energy requirement of humankind today is more or less a million times higher than 10,000 years ago. Sixty per cent of this colossal rise took place here in the last fifty years. Its historical origins can be found in the industrial revolution (Glaser, 2013, 33).

Overcoming the Malthusian Crisis – the idea that Thomas Robert Malthus formulated in his essay ‘The Principle of Population’ (1798) – postulates a quasi nomological cycle, in which population numbers without fail grow faster than the available offering of foodstuffs, which in turn must result in a progressive suffering of the population through disease and epidemics, and therefore ultimately reduces population numbers again. The gradual and continuous rise in life expectancy and the, at that time scarcely believable possible increase in prosperity, are the most prominent features of this development (see Braun 2006, 63ff; Landes, 1999, 186ff.). While in 1500, approximately 500 million people populated the earth, and circa 1800, it was a billion, today there are already more than seven billion people on the planet. In 1500, in the entire world goods and services valued at USD 250 billion in current terms were produced, today the figure is almost USD 60 trillion. Energy consumption in the same period rose from 13 trillion calories per day to 1,500 trillion. Harari estimates that fourteen times more people produce 240 times more and consume 115 times more energy (Harari, 2013, 301).

Industrialisation and population growth started a process of urbanisation that continues today. Circa 1800, the world still consisted of a collection of rural-agricultural societies in which the greater part of the population worked in agriculture (see Reiterer, 2010, 90). On a global level at that time, only about three per cent of the population lived in towns (see Bähr, 1997, 9ff.). The efficiency increases of agriculture made it possible to free more and more people from their subsistence economy and

to use their labour in the developing industrial and urban centres. An end to this development is not foreseeable. Circa 1950, some 28.8% of the world’s population lived in towns; currently it is already more than fifty per cent and by 2050, according to UNO estimates (2013) it will have risen to just under seventy per cent.

With urbanisation, however, also came a relocation of poverty from the country to the city, and the newly developed wageworker proletariat concentrated in the rising factories, for which ever more workers were required (Hobsbawm, 1996, 47ff.; Ziegler, 2005, 46). This resulted in continuous social problems with recurring worker revolts and social reform reactions, which cannot be addressed further here. The fact is, however, that the industrial revolution and its socio-political problems led to the creation of the European welfare states, with the result that the average citizens of today’s industrial states live better and have a far higher standard of living than monarchs of two hundred years ago, as defined by historian Eric Hobsbawm (2000; 1996, 297f.; see Harris, 1990, 9).

With the scientific and industrial revolution, according to the British historian John Darwin in his book *Imperial Dreams* (2010), began Europe’s global dominance. In 1750, Asia was still responsible for eighty per cent of the global economy, whereby China and India together approached two thirds of global economic production (Harari, 2013, 341; Darwin, 2010, 188). Europe’s share grew in contrast between 1750 and 1900 to more than sixty per cent. This increase is due in large part to Great Britain, whose share of global production increased almost ten-fold from just under two per cent in 1750 to more than 18% in 1900. The USA increased even more, with its share in this period rising from 0.1% to 23%. As such, the global economy at the end of the 19th century was almost completely dominated by the West and the global power centre shifted increasingly to Europe. In 1900, Europe dominated the global economy and most of the world unchallenged (Darwin, 2010, 156ff.; Harari, 2013, 341).

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The military-industrial-scientific complex, which established itself in Europe at this time, is mostly cited as the reason for this (see Fara, 2010, 165; Harari, 2013, 342; Morris, 2010, 498ff.). In his work *The Great Divergence* (2000) historian Kenneth Pomeranz describes the resulting divergent development of Europe, which ultimately – based on the new ‘enlightened’ and rational worldview, the resulting scientific and industrial revolution and an expansion of the trade volume building on the benefits of industrialised production – lead to a global shift in the power structure. Europe, and somewhat later the USA, experienced an enormous economic upswing, so that the share of global economic production of all other countries fell sharply. China and India in particular were seriously affected by this. China’s share of global economic production fell by 1900 to approximately five per cent. India, which had long served as the textile workshop of the world, plummeted to under two per cent (see Darwin 2010, 181ff.). China had been the greatest economic power in the world for approximately two thousand years (see Kang, 2012). This position was destroyed by the end of the 19th century. In his OECD study ‘Chinese Economic Performance in the Long Run’ (2007), British economist Angus Maddison sees the reason for this in the increasing isolationist and backward-looking politics of China since the 17th century (see Morris, 2010, 476ff.; Landes, 1999, 335ff.; Diamond, 1997, 411ff.). This brought the cultural and technological exchange with other countries to a halt, which caused a gradual decoupling of technological innovations outside the empire.

Consequently, there are also no signs that the Chinese economy would have developed further at any point in the direction of mechanisation (see Acemoğlu/Robinson, 2012, 231). This meant that agriculture as a key sector of both the Chinese economy and the manufacturing industry remained dependent on human labour. In the long term, the competition disadvantages that this generated compared with Europe could no longer be compensated. The downward economic spiral had far-reaching consequences for Chinese society.

European initiatives to open up the Chinese market for trade were not very successful at first. Still in 1793 Emperor Qianlong decided to inform Britain’s envoy, George Macartney, in categorical terms that China had everything it required and had absolutely no interest in importing foreign goods, and so abruptly rejected the British offer of a trade agreement (see Morris, 2010, 484). China consequently remained for quite some time in splendid isolation. This isolationism, however, ultimately revealed the weak ability of China’s economic and social structures to adjust. All attempts to resist foreign trade and its free trade policies, made increasingly more successful by industrialisation, failed. In the two Opium Wars (1839 to 1842 and 1856 to 1860), Great Britain aggressively forced the opening, which resulted in the humiliation of the ‘Unequal Treaties’, which imposed the removal of all trade barriers. China was forced to give up its economic protectionism and open itself to the trade interests of the Europeans. Subsequently, the development this triggered resulted in the collapse of the two-thousand-year-old monarchy, long years of bloody civil wars and occupation of the country by foreign powers such as Great Britain, France, Russia, Germany and Japan (see Darwin, 2010, 260ff., 332ff.).

At the end of this turbulence, which lasted over a century, the Chinese economy lay in ruins. The per capita income plummeted well below the global average. By 1952, it had even fallen below the 1820 level and made China one of the poorest countries in the world (see Acemoğlu/Robinson, 2012, 234; Maddison, 2007, 43). This downward spiral only began to end in the 50s, and in 1978, Deng Xiaoping led the way out of isolation, which initiated an extremely successful resurgence (see Zakaria, 2009). Whereas since the Enlightenment, therefore, Europe had established forward-looking thinking systems and institutions for scientific learning, facilities of this kind such as schools, universities, academies or scholastic societies were largely absent in China (Landes 1999, 343). Instead, the bureaucracy based on the Confucian education system hindered the development of innovations (Maddison, 2007, 17, 27). Moreover,

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whereas in Europe, gradually the belief in the progress of humanity and a better life in the future based on technological innovations established itself (Fara, 2010, 227ff.; Fischer, 2001, 48ff.), Chinese intellectuals looked for answers in conventions and old texts (Landes, 1999; 343; Morris, 2010; 481). After all, Chinese scientists never set up a scientific knowledge system that could compare with the European one, in which lessons learned or technological innovations are systematically documented and disseminated, in order to develop new lessons learned or technological innovations that built on this – as a result, important inventions in China sank into oblivion time and again (Landes 1999, 343).

So it was not simply technological skills or knowledge that were absent for the Chinese or other non-European peoples. What lacked were innovation-promoting ways and systems of thinking, as well as social, political or economic structures and institutions, which had grown in Europe over centuries and could not be simply copied or internalised at other locations (Acemoğlu/Robinson, 2012, 70ff.; Harari, 2013, 344f.). And these structures were based on an enlightened, scientifically established worldview that had been emerging in Europe since the Modern Age (Fara, 2010, 165ff., 224ff.; Harari, 2013, 345; Landes, 1999, 276ff.)

Austrian economist Joseph Schumpeter described this correlation in his theory of economic development ('Theorie der wirtschaftlichen Entwicklung', 1912) as follows: The triumph of a technical innovation is not based on the advantages of an invention alone. The innovation process is no simple linear sequence of inventions, of finished products or processes, but rather a complex interaction between scientific, technical, economic and social variables. It is therefore not only a technical process, as important as this is, it is also and not least a social process. Reservations, concerns or fears must increasingly be overcome here. The transformation of a technical innovation into a social process, which results in a positive evaluation by users, financiers and political decision-makers, is a challenge which innovations frequently also fail (Bauer, 2006, 316).

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The invention alone is therefore not yet an innovation. Innovations always require a specific forerun in which ideas or inventions are implemented in new products, services or procedures and successfully applied until they finally penetrate the market and are used in great numbers. An example of this lengthy, often disruptive process can be seen in the seminal inventions and developments of Thomas Alva Edison in the areas of electricity and illumination – from the first beginnings as inventor in the 1860s through the electrification of New York and the introduction of electric lighting in the 1880s to the extensive electrification of the industrialised world circa 1900 (see Baldwin, 2001).

A specific development pattern of technological innovations becomes evident here. Firstly, there is massive investment in a new technology and this produces an upswing. With the increasing establishment of this technology and its acceptance as a general purpose technology, investments fall and there is a medium to long-term downswing. During the downswing, work already starts on alternative technologies and a new paradigm is therefore prepared. Schumpeter defined the term of the Kondratiev waves (Schumpeter, 1939, 172ff.) for this waveform development pattern of technological paradigm changes and their effects on global economy.⁵

Schumpeter used the *The Long Wave Theory* of the Russian economist Nikolai Kondratiev in his explanation model for the evolution process of global business cycles. The basis for the observable cyclical sequence of global economic development is

⁵ The first Kondratiev wave from circa 1780 to 1840 was triggered by the invention of the steam engine and accompanied by the industrial revolution. The second wave from circa 1840 to 1890 is based on the development of the railroad and steam navigation. The third wave from circa 1890 to 1940 was defined by electrification and the internal combustion engine. The fourth wave from circa 1940 to 1990 was defined by the automotive industry, aviation and aerospace technology and the synthetics industry. The current fifth Kondratiev wave since 1990 is characterised by the innovations in information and telecommunication technology and biotechnology (see Duden, 2013). Some analysts have already identified signs of a new, sixth Kondratiev wave, whose engines are the basic innovations in biotechnology and psychosocial health (Nefiodow/Nefiodow, 2014).

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therefore provided by groundbreaking technical innovations – described by Joseph Schumpeter as basic innovations – which result in a radical change in production and organisation. Critically important here, however, is not the discovery of a basic innovation, but rather its massive dissemination, which causes a technological paradigm shift and a correlating economic and social change (Schumpeter, 1939, 213ff.).

Innovation is therefore always also a break with previous paradigms and customs and a process, during which the known or established is replaced by the new. This can happen with incremental improvement processes just as much as it can with radical, disruptive innovations and revolutionary changes. Schumpeter expressed this with the image of the storm of creative destruction (Schumpeter, 1912, 157). This occasionally resulted in desperate races, as established technologies cannot be so easily ousted – mail coaches versus railroads, sail ships versus steamships or oxen versus tractors, paraffin lamps versus electric bulbs, to name but a few examples. This competition is decisive for further economic development and a motor for history.

DESIGNING THE FUTURE:

POSSIBLE DEVELOPMENT LINES AND NECESSARY REQUIREMENTS

The history of humanity, as mentioned at the beginning, is also the history of a chain of ever faster successive innovations. This process is neither complete today nor is its continued course foreseeable. Danish physicist and Nobel Prize Winner Niels Bohr is quoted as saying that forecasts are difficult, especially about the future. Futurologists nevertheless increasingly dare to make prognoses. Most of them assume that the recent crisis-related developments illustrate the need for a radical global economic and social change (see Androsch / Gadner, 2013, 256ff.; Morris, 2010, 598ff.).

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The next, already incipient basic change, which is described as the 'third industrial revolution' (Rifkin, 2011), is based on the consequences of 'networking the world' (Schmidt/Cohen 2013) through digitalisation and its interfacing with renewable energy systems and intelligent production methods, which are encapsulated with the keyword 'Industry 4.0' (see Bauernhansl et al., 2014; Marsh 2012). The idea of the third industrial revolution does actually indicate that technological innovations will play a key role for the future of humanity. At the same time, however, it also implies social innovations and the necessary reorganisation of a number of correlated political, economic and social processes (see Anderson 2012; Rothkopf 2012).

As a result of these radical changes, American futurologist Jeremy Rifkin (2011) forecasts a new economic and social paradigm, which entails far-reaching social consequences. In addition to the change in social structures, which will be more democratic and less hierarchical, the changed production conditions will have massive effects on working life with increasingly automated processes. The progresses in the area of Artificial Intelligence in particular also play a key role here (see Anderson 2012; Marsh 2012).

The renowned science journal *Science* published a special insert on the topic of 'The social life of robots' at the beginning of October 2014. It summarises the status of current developments in the area of Artificial Intelligence (AI) and derives possible implications of the automation of intelligent behaviour. According to *Science*, robotics have now become so advanced that it is possible to generate a form of manipulative intelligence, which, on the basis of artificial information processing and with the aid of sensors and actuators, enables an almost intelligent interaction with the physical environment. The basic idea here is to create systems that can understand the intelligent behaviour of life forms (Science, 2014, 182f.).

Robots can consequently already flexibly apply basic human senses in the most diverse of contexts: seeing, hearing, smelling, tasting or keeping balance have all been

in use for some years now (Science, 2014, 184f.). A more recent event by contrast is the information technology-based ability of 'deep learning', which employs a feedback system that enables robots to learn – to date mostly from visual impressions and experiences and to adjust their behaviour on this basis (Science, 2014, 186f.; see The Economist, 2015, 17f.).

With the help of robots, potentially dangerous activities such as finding leaky gas lines, the removal of rubble from natural disaster areas and rescuing people from collapsed or burning houses, or even processes and manipulations that always run the same, such as welding, painting, etc. can be exceptionally well automated. But even more complex tasks, such as recording data-based short messages, running repetitive lab tests in research or work as a chauffeur, according to Science, are already carried out today by robots (Science, 2014, 190f.).

The possible future development of these complex systems can, however, also conjure up horror scenarios, such as, for example, the uncontrollable independence of the artificial intelligence that all these processes are based on (see The Economist, 2015, 9). Physicist Stephen Hawking consequently warns against the further development of AI leading to the emergence of an awareness of the machines and therefore ultimately to the end of humanity (The Guardian, 2014; see Morris, 2010, 617f.). Even if these dangers cannot be entirely relegated to the realm of science fiction and the concerns of the critics must be taken seriously, from today's point of view the most diverse benefit aspects prevail (The Economist, 2015, 9).

At any rate the fusion of new possibilities of information and communication technologies with synthetic biology, as they are already applied in the area of bio-robotics, for example, holds the potential for completely new developments (Science 2014, 196ff.). The fusion of man and machine building on this is referred to in philosophy as transhumanism or technological singularity. In his book *Menschheit 2.0 – Die Singularität naht* ('The Singularity Is Near: When Humans Transcend Biology', 2013), as a

realistic possible consequence of this bio-technological evolution, MIT professor Ray Kurzweil forecasts not only a basic change in our image of humanity, but rather also a break in the structure of the history of humanity.

This development will naturally also have implications for the constitution of societies, and in particular for the structures of the working world of the future (see Anderson, 2012; Marsh, 2012). This thesis has also been studied in more detail by the two MIT professors Eric Brynjolfsson and Andrew McAfee in their books *Race Against the Machine* (2011) and *The Second Machine Age* (2014). According to these, technological progress ultimately results in knowledge-based economies being able to increase their productivity detached from human work performance. This causes the number of jobs to stagnate, as can be seen in most OECD countries for some years now. At the same time, the productivity rate increases. Globally successful companies are already today demonstrating how massive turnover can be generated with just a few hundred employees. This therefore not only affects the much-cited cashiers who are being successively pushed from the tills of supermarkets by the use of self-service terminals. In the long-term, it will also affect specialist workers who will be replaced by intelligent industrial robots. The aptly named knowledge workers are not out of the woods here either, as AI systems will also endanger their jobs (see The Economist, 2015, 20). Translation programmes are already competing today with well-trained translators. IT experts or mathematicians with academic algorithm degrees will be replaced by automated data analysis – the latter in particular is a highly topical issue in conjunction with the global 'Big Data' mega trend (Mayer-Schönberger, 2013).⁶ All indications are that the discrepancy in particular between the loss of work and a simultaneous deficit in qualified workers with adjusted and increasingly quicker

⁶ See also President's Council of Advisors for Science and Technology (2014): Big Data: Seizing Opportunities, Preserving Values. Executive Office of the President.

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changing requirement profiles will become a key issue in the near future, because, while in all leading industrial countries the number of jobs stagnates or occasionally even falls dramatically, in others highly qualified workers that satisfy the current requirements profiles of the economy are in demand (see OECD, 2012). In a somewhat more distant future, however, should the apologists of the rise of the robots be proven right, the difference between qualified and unqualified workers and jobs will become increasingly less important. Should this happen, it will result in any case in a further decoupling of productivity and (human) work (see Morris, 2010, 597f.).

If we follow the thoughts of the British economic historian Robert Skidelsky elaborated in his essay 'The Rise of the Robots' (2013), this development inevitably results in a social revolution that necessitates a redefinition of the concept of work. In his book *Bürger, ohne Arbeit* ('Citizens Without Work', 2005), German sociologist Wolfgang Engler also points out that in the age of the third industrial, digital revolution, we will inevitably have to deal with the fact of disappearing work and the resulting implications. Skidelsky and Engler in particular want to ask how societies can function if large parts of the population are not involved in the acquisition process because, on the basis of the changes to be expected in production conditions, full-time employment can no longer be taken seriously as a political goal, and we must bid adieu to the principle of a right to work. In the future, it will be more about thinking about a right to income and discussing possibilities to better use the free time gained through machine progress and automation, and guaranteeing personal self-esteem and social recognition and appreciation outside of classic work processes (see Rifkin, 2004). Whether or not humanity will actually lose work can, however, be questioned with a look at the past, and in particular at the consequences of the scientific and industrial revolution. The accelerated development of technology, productivity and the sciences since the 18th century may have resulted in a population explosion. At the same time, however, new jobs emerged in previously unprecedented numbers (see Braun, 2010,

63ff.). And although innumerable occupations have disappeared over time (see Pala, 2014), the working society has still never lost its work. This is proven, not least, by the further rise of global labour force participation rates (see OECD, 2014) and also, for example, by the current and acute deficit of IT workers in Germany (Frankfurter Allgemeine Zeitung, 2015).

On the contrary, there will arguably be work in the future. It will be different, and with the accelerated rate of change, it will bring new requirement profiles with it and require different qualifications. According to sociologist Richard Senett (2006), it will be a work world in which there are less and less jobs for life, and more and more flexibility will be needed. This development will require numerous answers in the area of education, training and further training, as well as in the legal system and in the welfare state area. Jeremy Rifkin also sees a similar scenario in his book *The End of Work* (2004). Consequently, the orientation of today's political activities is too structure conserving and too focused on the status quo and outdated conditions. This increasingly produces the danger of splitting societies into modernisation winners and losers and, connected with this, the danger of populist extremism at the edges of the political arena.

Whether the future will bring the end of work or the end of humanity and its replacement by intelligent machines cannot be naturally predicted. At any rate, today we live at the high point of what some scientists refer to as the Anthropocene (see Crutzen/Stroemer, 2000). This is the age since the scientific and industrial revolution in which the human has become one of the most important factors influencing the biological, geological and atmospheric processes on earth (see Glaser, 2013, 33ff.). Humankind has, however, to date only insufficiently appreciated its growing responsibility, which has resulted in a great threat to our planet. The consequences are everywhere: the climate change caused by humankind, the scarcity of resources caused by economic production of previously unknown proportions, the continuing

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rapid population rise in many regions of the world, the unchecked energy hunger or, in places, the already dramatic pollution of the oceans, the land and the air are just some of the more prominent examples (see SOER, 2015; IEA, 2014; IPCC, 2014; UNO, 2013; UNEP, 2011a; UNEP, 2011b).

Notable in particular here are the extent and speed of the global change caused by humans. In the last fifty years, humankind's encroachment on nature has been so radical and extensive that it has introduced an unprecedented transformation process, with effects of global dimension (see Diamond, 2005, 486ff.). Glaser remarks that the key question is, to what extent and in which areas the human has overstressed the earth system so much that its primal basis of existence, its 'life assurance system', so to speak, based on clean air and drinking water, fruitful soil, a diverse plant and animal world, healthy and sufficient food, sustainable energy supply and mineral planning, is endangered. In addition to these supply issues there are also urgent disposal issues: rubbish, neglected deposits, devastated swathes of land, *dead zones* in seas and oceans, smog and fine dust pollution rank among the most obvious excesses of the unchecked encroachment and greediness of humankind. Consequently the loss of biodiversity, climate change, landscape degradation, desertification and the change in the material cycles of ozone, carbon and nitrogen have become urgent issues concerning our sustainability (Glaser, 2013, 7).

The fact is that our current ways of life and production are not sustainable and humankind is facing unimagined challenges. History tells us that earlier cultures have always reached growth limits or failed in their production methods and technologies (see Diamond, 2005; Harris, 1990). Humanity has always overcome growth limits and met pending challenges with technical innovations (see Morris, 2010, 144ff.). Failed technologies of earlier cultures were replaced by new ones and existing growth limits were surpassed (Harris, 1990, 8). The big difference between the current challenges and those of earlier cultures is that today we know which

problems are involved and which solutions are required (see Morris, 2010, 621). Not least of all the modern sciences are responsible for this, and although this knowledge must also be followed by appropriate actions, cautious optimism appears to be thoroughly justified (see Diamond, 2005, 525). 'The voice of the intellect is a soft one,' Sigmund Freud wrote in *The Future of an Illusion*, 'but it does not rest till it has gained a hearing. Finally, after a countless succession of rebuffs, it succeeds. This is one of the few points on which one may be optimistic about the future of mankind, but it is in itself a point of no small importance' (Freud, 1961, 53).

'The future is open,' agree the Austrian behavioural scientist and Nobel Prize winner Konrad Lorenz and philosopher Karl Popper in their book entitled *Die Zukunft ist offen* ('The Future is Open,' Popper / Lorenz, 1985). While it remains unclear what shape the future will actually take and which of the outlined developments will become this or a similar reality, it is nonetheless clear that we must prepare ourselves for a fundamental change. To be able to meet this change in the right way, we require one thing in particular: education. Well-trained, independently thinking, critical and creative heads are a basic requirement to overcome the grand challenges and find the technological and social innovations required for this. A modern education system that optimally prepares people for the new challenge is therefore required. Energetic and determined state action must be provided to guarantee this.

In her book, *The Entrepreneurial State* (2013), economist Mariana Mazzucato argues that the role of the state is decisive for the formation of a functioning innovation culture. Legal and taxation framework conditions are just as critical here as the education system or research promotion programmes and instruments of intervention. An innovative, entrepreneurial culture cannot establish itself without appropriate state support structures. On the contrary! According to Mazzucato, creative entrepreneurs and risk-ready venture capitalists were not and are not the motor of the development of technological innovations and the resulting economic upturn and wellbeing, but

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rather it is an active state, which finances the public education institutions, sets up and expands infrastructures, promotes basic research and implements measures to support the market entry of young knowledge-intensive companies. Examples of this range from electrification through to the internet, whose creation and expansion would never have come about without the public sector. Apple's success, for example, is based on technologies that were almost entirely promoted by the public sector (see *The Economist*, 2013).

The MIT economist Daron Acemoglu and Harvard political scientist James Robinson also argue similarly in their bestseller *Why Nations Fail* ('Warum Nationen scheitern', [2013]). According to this book, the regulations and institutions chosen by the state are responsible for economies realising their innovative potential, and therefore lay the basis for their economic success. Economic growth has always been driven by innovations and by technological and organisational change (but today increasingly so), which are based on the ideas, talents, creativity and energy of the individuals of a society. The basis for this are, on one hand, appropriate incentive systems, and on the other hand structures that promote the abilities and talents of as many members of a society as possible, and therefore specifically utilise the available innovation potential. This requires suitable education institutions, but also promotional framework conditions, such as, for example, strict ownership and contract laws, a functioning justice system and free competition. Only then can the majority of the population productively take part in economic life.

In his book, *The Wealth and Poverty of Nations* (1999), economic historian David Landes illustrates the eminent importance of innovations and the passing on of new knowledge for the prosperous development of economies. Even if this approach is controversial and was the subject of heated debates due to its Eurocentric position, Landes' analysis of the role of scientific and technological innovations is a coherent explanation for the wellbeing or poverty of nations in the past and in the present world.

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The consequences to be drawn today for political decision-makers were recently addressed by the chief economist of the Bank of England, Andrew Haldane, in a speech entitled 'Growing, Fast and Slow' (2015). The ingredients for economic growth remain as mysterious as they have always been despite centuries of experience. Regardless of all uncertainty, one thing does become evident from the global history of humanity: in addition to sociological factors, education, research, technology and innovation in particular play an important role for the wellbeing of successful states. The most innovative countries in the world – in particular the USA, Germany, the Scandinavian countries, Switzerland, Japan and South Korea – have reacted appropriately to the realisation that the road to overcoming the great challenges of humanity requires increased efforts in the areas of education, research and innovation. In the recent years of crisis, they have massively increased their investments in these elements of the future.

This book intends to help re-ignite the discussion required on the central role of innovation in the past, present and future from new points of view. Both the international comparisons and the different perspectives of the authors will introduce new arguments to the political discourse. The conclusions the reader draws from this remain, necessarily, open. From our point of view, however, the book very clearly shows the following: If it is possible to sustainably establish the key basic requirements for innovation outlined in all contributions, then a self-determined designing of the future that meets the major social challenges is possible. Essential here is that the required steps are not left until tomorrow and the required reforms put off even further. Because everything that is neglected today will have far-reaching consequences tomorrow. We must, therefore, begin to work on tomorrow today – because designing the future begins now!

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CHAPTER 1

THE CULTURAL AND HISTORICAL DEVELOPMENT OF INNOVATION

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INNOVATION IN THE ENLIGHTENMENT: INVENTING PROGRESS

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**But catastrophes only encouraged experiment.
As a rule, it was the fittest who perished, the
misfits, forced by failure to emigrate to unsettled
niches, who altered their structure and prospered.**

W. H. Auden, 'Unpredictable but Providential (for Loren Eiseley)' (1976)

'If I have seen further,' wrote Isaac Newton to his arch-enemy Robert Hooke, 'it is by standing on the shoulders of giants.' Newton had borrowed this expression from Bernard of Chartres, a twelfth-century monastic philosopher, but whatever he was trying to imply (and opinions vary), it has now come to encapsulate the upward trajectory of scientific achievement towards absolute truth. Progress has become a leit-motif of modernity, so ingrained that it feels instinctively both normal and desirable. Marching forwards seems inevitable – and the obvious routes to choose are science, technology and invention. Shaping the future of planet Earth has become a major human responsibility.

Without a concept of progress, innovation has no meaning. Progress was not, however, generally accepted as an underlying characteristic of society until the early nineteenth century (Spadafora, 1990). In the absence of any need to display growth, there were no graphs or histograms to demonstrate an upward trend. Although Newton is often identified as the herald of modernity, neither he nor his contemporaries perceived life in that way. They did endorse personal self-improvement through prayer, which they regarded as moving nearer towards God, but they believed that the overall future of humanity was divinely ordained. The concept of innovation, which implies marketing potential as well as novelty, had not – could not – be appreciated, because

it held no place in the European world view. Their lives were characterized not by change but by stability: 'revolution' referred not to social upheaval, but to the steady rotation of the planets in their orbits.

At the end of the seventeenth century, new ideas faced huge resistance and there was no consensus that the future would be any better than the past. Modern critics point to global warming, nuclear devastation and chemical pollution as obvious downsides of technical advance, but even these reservations are incorporated within a vision of progress. Such warnings are fundamentally different from earlier convictions that God had created a stable universe; many believed that if European civilization were to alter, the only direction it could go would be downwards. As Newton's philosophical colleague John Locke memorably put it, 'the imputation of Novelty is a terrible charge amongst those who judge of Men's Heads, as they do of their Perukes [Wigs], by the Fashion; and can allow none to be right, but the received Doctrine' (Iliffe, 2000, 431). Of course, automatically resisting changes in daily routine is still a common reaction, but Locke was protesting against a deeper philosophical perspective about long-term transformation.

Locke was just one of the many Enlightenment writers who insisted on regarding invention as stemming from human capability rather than divine revelation. They celebrated printing, gunpowder and the magnetic compass as a triplet of major inventions marking the triumphant arrival of a modern age – what later became known as the Renaissance, a rebirth towards a new future. In north-west Europe, the rate of industrial and agricultural change accelerated rapidly during the eighteenth century. This shift towards a culture of technological innovation relied on the ingenuity of inventors and increasing scientific knowledge, but it would not have occurred without a corresponding alteration in beliefs about people's relationships with the universe. The word 'invention', which has Latin roots, originally referred to discovery, reflecting the conviction that new ideas were the providential outcome of God's plan

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for gradually revealing His secrets to humanity. As part of a general move towards personal rather than divine responsibility, new laws on patents and copyright ensured that individual creativity could be fully recognized by being financially rewarded and legally protected.

The past is often said to be another country, but so too is the future. Connected as they are by the transient present, it is impossible to think of one without the other. Because the route ahead depends on the journey travelled so far, understanding modern attitudes towards progress and innovation depends on appreciating how they have developed from earlier opinions about the relationship between human beings, their physical surroundings and their temporal environment. In previous ages, it would have been impossible even to contemplate what has now become a major preoccupation – ensuring that subsequent generations inherit a world worth living in. In this respect, the Enlightenment is a particularly fascinating period to study because that was when it first became accepted that the future of the universe was – to some extent, at least – under human control. It was also the time when commercial consumption and technological invention began to be promoted as desirable ways of stimulating economic growth.

CHANGING TIME

Writers respond to their predecessors rather than presciently anticipating the opinions of their successors. Newton may now seem like the world's first great scientist, but as the economist John Maynard Keynes pointed out, from his viewpoint he was building on beliefs that had originated with the Babylonians. Enlightenment thinkers inherited two approaches. One tradition stemmed from the Judaeo-Christian belief that God formed the world in a specific act of creation. In this version, time flies like an arrow, shooting out from its origin to leave the past behind as it travels towards the future. When twentieth-century cosmologists suggested that the universe had

started with a Big Bang, this biblical story helped to make their model acceptable. There is, however, a crucial difference: whereas modern Big Bang scientists hold that the universe has been developing ever since its beginning, many of Newton's contemporaries interpreted the Bible to understand that the universe – along with its inhabitants – had been created as it is now.

On the other hand, many Greek philosophers had envisaged a cyclical universe that keeps recurring. An Aristotelian cosmos exists in its own right, with no need for any external Divine Creator. A rosebud becomes a flower not because God ordained it, and not because it has consciousness, but because that is its purpose. Instead of directionality, there are no definite beginnings or ends, but a never-ending sequence, rather like the annual seasons on a grand cosmic scale. Modern physicists are still discussing the possibility that the Big Bang may be not a unique event, but just one in a never-ending cyclical series.

Considering terrestrial rather than cosmic history, if you visualize humanity travelling through time as if through an undulating landscape, then on every downward slope it makes sense to look back for lost wisdom rather than assume inevitable progress towards a better future. Few people nowadays would maintain that civilization has gradually declined since the classical age, but that used to be a common point of view. Commissioning a portrait of himself as a Roman sage, Newton dedicated great energy to restoring the lost, pure knowledge of the Greek civilization. After Adam Smith laid down the principles of capitalist economics in *The Wealth of Nations* (1776), a fellow Scot scoffed that he 'has produced a book upon trade, from which one would think he had never read any of the writers of Greece and Rome' (Wokler, 1988, 146). The foundations of the modern commitment to progress were laid down during the Enlightenment era, when there was a broad shift away from regarding the universe as being solely directed by God (Porter, 2000, 424–445). Instead, imagining the possibility of human intervention and control began to prevail, although this was not simply

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a process of increasing secularization: there was no automatic loss of faith. Natural philosophers started to feel that instead of merely trying to divine God's plan, their responsibility was also to alter the destiny of the human race. Symbolically, this gradual and uneven transformation from divine to human power is represented by three great books that span that period of around 150 years commonly known as the long eighteenth century: *Paradise Lost*, *Essay on Man* and *Frankenstein*.

These texts have achieved canonical significance not only because of their authors' talents, but also because they seem to capture the sentiments of their respective ages. John Milton's epic poem *Paradise Lost*, first published in 1667, was based on traditional Christian views that God created the universe as it is now; at the last stage, He introduced human beings, sinners fated to be punished by God for their disobedience. Far from being restricted to theological or literary texts, this belief permeated European thought. When Hooke described his powerful new microscope in *Micrographia* (1665), which is often cited as a groundbreaking scientific text, he explained that instruments were necessary to supplement the human senses, because they had been rendered defective during the Fall of Adam in the Garden of Eden.

Like many of his scientific contemporaries and successors, Hooke was strongly influenced by the work of the Elizabethan philosopher and one-time Lord Chancellor Francis Bacon, whose ideas underpinned London's Royal Society, Europe's first formal scientific organization. Bacon taught that research had a double function: to explore and measure God's world, and also to improve human welfare. Those might now seem admirable aims, but his recommendation to study nature by altering it aroused great hostility. The Royal Society's iconic new instrument was the air-pump, which for the first time enabled experimenters to create a vacuum and hence learn about the role of the atmosphere. Even after sceptics had accepted that creating a vacuum was physically possible, they still insisted that no valid inferences could be made about God's universe from an artificial state.

These conventional attitudes towards God's role and the feasibility of changing His created world slowly shifted towards a more person-centred approach. This alteration in general opinion was most famously articulated by Alexander Pope in his *Essay on Man* (1733–34). Whereas Milton's poetic narrator had asked for guidance to 'justify the ways of God to men', Pope endorsed introspection and self-knowledge:

*Know then thyself, presume not God to scan,
The proper study of mankind is man.*

Repeatedly reproduced as an epigraph, this renowned couplet was familiar to Enlightenment readers all over Europe; it both summarized and stimulated a new attitude towards acquiring knowledge.

By the early nineteenth century, it had become possible to envisage a future that could be manipulated and improved by human intervention. The most striking example from that time is Mary Shelley's *Frankenstein* of 1818, in which the eponymous doctor features as a new Prometheus who wrests power from the heavens to create a living being. Although Shelley was, of course, describing an imaginary situation, her book reflected contemporary confidence that scientific and technological inventions could substantially alter the future of the human race – whether for the better or for the worse.

Milton, Pope and Shelley attracted huge attention not because they were campaigning pioneers, but because they gave evocative expression to contemporary ideas. Looking back from the present, this adoption of a human-oriented vision to replace a divinely-dominated one has often been interpreted as progress rather than transformation. But to think of it in that way has in itself only been made possible by the assumption that progress is both intrinsic to civilization and also commendable. In other words, intellectual snobbery dictates appraising our ancestors with modern

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criteria: because we now believe in progress, our outlook on life must be superior. But history is told by the victors, and during the Enlightenment there were many opponents of progressive attitudes who have now largely been forgotten. For example, critics of technological invention feared that enhancing physical comfort would inevitably lead to moral decadence: when Europeans learnt about the Pacific Islands newly encountered by explorers, they hailed them as earthly paradises uncorrupted by modern commerce. In addition, pious Christians maintained that it was sacrilegious to make a financial profit from God's created world by marketing instruments or even by lecturing about scientific knowledge.

By around 1830, most educated Europeans regarded progress as being effectively a Law of Nature. Naturalists had long since discarded any strict adherence to a literal interpretation of the Bible, and various evolutionary theories helped to make progress central both to daily life and to abstract ideas. Scientists taught that the solar system had condensed from an original chaos of swirling clouds; following that, primitive types of life had eventually led to sophisticated organisms, which in turn had resulted in the arrival of mankind on earth. Progress was not restricted to natural phenomena. In this age of exploding confidence, great technological improvements were predicted – machines would become more efficient, education would improve, travel would get faster and books would get cheaper.

Yet even then, commercial, scientific, political and industrial interests were not as inextricably knitted together as they are today. Even during the first third of the twentieth century, 'innovation' had not yet acquired its current meaning of deliberately introducing a new product into the market-place. Progress towards the future entailed building up from the past rather than shifting direction and laying down a new route. Perhaps it took the shock of two atomic bombs and the threat of nuclear annihilation to jolt human beings into realising that they must take control of their own future as well as that of their planet.

IMPROVEMENT

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The most famous Enlightenment inventor is James Watt, who modified steam engines to make them vastly more powerful and versatile. His wife Annie wrote to their son that 'we live but to improve,' although it is hard to pin down one single meaning to her claim (Porter, 2000, 424). Certainly Watt's inventions were increasing industrial output and benefitting the European economy, but the still contested concept of progress meant far more than simply material gain. Improvement had become a buzz word with multiple connotations, embracing all possible aspects of moral, social, natural, material and scientific progress.

As Europeans increasingly travelled to distant parts of the globe and encountered societies overseas, they began to use the capacity for self-improvement as a marker of civilization, regarding themselves as being above other peoples, who in their turn were superior to animals. Influential authors such as the philosopher David Hume and the economist Adam Smith lent their support to the possibility of studying history scientifically. Just as Newton had brought mathematical order to the cosmos, so too, they insisted, rules could be established for demonstrating the progress of humanity. Primitive peoples (their term, not mine) were preoccupied with finding food, keeping warm and defending themselves against their enemies. It was only when material conditions improved that they gradually found time to stabilize their systems of government and engage in intellectual or artistic activities.

Such pictures of historical progress were especially prevalent in Scotland and France, where philosophers and historians explained that all societies gradually develop from an original barbaric state, following the same basic pattern but at different rates. These 'rudeness to refinement' models of human culture hypothesized four major stages. Early communities relied on hunting, but subsequently began cultivating crops in a nomadic existence. This was followed by settled agriculture, and finally – in Europe at least – a commercial economy. Variants of this stadial history were often

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expressed. In *The History of the Decline and Fall of the Roman Empire* (1776–1789), Edward Gibbon commented that although progress had been irregular, human beings had gradually emerged from savagery ‘to command the animals, to fertilise the earth, to traverse the ocean, and to measure the heavens’ (Porter, 2000, 426).

The notion of improvement was being incorporated within evolutionary ideas long before 1859, when Charles Darwin published *On the Origin of Species*, the famous book setting out his theory of evolution by natural selection. In the previous century, Pope was still describing an Aristotelian fixed Chain of Being, in which living creatures were arranged in hierarchical order from the lowest grubs up through fish, birds and animals to human beings, and then on and beyond through angels and other spiritual beings to God. But by 1800, many naturalists believed that the world and its inhabitants had not been fixed at the Creation, but had gradually changed over time; they also accepted that to accommodate evolution, the world must be far far older than had previously been estimated. As Darwin’s own grandfather Erasmus put it, the Earth’s creatures ‘have constantly improved, and are still in a state of progressive improvement’ (Darwin, 1794–1796, I, 529).

Improvements in civilization were also beginning to be correlated with scientific and technical invention, thus conveniently providing Europeans with evidence to confirm their belief in their own superiority. The most influential Enlightenment exponent of progress was Nicolas Condorcet, the mathematician and philosopher who played a leading role in the French Revolution. Coining the word ‘perfectibility’, he maintained that human beings were constantly improving towards an ultimately unattainable state of perfection, and he predicted a future utopia in which society would be based on order and reason. Joseph Priestley, the Birmingham chemist who first isolated oxygen, felt that optimism about the future was vindicated by scientific research: ‘it is nothing but a superior knowledge of the laws of nature,’ he wrote, ‘that gives Europeans the advantages they have over the Hottentots [...]

science advancing as it does, it may be taken for granted that mankind some centuries hence will be as much superior to us [...] as we are now to the Hottentots (Priestley, 1790, I, 31).

The virtues of material improvement were also being touted. The eighteenth century is often called the Age of Reason, but it also saw the Birth of the Consumer Society. In Britain, the population was increasing rapidly, the rate of inventions was accelerating and the British economy was booming. Josiah Wedgwood – Charles Darwin’s other grandfather – is now renowned for his fine blue and white china, but perhaps an even greater legacy was his introduction of the idea that social promotion could be achieved through shopping. Devising ingenious advertisements, he persuaded customers that they should abandon their old but still functional possessions, and replace them with new up-market substitutes. ‘Keeping up with the Joneses’ is a twentieth-century Americanism, but the notion originated with Wedgwood’s promises that if a maid acquired a dress like her mistress’s, or if a middle-class housewife bought tableware more appropriate for an aristocratic family, then her status would automatically be boosted. The Enlightenment invented conspicuous consumption as well as steam engines and rationality.

Supply and demand are intimately linked, and economists disagree about which came first in the eighteenth century. Even so, it is clear that the wider availability of relatively cheap goods was only made possible by changing production methods – which in itself helped boost demand. When viewed retrospectively through the murky smoke of Victorian factories, mechanization seems a retrograde step that forced huge swathes of the population into abject poverty, but the early industrializers of the eighteenth century knew nothing of what lay ahead. Many of them were idealistic, enthusiastic reformers, convinced that they would not only increase the quantity of manufactured products, but also improve the lives of their employees by reducing their workload and by providing subsidized medical treatment and education.

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It is only when surveying the past that historians can detect long-term patterns imperceptible at the time. But change is not an abstract entity: it can only be effected by the cumulative actions of individuals who have no way of appreciating the long-term collective impact of their lives. While philosophers in France, Germany and Scotland were discussing theoretical concepts of Enlightenment, in the English Midlands practical men were introducing a combination of industrialization and social improvement. To adopt modern phraseology, the hub of progress was located at the Lunar Society, a centre of excellence and innovation that brought together entrepreneurs, doctors, factory owners, naturalists, inventors and social reformers. Focusing on this particular group provides real-life examples of how broader changes were established.

THE LUNAR SOCIETY

Because it included wealthy factory owners, inventors and doctors, the Lunar Society has often been credited with bringing industrialization to Britain before the rest of Europe. As science and technology became increasingly dominant during the second half of the twentieth century, historians paid increasing attention to tracing their origins and their rise. Regarded from that perspective, the Lunar Society was generally characterized as a fertile seed-bed enabling scientific and commercial innovators to exchange ideas and hence pave the way towards a scientific future. But the past is always open to reinterpretation. Although the great majority of the Society's members were also Fellows of the Royal Society (FRS), some were social reformers who knew little about steam engines, pottery or medicine. Although these campaigners were influential at the time, they have received relatively little attention, and are usually glossed over as insignificant hangers-on. Reappraising the Lunar Society by placing it within its contemporary context reveals how scientific advance was inseparable from political change and commercial interests; rather than providing the stimulant for technical advances, scientific knowledge was often their product (Fara, 2012).

A loose association of around fourteen forward-thinking colleagues who met monthly from the mid-1760s to the early 1790s, the Lunar Society's membership fluctuated, but regularly included Wedgwood, Priestley, Watt, (Erasmus) Darwin and the factory owner Matthew Boulton (see Appendix for full list). The mixed composition of the Lunar Society reflected their belief that wealth should be based on ability rather than on birth and family pedigree, and the newly developing industrial north provided unprecedented opportunities for uneducated, unprivileged workers to become rich and powerful employers. These Midlands men shared the overriding goal of progress, but they had no government backing, no metropolitan head office, and saw no need for bullet point lists of aims and objectives. Meeting in their own homes, they were committed not only to bettering themselves (several of those from unprivileged backgrounds made vast fortunes) but also to improving the lives of the nation. Pioneers of progress, they drew no hard divisions between their scientific ambitions and their political ones (Uglow, 2002).

The Lunar men can be made to appear overwhelmingly dedicated to science, but modern categories such as 'scientist' are unhelpful for describing them. For example, Boulton was an FRS but had little formal scientific training. Commercially extremely successful, he expanded his father's small metalworking business by introducing steam engines and producing fine silver ornaments for the luxury market. His innovations depended on investigations that now sound scientific but took place in a factory, not a laboratory: finding durable substances for heavy machinery, testing unusual minerals for decorating tableware, assessing alloys for strength and weight. Similarly, Wedgwood was also an FRS, even though he never went to university. The high-temperature thermometer (pyrometer) he developed for his pottery kilns proved invaluable for chemical experiments, and he embarked on an intensive, systematic and well-documented research programme in order to develop new glazes and stay ahead of his competitors. 'I scarcely know without a good deal of recollection whether

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I am landed gentleman, an engineer or a potter,' he wrote to Boulton; 'for indeed I am all three by turns [...]' (Fox, 2010, 222).

By offering each other technical advice, commercial contacts and emotional support, the Lunar colleagues improved their own lives but also cooperated to transform British science, industry and agriculture. Contributing their own wealth and expertise, they built canals that literally transformed England, criss-crossing the land with waterways to link the newly expanding provincial centres so that raw materials and finished products could be efficiently shipped across the country to be sold or exported. This rapid improvement in internal transport was funded not by the government, but by private financiers – men like Wedgwood who were inspired by personal ambition as well as by grandiose visions of the future.

The Lunar men saw nothing wrong in promoting their financial interests: on the contrary, they claimed that improving their own positions would benefit the entire nation. This emphasis on the rewards of individual gain typified the new Enlightenment code of morality. In the past, being virtuous had entailed suppressing any wish for personal advantage, but instead giving priority to others. In his innovatory economic philosophy, Adam Smith maintained that full recognition should be given to the realities of human nature: for most people, the strongest incentive for action is to better their own situation. Smith argued that this was not necessarily a selfish way of behaving, but one that benefitted manufacturers and consumers alike. For producers to make profits, they must sell goods – but purchasers desire these to improve their lives. In this win-win situation of enlightened self-interest, the economy booms, there are more things to buy, and more money to buy them with. For example, the factory owner James Keir became rich and famous through recognizing the need for cheap soap. As well as making his personal fortune, Keir also fulfilled the Enlightenment ideal of improving the nation: the marked rise in general health at the end of the eighteenth century owed less to medicine than to increased hygiene. Keir's mass-produced soap

(along with cotton clothes and the abolition of window tax) produced far wider effects than any medical innovations.

Despite these men's high-sounding ideals and hopes for the future, their ambitious entrepreneurship involved costs, compromises and concealments. Enthused by profits and progress, the Lunar industrialists built ever faster and more powerful machinery, but not everybody gained from these changes. When Boulton developed his Soho estate, he aimed to improve working conditions by providing well-lit rooms, health care and education – but clearing the site entailed demolishing its existing cottages and moving its inhabitants away. His factory boosted the national economy by mass-producing 30,000 identical coins an hour, but there seems to have been little sympathy for either the displaced hand-workers or the young boys trying to keep up with the machinery's rapid output (Carter, 2005, 295).

However well-intentioned they may have been, some Lunar Society members introduced measures that can now – looking back – be seen to have presaged the soulless production lines and sweatshops of the nineteenth and twentieth centuries. Wedgwood had grown up in poverty and was a leading abolitionist, yet towards his employees he was a strict disciplinarian who wanted to 'make such *machines* of the Men as cannot err' (McKendrick, 1961, 39). Following Smith's guidance on the division of labour, Wedgwood increased productivity, but this had the effect of decreasing morale by obliging his workers to perform simple repetitive actions instead of being responsible for making a complete item. Showing few qualms about firing people he no longer needed, he introduced an oppressive clocking-in and clocking-out system – and he employed women not because he wanted to help them, but because they were so desperate for jobs that he could get away with paying them lower wages than men for the same work. Furthermore, the Lunar Society was only able to function so effectively because the members benefitted from the concealed labour of their energetic wives and daughters. The meetings were domestic events that took place in private homes rather than

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in the male territory of clubs and coffee houses. As well as catering for the social aspects of these monthly gatherings, women were regularly recruited throughout the year to keep accounts, wash out instruments and record results. Several of them were still more intimately involved in the scientific research that made their menfolk famous. For example, Watt sent technical letters about chemistry to his wife Annie, whose family was in the bleaching trade, while Wedgwood's wife Sally advised him on pottery patterns and kept up the shorthand notes in his log book (Uglow, 2002).

It is anachronistic to regard the Lunar Society as a purely scientific organization. To make people's lives better, its members wanted not only to introduce technological improvements, but also to reform social structures. Even those generally associated solely with scientific or technological innovations were also politically active. Priestley is celebrated as a great chemist (such a pity he sold the secret of fizzy water to a Mr Schweppes!), but he was notorious for his unorthodox religious views and his radical political tracts. Although less out-spoken than Priestley, Darwin endorsed the revolutionary ideals of his American friend Benjamin Franklin and supported Wedgwood in his campaigns against slavery. 'Do you not congratulate your grand-children on the dawn of universal liberty?' Darwin asked Watt in a letter of 1790, during the French Revolution; 'I feel myself becoming all french [*sic*] both in chemistry and politics' (King-Hele, 2007, 359).

The Lunar Society's reforming ideals were taken in a fresh direction by two younger men, Richard Lovell Edgeworth and Thomas Day. Edgeworth was already a prolific and ingenious inventor, but under Day's influence he became enthused by the latest French ideas about education. Because of his mechanical achievements, Edgeworth is now seen primarily as a scientific innovator, but at the time he also enjoyed a wide reputation as an educator. In contrast, Day is now often regarded as an outsider to the Lunar Society because he made no scientific contributions and his first social experiment ended in failure. Of a more philosophical bent than Edgeworth, he decided to

fashion a wife for himself by adopting two girls from an orphanage and bringing them up according to the educational philosophy of Jean-Jacques Rousseau. Teaching them to love reading rather than clothes and to live naturally without relying on the trappings of modern civilization, Day encouraged his protégés to develop minds of their own by pursuing their own interests. In an attempt to strengthen one girl's fortitude, he sprinkled her arm with hot sealing-wax and fired pistols through her skirt. Perhaps unsurprisingly, the girls became uncooperative, and he ended up apprenticing one to a milliner and dispatching the other to boarding school.

Tempting as it is to mock this unsuccessful attempt at improvement, it seems fairer to point out that, despite this initial setback, Day continued to attend Lunar Society meetings and went on to become a very influential social reformer. His moralizing children's book, *Sandford and Merton* (1783–1789), remained a bestseller for eighty years. It describes how, under the guidance of a patient teacher, a spoilt rich child gradually recognizes his inferiority to his impoverished but upright playmate and resolves to reform. A fervent supporter of the American revolutionaries against the British government, Day was also a leading anti-slavery campaigner whose heart-rending poems did much to inflame public outrage at the conditions on trans-Atlantic slave ships. Partly thanks to Day's influence, other Lunar men campaigned to improve women's education and give them greater freedom. For example, in an early version of a correspondence course, the botanist Dr William Withering instructed several young women in scientific ideas, while Darwin bought a large house so that his two illegitimate daughters could set up a school for girls. In his progressive syllabus (in which he shrewdly recommended books written by himself and his friends), he specified that the pupils should have plenty of fresh air and exercise, wear loose clothes, and study the scientific and mathematical topics normally reserved for boys.

By embracing the concepts of rationality and progress, the Lunar Society's aspirations overlapped with those of French *philosophes* such as Condorcet. But although

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these Midlands friends held in common a progressive attitude, they were politically diverse, acting as individuals, not as a single group. ‘We had nothing to do with the religious or political principles of each other,’ Priestley declared later. ‘We were united by a common love of science, which we thought sufficient to bring together persons of all distinctions, Christians, Jews, Mohametans, and Heathens, Monarchists and Republicans’ (Uglow, 2002, 14).

When painting this utopian picture of a collaborative community, Priestley glossed over the internal conflicts – especially about the American and French Revolutions – that contributed to the Society’s demise. However, for the fifty or so years that it flourished, this informal group brought together men of enormously varied interests and backgrounds who collectively had a dramatic effect on industry, science and society. Many of their individual projects failed (Darwin never did get his speaking machine to work), and society has certainly not yet reached the state of perfection predicted by Condorcet. Indeed, following the laws of unintended consequences, some of their innovations proved to have disadvantageous implications, but by promoting the relatively recent concept of progress, the members of the Lunar Society made it possible for its successor – innovation – to be invented.

APPENDIX: MEMBERS OF THE LUNAR SOCIETY

I have used modern terms to describe them. ** indicates that the man was a Fellow of the Royal Society.

- ** Matthew Boulton (metal manufacturer)
- ** Erasmus Darwin (physician, botanist, poet, political radical)
- Thomas Day (social reformer, abolitionist poet)
- ** Richard Edgeworth (inventor, educational reformer)
- ** Samuel Galton (gunmaker, Quaker)

- ** Robert Johnson (Anglican minister)
- ** James Keir (chemical manufacturer, supported French Revolution)
- ** Joseph Priestley (chemist, dissenting minister, political radical)
- William Small (physician, supporter of American Revolution)
- Jonathan Stokes (physician, botanist)
- ** James Watt (engineer)
- ** Josiah Wedgwood (mineral expert, business man, abolitionist)
- ** John Whitehurst (geologist, supported American Revolution)
- ** William Withering (physician, botanist, popular educator)

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EUROPEAN UNIVERSITIES IN THE CONTEXT OF THE PRE-MODERN AND MODERN KNOWLEDGE SOCIETY

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For decades, the relationship between universities and modern knowledge society has been the subject of controversial debate. Its theoretical impulses can be traced back to sociological and economic works by Peter Drucker, Daniel Bell, Nico Stehr or Helga Nowotny, whose social analyses and predictions, for all their differences, all identify knowledge and science as the key socio-economic resources of modern culture [Bell, 1999; Drucker, 1993; Drucker, 1969; Nowotny et al., 2004; Stehr 1994]. To date, this shift from an industrial to a knowledge-based service society has been studied using many different terminological approaches. Categories used have included 'the information age', 'learning society' and 'knowledge society', although it is this last term that has become widely accepted in politics and among the general public. The concept of a knowledge society is generally associated with a variety of developments. Firstly, it is often claimed that knowledge and science have become progressively more oriented towards criteria of utility and applicability: to be productive, knowledge has to have a practical use, it has to be convertible into an information advance or technological innovations. Secondly, scholars have individuated an economization of knowledge, whose production and distribution have become increasingly subject to global competition. Thirdly, there has been talk of a 'de-institutionalization' and contextualization of knowledge and science, which are increasingly oriented towards their respective applications, abandoning their traditional functions in the process.

In contemporary debates, all of these aspects of modern knowledge society are considered – by critics and proponents alike – to constitute a challenge to the classic self-image of the university (the 'idea of a university'). The economic exploitation,

practical application and contextualization of knowledge seem to question the traditional functions of the university. This applies both to the cognitive claim of academic education and science to be the sole representatives of knowledge, and to their self-determination, reflexivity, and freedom from utilitarian goals (Scott, 1999).

The following article attempts to shed light on the problematic relationship between universities and knowledge society from a historical perspective. It will address two conflicting approaches to the topic. On the one hand, theoreticians like Drucker, Bell or Stehr invariably identify knowledge society as a phenomenon specific to the twentieth century, a feature of the 'post-industrial age'. On the other hand, in opposition to this analysis of our times, universities have continued to lay claim to their traditional monopoly on higher education and scholarship. Both views deserve to be critically re-assessed and relativized with reference to recent and older literature on cultural and social history.

ON THE RELATIONSHIP BETWEEN UNIVERSITIES AND KNOWLEDGE SOCIETY

Since the Middle Ages, the claim to be the exclusive locus of knowledge and scholarly production has been part of the universities' self-image. The cognitive and social accuracy of this claim to uniqueness has, however, been held up for scrutiny by leading theorists of knowledge society, albeit solely with respect to the modern age and to what are referred to as post-industrial societies. At the same time, the Enlightenment ideas of linear progress and of periodization have been questioned (Latour, 1998) and the role of the university in relation to external institutions relativized.

Deploying theories of knowledge society, the cultural historian Peter Burke has shown that analyses restricting knowledge society to a particular era fall short of the historical truth. Cognitive activities such as locating knowledge, classifying it, teaching it, controlling it, selling and acquiring it have always been embedded in social

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contexts and have been the order of the day since the beginning of the Early Modern period at the latest – with or without the universities. To Burke's way of thinking, the universities are only one factor among many in a dynamic process from the 'birth of the knowledge society' in the fourteenth and fifteenth centuries to the 'explosion of knowledge' in the nineteenth and twentieth centuries (Burke, 2014; Burke, 2001).

Given the ever-increasing amount of international literature on information societies and knowledge societies that has appeared alongside historiographical studies of the universities, it seems appropriate to expand on Burke's approach by examining more thoroughly the origin, development and in particular the interaction of both domains with respect to debates about modernization, differentiation and professionalization. Such an approach reveals surprising gaps in mutual perception as well as a remarkable failure to make these issues the explicit subject of research. A successful example of an integrative method of this kind are the historical and sociological studies of the intercultural globalization of knowledge, which began long before the computer age and the digital revolution of the twentieth century (Renn, 2012).

If the image of universities as social sub-systems – as suggested by the sociology of knowledge analysis – is considered correct, this new perspective can integrate the conventional history of institutions, disciplines and academic subjects, and place it in its wider sociocultural context (Luhmann, 1992; Stichweh, 1994). Moreover, this kind of historical approach can help to overcome the cognitive unclarity of popular conceptions of knowledge society: even if scientific and systematic forms of knowledge do not constitute the sole legitimate source of human knowledge production, they should by no means be equated with mere information, as talk of the 'google society' or the 'information age' suggests (Lehmann/Schetsche, 2005).

A further problem with theories of knowledge society is a notorious presenteeism along with the associated concept of an eruptive development in knowledge – both of which, despite being problematic, have become guiding premises in research, not

least in the humanities. Over the last quarter century, for instance, the concept of a (post)modern knowledge society has expanded into the fields of cultural studies and contemporary history. The focus lies primarily on the transition from industrial society to modern-day knowledge societies. By analogy with the narrative of an Early Modern 'scientific revolution', a 'second modernity' has been diagnosed with respect to the present socio-economic importance of knowledge and science.

A phenomenon which is indeed specific to the twentieth century is the debate about the sociology of knowledge and the transformation of knowledge in the wake of the displacement, exile and emigration of scientists and intellectuals in the age of fascism, National Socialism and communism. A critical consideration of the dominant knowledge economies in the era of globalization has resulted in a history and theory of local and global knowledge societies and knowledge cultures (Frank, 2000; Gorz, 2004; Stehr, 2000).

The increasing presence of social networks and online encyclopedias, such as Facebook or Wikipedia, and the establishment of specialist subjects and research areas such as 'Media Philosophy' or 'Digital Humanities' mark the quantitative and qualitative shift to a digital global knowledge society. On top of this, there is increasing demand for open access in all areas of general and scientific knowledge, which marks a huge revolution in scientific communication, particularly for universities, although the epistemological and ontological dimensions of this 'knowledge avalanche' have been ignored to a large extent (Engelhardt/Kajetzke, 2010; Mainz et al., 2008).

HOW THE UNIVERSITIES EMERGED OUT OF MEDIEVAL KNOWLEDGE SOCIETY

Under this present trend, the actual origins of modern knowledge society are largely obscured or ignored. A notable exception is the cultural history of knowledge discussed above, as represented by the works of Peter Burke and others. This approach traces

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the roots of our modern knowledge society back far beyond the twentieth century to the social and cognitive transformations of the Middle Ages and Early Modern period. In the 1950s, the historian Jacques Le Goff, a member of the French *Annales* school, described the emergence of a pre-modern form of knowledge society in his book *Intellectuals in the Middle Ages* (Le Goff, 2001). During the process of urbanization that took place in the twelfth century, medieval clerics attained the status of an intellectual class of their own ('the clergy'); they served as private tutors to the local middle classes in cities like Paris or founded their own schools. In contrast to the 'three estates' model that still prevails today, members of the clergy saw themselves, not so much as ecclesiastical dignitaries as 'peddlers of words', 'professional thinkers who teach their thoughts' (Le Goff, 2001, 9). In Peter Drucker's terminology, one could speak in this context of medieval 'knowledge workers'.

One of the key points of Le Goff's study is that these urban education markets eventually developed into the universities. During this process, the stocks of knowledge, which had hitherto been passed on within a free market, became consolidated into set curricula. This institutionalization of knowledge gave rise to the scholastic disciplines, an argument which Le Goff bolsters with a further economic aspect, namely that the increased abstraction and formalization of knowledge was accompanied by the economic saturation of university teachers. The increasingly close affiliation with the Church made the professors and lecturers largely independent of the fees of their students because the university provided sinecures and private income (Le Goff, 2001, 98–102, 124–146). This change in economic conditions crippled the previous intellectual *avant-garde*. Le Goff sees in this process the key reason for the decline of scholasticism. Not until the rise of the Humanists in the fourteenth and fifteenth centuries would the universities experience a new blossoming – initiated once again from outside, via a similar market mechanism. In Le Goff's view, the origins and evolution of the universities are thus rooted in a knowledge economy.

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Frank Rexroth, a medievalist at Göttingen, argues for a rather different history of the founding of the universities, although it is equally as interesting as regards the concept of knowledge society (Rexroth, 2011; Rexroth, 2009). As opposed to Herbert Grundmann and Walter Rüegg, who advance the thesis that the universities were an autonomous project, Rexroth's approach is distinctly more nuanced. During its medieval beginnings, European higher education developed a dual cognitive profile, which Rexroth illustrates using the example of the universities of Paris and Bologna. The two universities, in his view, represented 'radically different conceptions of scholarship'. In Paris, the focus lay primarily on the link between theology and the *artes liberales*, organized to this end around a common truth discourse, 'the key distinction between 'true-untrue''. In Bologna, the study of jurisprudence and the education of lawyers took precedence and the decisive 'scholarly criterion of difference' was the question of social relevance and utility (Rexroth, 2009, 97). These differing orientations gave rise to a discourse of scholarly exclusion. Paris scholars spoke disparagingly of Bolognese jurisprudence as *scientiae lucrativae*, 'bread-and-butter studies', while in Bologna, students arriving from Paris were advised to forget all knowledge of the logic and grammar they had acquired there: 'Write not of subtleties but of useful things' (Rexroth, 2009, 95). In Rexroth's view, the relevance of this to the history of the universities lies in the fact that, over the course of the thirteenth century, various contingent factors led to these fundamentally different conceptions of scholarship coming together under one roof as a *studium generale*. This represented the true origin of the European university, which from then on would continue internally the struggle that had originally existed between Paris and Bologna, as the 'conflict between faculties'. As Niklas Luhmann and Rudolf Stichweh put it, the institutional merging of Paris and Bologna turned the universities into a social *and* scholarly system. The fields of study they brought together in one institution not only gained autonomy and self-critical freedom, they also became available for appropriation by society:

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'Their ambivalent position as both the first observers of society and as part of that society was only endurable because the universities were Janus-faced, the home of both philosophers and social engineers' (Rexroth, 2009, 92).

According to the work of Rexroth and Le Goff, the history of the European universities can only be understood in the context of far-reaching social and cognitive developments. From their very beginnings, the motives for founding universities were economic and socio-political in nature. Scholarly learning has always required a practical and economically relevant dimension. Humboldt's oft-cited 'idea of a university', with its ideals of pure, disinterested education and research, is contradicted by the history of the universities' actual origins as outlined above. Those involved in current reform debates are fond of invoking academia as the opposite of knowledge society and its socio-economic needs, however the university as ivory tower has no basis in reality.

THE ORIGINS OF EUROPE'S KNOWLEDGE SOCIETY

While Jacques Le Goff traces the origins of knowledge society back as far as the Middle Ages, recent approaches to the cultural history of knowledge associate its origins primarily with the start of the Early Modern period. This approach frequently links the beginnings of knowledge society with the rise of modern natural sciences, although it transcends the limitations of a mere history of scientific ideas and methods.

One example is Richard van Dülmen and Sina Rauschenbach's voluminous anthology *Die Macht des Wissens* ('The Power of Knowledge', Dülmen/Rauschenbach, 2004). Under the motto 'knowledge is power' originally coined by Francis Bacon, they place various different forms of knowledge in their social and cultural context. At the beginning of the development they sketch out, new knowledge and new understanding of the world was linked to the practical goal of mastering nature. Techniques of collect-

ing, systematizing and passing on knowledge made nature, society and culture cognitively available. Knowledge and science became factors in the world of scholarship, which had not yet separated nature from history.

In the introduction to their anthology, van Dülmen and Rauschenbach distinguish between two initially separate forms of knowledge in the Middle Ages and Early Modern period (Dülmen/Rauschenbach, 2004, 4). On the one hand, there was scholarly knowledge, which was generally passed on in written Latin and was limited to the universities and monasteries. It included the seven liberal arts, and ecclesiastical and secular legal texts. On the other hand, there was the empirical, common sense knowledge of artisans, surgeons and builders, which was passed on orally and deictically through 'application and observation'. During the rise of Humanism and the Renaissance, these two forms increasingly merged, resulting in both the technical and instrumental skills of a Leonardo da Vinci and the empirical and experimental culture of modern science.

'Scholars and artisans, healers and doctors of medicine worked together for the first time. Everything was to be substantiated and systematized anew, better than before, and then preserved in writing; mathematics was to be an instrument for re-interpreting and representing nature and the environment. Empirical and received knowledge, scholarly and non-scholarly knowledge merged with each other and became one.'

(Dülmen/Rauschenbach, 2004, 4)

This historical process of synthesis between the different knowledge cultures leading to empirical science had already been investigated by the philosopher and educator Edgar Zilsel in his studies of the social origins of Early Modern science (Zilsel, 2000; Zilsel, 1990; Zilsel, 1976). Zilsel was born in Vienna and forced into exile in 1938; the results of his studies are now known in historiography as the Zilsel hypothesis. Like van Dülmen and Rauschenbach, Zilsel regards the development of modern science

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as the communal work of two different social groups, whose interaction increased significantly between 1300 and 1600: on the one hand, the university scholars and humanists, and on the other the artisans and artists. According to Zilsel, the humanists and university scholars had been schooled in reason but nonetheless differentiated between the liberal and mechanical arts, disparaging the latter ('handicrafts, experiments and dissection') as wearisome activities (Zilsel, 1976, 49). On the other hand, the artisans, 'pioneers of causal thinking', experimented, quantified, and invented new instruments for nautical, musical and military purposes. In contrast to the academic and humanist scholars, however, they lacked intellectual and formal training. Zilsel's main argument is that these two different knowledge cultures were kept apart out of socio-economic motives:

'Thus the two components that make up the scientific method were kept apart by a social barrier. Schooling in logic was restricted to upper-class scholars; experimentation, an interest in causality and quantitative methods were more or less the province of plebeian artists. Science was born when technological advances finally enabled the experimental method to overcome social prejudices against artisanal work, meaning that it could be adopted by scholars trained in reasoning. This took place around 1600 [...]. At the same time, the scholastic methods of disputation and the Humanist ideal of attaining individual renown through the ideals of mastering nature and the progress of knowledge were overcome by scientific cooperation.' (Zilsel, 1976, 49)

Van Dülmen and Rauschenbach as well as Edgar Zilsel argue – at least implicitly – against the narrative of 'scientific revolution' mentioned briefly above. The origin of Early Modern science, which is frequently viewed as similar to the current day 'explosion of knowledge', was neither an eruptive process nor one that can be reduced in epistemological terms to the evolution of theories and ideas. Instead, it was

a dialectical development that involved various different social groups, rational cultures and irrational objections. The rise of a science-based society in Europe was thus also a socio-political phenomenon.

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EUROPEAN KNOWLEDGE DEVELOPMENT AS A *LONGUE DURÉE*

Almost fifteen years ago, at the peak of the debate about knowledge society, the cultural historian Peter Burke published a similarly substantial study to van Dülmen and Rauschenbach. From a perspective that is clearly and explicitly informed by the sociology of knowledge, Burke describes the development of a European knowledge society in two dense and extensive volumes, tracing a *longue durée* from the Middle Ages to the twentieth century (Burke, 2014; Burke, 2001). He takes a diachronic structuralist approach, which highlights individual aspects of the process logic of knowledge from production to reproduction to distribution. Burke also presents his own narrative of knowledge development by combining cyclical and dialectical forms of historical theory, which allows him to outline a common context for both modern and pre-modern knowledge society.

Burke's argument begins at the point where the analyses of Jacques Le Goff and Edgar Zilsel leave off; he connects the origins of knowledge society with its beginnings. For Burke, both aspects ultimately constitute a double defeat for the universities. Like Le Goff and, in a broader sense, Johan Huizinga, he regards the history of medieval scholasticism as a trajectory of rise and fall (Huizinga, 2006). What began as the intellectual *avant-garde* of an early capitalist urban society, ended in an authoritarian and purely reproductive form of dogmatic knowledge because of the universities' increasing affiliation to the Church:

'During this period it was tacitly assumed that the universities should concentrate on conveying knowledge rather than discovering it. It was considered equally self-evident that present scholarship could offer

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nothing of equal value to replace or refute the opinions and interpretations of the great scholars and philosophers of the past. That meant the task of a teacher was limited to interpreting [...] the views of authorities. The disciplines that could be studied were – at least officially – set in stone: the seven *artes liberales* and the three higher disciplines, Theology, Jurisprudence and Medicine.’ (Burke, 2001, 46–47)

Humanism in the fourteenth and fifteenth centuries represented a new modernist philosophy which had arisen in opposition to scholasticism’s increasingly dogmatic outlook. According to Burke, this movement initially took shape at the universities, but its new understanding of scholarship and education as arts of conduct and self-development meant that it mainly found fields of activity outside them. Empirical natural philosophy could have given the universities an injection of fresh blood, but they missed this opportunity as well. It was not until the end of the seventeenth century that scientific ideas and methods found acceptance in academia. By then, an independent, learned public, the *res publica literaria* of the Enlightenment, had long since arisen from the Humanist and natural history movements (Burke, 2001, 59). Outside the universities, these scholars established new scientific institutions and forms of communication such as museums and academies, including the Royal Society in London (1660) and the government-approved Académie royale des sciences in Paris (1666). In 1717, the Engineering Academy was founded in Vienna. At around this time, the scientific journal was born with the *Acta eruditorum* (1682), published in the trade fair city of Leipzig, and the French *Journal des sçavans* (1665) (Gierl, 2004).

Much of this learned communication occurred in secret, independent of official scholarly discourse and under the radar of Church and state censors. Banned or clandestine texts travelled across Europe via trade routes and fairs as a kind of forerunner of modern *samizdat*. Martin Mulsow, a historian of ideas, has recently conducted a trail-blazing study of these forms of ‘precarious knowledge’ (Mulsow, 2012). Ecclesiastical

institutions also participated directly in the learned discourses of the Enlightenment, as becomes clear from a recent research project on Benedictine monks (Wallnig et al., 2012). A further example is early Kantianism in Austria, which enjoyed a particularly warm reception at seminaries (Sauer, 1982). Burke writes of these various Enlightenment tendencies:

‘Firstly, the monopoly on education which the universities held in practice was called into question in this period. Secondly, research institutions, the profession of researcher, and the very idea of research itself came into being. Thirdly, the clergy, above all in France, devoted themselves more intensively than ever before to social and political reform projects, or, in other words, to the Enlightenment.’ (Burke, 2001, 58–59)

The historical dynamic of the Enlightenment is of central importance to our understanding of modern knowledge society. Because the universities only reluctantly opened up to humanist and empirical scientific culture, thereby delaying their institutionalization, scholarly knowledge was diffused throughout society and became part of general culture. The ‘explosion of knowledge’ so often invoked these days has its forerunner in this development.

The universities would not succeed in absorbing Enlightenment scholarly culture until the eighteenth century, for instance, with the founding of the Reform University at Göttingen (Clark, 2006). In the course of this process, university teaching became more scientific and scholarly knowledge more professional and disciplined (Stichweh, 1984). Since this process was not completed in Austria until the mid-nineteenth century, the literature often refers to Austria as a ‘delayed nation of science’ (‘verspätete Wissenschaftsnation’) (Höflechner, 1999). Despite this process, research and higher education were never completely absorbed by university structures. The idea of the universities as the unified locus of science has never been more than a fiction or guiding principle.

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As already mentioned, Burke bases his 'grand narrative' of the development of European knowledge and science on a twofold structure of historical theory. Unlike van Dülmen and Rauschenbach, he sees the history of Early Modern knowledge as a cyclical process. Following Max Weber and Thomas Kühn, he assumes this consists of a succession of cumulative and eruptive phases:

'From the perspective of the *longue durée*, we are dealing with cycles of innovation followed by phases of "generalization", to use Max Weber's term or, as Thomas Kühn, puts it, by "normal science". In Europe, these cycles – which continue into the present – began in the twelfth century when new institutions, known as universities, replaced the monasteries as centres of scholarship.' (Burke, 2011, 63–64)

This narrative of circularity enables him to connect modern day knowledge society directly with aspects of the Pre- and Early Modern periods. One example is the relativization and self-critical nature of knowledge. Peter Drucker and Nico Stehr consider the application of knowledge to knowledge to be one of the key features of modern knowledge society (Stehr, 2001). It is no longer merely a matter of producing or communicating knowledge; rather, knowledge must be tested, sorted and made productive. In other words, knowledge must be relevant. Burke sees a similar phenomenon at work in the course of the Enlightenment (Burke, 2001, 183–196). Once the authoritative entrenchment of knowledge had been rejected, leaps in technical and epistemic innovation became possible, leading not only to a flood of information but also to a new awareness of the provisional nature of knowledge and its temporal limitations. Science was given increased credibility by the development of moral conceptions of truth and truthfulness, as described by Steven Shapin in *A Social History of Truth* (Shapin, 1994). Philosophical epistemology and theoretical scepticism enjoyed a new flowering. Moreover, the seventeenth century saw the invention of the footnote as a way of getting to grips with the flood of publications, as well as trying to ensure the

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validity of scientific knowledge (Burke, 2001, 192). Burke draws a direct line from this point to modern self-critical and scientific research on the phenomenon of 'knowledge': 'There is a thought-provoking continuity between twentieth century sociology of knowledge and attitudes in the Early Modern period' (Burke, 2001, 192). Thus the Pre-Modern period not only paved the way for knowledge society but also for its theoreticization.

The second aspect concerns the internal dynamic of European knowledge and science history. For Burke, the cycle of innovative and cumulative phases is characterized by a dialectical process in which opposing tendencies such as nationalization and internationalization, secularization and religious fundamentalism, professionalization and laicization, democratization and monopolization alternated continually:

'There is an interplay between innovation and routine, flexibility and rigidity, thawing and freezing tendencies, unofficial and official knowledge. On the one hand we have open circles and networks, on the other institutions with fixed membership and officially defined spheres of responsibility that erect enduring barriers between themselves and the non-experts.' (Burke, 2001, 67)

This interplay is especially significant for the role of the universities. Modern theories of knowledge society frequently refer to the 'de-institutionalization' of science, whose production and reproduction is linked ever more closely to specific contexts of use (Nowotny et al., 2004). Peter Drucker, for instance, writes that modern knowledge society 'needs people who can put knowledge to work rather than people who are prisoners of discipline or method' (Drucker, 1969, 334). A clear indicator of this development is the growth of educational and research institutes outside the universities, which to some extent undermine the universities' 'scientific hegemony' on two sides (Nowotny et al., 2004, 107). In academia, this sort of attack has been met with a fair degree of alarmism, although Burke's analysis suggests academics can

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console themselves that from a historical perspective this is a positive development: interaction – although often reluctant – with other knowledge and scientific cultures has always enriched academia, or, to put it even more bluntly, has been a constitutive element of the universities' success.

CONCLUSION

The concept of knowledge society has been called into question by various commentators because of its focus on the present and its underlying socio-political optimism. Historiographers have suggested that we should speak not of 'knowledge society' but of differing 'knowledge cultures' in order to better integrate the multifarious historical and social dimensions of knowledge (Fried/Kailer, 2003). This approach may have prevailed in more recent theories of the history of knowledge and science, but the heuristic value of the economic and sociological concepts of knowledge society, especially for historiography, should not be forgotten.

The frequently hermetic and subject-based understanding of knowledge and science that has dominated traditional historical work on science and the universities up to the present day has to a large extent been dismantled by the pioneering work of Fritz Machlup, Peter Drucker, Daniel Bell, Nico Stehr and Helga Nowotny. A further impulse comes from the socio-political transformations of recent decades. The increasing focus on the socio-economic relevance of knowledge and science has forced the universities, humanities faculties in particular, to re-examine their own institutional, historical and cognitive assumptions. The concept of knowledge society was a warning to academics that they would have to engage in a greater degree of self-reflection to renew their discursive sovereignty, especially given the pernicious demands for practical applicability made of research and education, schools and universities. The universities' values and traditions should be 'more than just the soundtrack to liberal economic imperatives', as the then Chancellor

of Vienna University, Alfred Ebenbauer, put it almost twenty-five years ago (Ebenbauer, 1992, 27). The new 'cultural history of knowledge', put into practice by the studies of Jacques Le Goff, Peter Burke or Richard van Dülmen, is in part a reaction to this process.

Even if the various aspects and problems of knowledge society can be only briefly outlined here, a number of points can be drawn in conclusion. Firstly, as the developments described above have hopefully made clear, knowledge society is not unique to modernity, nor a feature exclusive to the so-called 'post-industrial age'. Phenomena such as the economic exploitation, practical application and professionalization of knowledge can already be identified in the Late Medieval and Early Modern periods. The same is true of the oft-cited 'explosion of knowledge', which had forerunners in the establishment and proliferation of the universities as well as in the invention of the printing press. In this respect, the distinction between the Modern and the Pre-modern period is one of quantity rather than quality. Secondly, the universities' claims to hegemony, frequently asserted by academia and vigorously contested by knowledge society theorists, need to be relativized by both sides of the debate. Since their rise in the thirteenth and fourteenth centuries, the universities have never had a monopoly on research and education, let alone on scholarship in general. Along with the academies, the monasteries, the courts and learned societies, they were only one factor among many, even if their trajectory is an undoubted success story. Thirdly, the course of European cultural development clearly shows that scholarly and everyday knowledge, theory and practice, craftsmanship and linguistic skill have always interacted and been closely intermeshed. Knowledge society theorists often emphasize the contextualization, de-institutionalization and socialization of knowledge, but this is by no means unique to the modern age.

Debates about knowledge society have always been accompanied by a degree of alarmism, especially in academic circles. The sociological diagnoses put forward by

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theorists like Drucker or Bell were frequently seen as a cover for a neoliberal university policy that ultimately aimed at the corrosion and misappropriation of science and higher education. In many respects, concerns such as these cannot be dismissed out of hand, but given the contexts described above, it is important not to cling to our own idealizations and fondly cherished self-images. If the course of European knowledge development can be summed up at all, it is with the famous epigram of Heraclitus of Ephesus: 'Nothing is so constant as change.' What is most important is to continue participating actively in this change in the future.

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THE HISTORICAL DIMENSION OF INNOVATION

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LONG WAVE THEORY

Looking back over the economic history of the last three hundred years, it becomes immediately obvious that innovation has repeatedly been a major driving force behind growth, wealth creation and modernization. It is therefore hardly surprising that innovation has also been an important component of theories of economic development, in particular theories of economic growth and modernization. The best-known is probably long wave theory, developed by Nikolai D. Kondratiev in the 1920s and subsequently expanded on by Schumpeter with particular reference to innovation (Schumpeter, 1964). The theory attributes the initiation of long-term growth cycles, the eponymous 'long waves', to the diffusion of fundamental technological innovations, known as 'basic innovations', and their secondary and multiplier effects (Kleinknecht, 1992; Kleinknecht, 1987; Maddison, 1991; Spree, 2006; Spree, 1991).

The prevailing if somewhat controversial theory of forty to sixty year wave cycles identifies the following technologies as basic innovations: around 1800, the mechanised loom, the spinning machine, steam power, coal and iron mining machinery; in the mid-1800s, the railway, the telegraph, cement, and photography; at the turn of the nineteenth century, electrification, chemistry, the car and aluminium; in the second half of the twentieth century electronics, television, nuclear power, plastic and the computer (Walter, 1998).

Adopting a historical perspective makes two things clear. Firstly, it is not the invention itself but rather its deployment within the economic system that triggers the wave, which is then spread by diffusion and/or by secondary and multiplier effects. Secondly, such waves do not spread evenly or simultaneously through different regions; instead, they diffuse geographically over time. In the process, there is a degree

of change in the way they spread. If the first two waves essentially arose in Great Britain and spread across continental Europe, this was no longer true of subsequent waves. For instance, late nineteenth-century Germany had become one of the leading industrial nations and was a significant factor in triggering the third wave. Subsequently, the USA became the driving force behind innovation, although in recent years the leading role played by the Atlantic axis (USA–Europe) in global industrial innovations has shifted towards the Pacific axis (USA–Asia).

As the concept of long waves gained in popularity, it became common to talk of the first, second and third ‘industrial revolutions’ when referring to these basic innovations, although the order varies according to the reference criteria applied.

THE ‘FOURTH’ INDUSTRIAL REVOLUTION

Nowadays, it has become increasingly common to talk about ‘industry 4.0’ in the sense of a ‘fourth industrial revolution’. Essentially, this refers to those innovations in the industrial production process which fuse information and manufacturing technology ever more tightly, allowing machines to communicate independently with one another and to make autonomous decisions. This is made possible by innovations in the area of digitalization, the interconnection and use of vast quantities of data (‘big data’) and the development of networked robotics, in which field robots are equipped with artificial intelligence and are hence capable of learning. In this context, expressions such as ‘the internet of things’, ‘the industrial internet’ or ‘robotization’ are frequently employed. In a parallel development, 3-D printing also appears to possess the characteristics of a basic innovation. Roland Stelzer, one of the founders and current director of ‘HappyLab’ in Vienna, part of the global ‘Fab-Lab’ movement and a pioneer of 3-D printing, sees this technology as ‘a genuine revolution’ that ‘will democratize the economy’. He believes 3-D printing will make it possible ‘to penetrate areas of manufacturing that were previously restricted to large corpora-

tions’, turning consumers into producers, who can thereby avoid being ‘blessed with products which they may not even need’ (Roland Stelzer in an interview in *Wiener Zeitung* 22/23, November 2014, 38f). There are indeed good reasons for believing that such changes to the industrial system have the characteristics of a new basic innovation that will unleash a long wave, analogous to steam power, electricity, motorization and automatization. Many arguments and prognoses to this effect have already been made.

From a historical perspective, it seems particularly relevant that such arguments make reference to the changes that can be expected or are already occurring within the capitalist system as a whole. One of the main protagonists in this discourse is Jeremy Rifkin, who speaks of a ‘new economic paradigm’ and classifies these innovations as a ‘remarkable historical event’ which ‘by the mid-21st century’ will cause ‘a transformation in the nature of the capitalist system’ (Jeremy Rifkin in an interview in *Wiener Zeitung* 27/28, September 2014, 3; see also Rifkin, 2014). Similarly, Hannes Androsch predicts that just as mechanization once transformed households, agriculture and industrial manufacturing, ‘industry 4.0’ will revolutionize every aspect of life, but above all mobility, medicine and most particularly the industrial sector. Networked robotics, big data and 3-D printing will make new means of production and more efficient production processes possible through advanced manufacturing techniques. The concepts of nanomanufacturing, biomanufacturing and industrial robotics represent the future of industry (Androsch, 2014a).

From a historical perspective, two observations can be made *a priori*. Firstly, the historical basic innovations had similarly far-reaching effects by virtue of the long waves they unleashed. Secondly, these effects led to a series of institutional innovations to the corporate, socio-political and financial systems (Perrez, 2002). In this connection, it is worth noting that current discourses focus to a great extent on the huge potential impact of ‘industry 4.0’ on labour, production and consumption, and

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hence ultimately on society as a whole. Above all, 'industry 4.0' will usher in new forms of employment and new qualification requirements. In this respect it should be remembered that 'classical' industrialization in the nineteenth century created a demand for mass labour that was met by an 'industrial reserve army' in the Marxist sense. 'Industry 4.0', by contrast, assumes a far-reaching elimination of the labour force and its replacement by 'intelligent' robots, which is likely to have a major impact on the role of labour within the industrial system. The 'internet of things' will, according to Hannes Androsch, 'transform social relations and the world of work. However, as with the earlier industrial waves, there will be more rather than fewer jobs, albeit different ones. People will be liberated from monotonous routine tasks and freed for higher quality, more demanding work. After all, robots have to be designed and manufactured, and the system controls programmed, tested and made secure' (Androsch, 2014b).

It thus seems likely that labour will be incorporated more directly and flexibly into the innovation process than was the case during earlier waves of industrialization. 'The fourth industrial revolution,' according to the German entrepreneur and political consultant Roland Berger, 'will be even more comprehensive, more complex and have an impact on more industrial sectors. 'Industry 4.0' is about making innovative connections between big data, plant-specific software and hardware production technology' (Berger, 2014). Peter Brandl, assistant research project manager and senior researcher for the technology development company Evolaris, emphasizes that the role of the classical industrial skilled worker will change significantly. Increasing individualization of products and diminishing batch sizes means that production planning will have to adapt in the future. Future workers will be deployed in a range of very different production processes according to the demands of production planning and largely independently of their level of qualification (*Die Presse*, 30 September 2014, 'Focus on Industry'). He considers it essential, therefore, to create an environment

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which furthers the acquisition of new knowledge in a way that is as practical and relevant as possible and which takes into account the individual worker's level of existing knowledge.

An interesting historical parallel can be drawn here with the theoretical analyses that were developed during the beginnings of 'classical' industrialization in the late eighteenth century. In his most important work, *The Wealth of Nations* (1776), Adam Smith foresaw that the developing manufacturing systems based on the division of labour, a principle that would find its ultimate industrial expression in the so-called 'Fordist system', had significant potential for process innovations because the specialized labour force employed at each stage of the production process would develop improvements to its own particular section of the process (Smith, 1978). Given the rapid changes that occurred in industrial manufacturing in his times, Smith saw the elements of process innovation which emerged from the division of labour as part of a wider-reaching innovation scenario in which inventions, research and science all played key roles in furthering progress.

The principle of the division of labour in industrial capitalism was, in turn, the basis for Karl Marx's theory of the 'alienation of labour' in the early nineteenth century. Given the fundamental changes in mass production that are becoming apparent with 'industry 4.0' and 3-D printing, the question arises of whether and how far this 'alienation' will be eliminated and replaced by a 're-appropriation' (in the Marxist sense) of labour by individuals engaged in their own manufacturing process.

THE COMPLEXITY OF INNOVATION

Although the status of long wave theory as a theory of economic development has long been the subject of controversy and debate among experts, it has considerable explanatory power and serves as a starting point for examining the historical dimension of innovation. If we examine more closely the general secular process of

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development proposed by long wave theory, it rapidly becomes clear how complex a phenomenon innovation really is.

Innovation theory, which draws to a large extent on Schumpeter, states that we can speak of an 'innovation' when an invention is implemented and has an impact on economic and hence social development. This impact occurs, according to innovation theory, via the 'diffusion' of the innovation through the economic system. Observation of history reveals that diffusion is essentially a matter of complex learning processes, in the course of which basic innovations are generally linked to numerous complementary innovations, generating 'interactions between clusters of innovations' or 'swarms of innovations' and 'bandwagon effects'. These are associated with a rapid growth in markets and the mobilization of investment capital (Spree, 2006). Diffusion can in turn be explained as a consequence of the 'monopoly profits' initially gained by the innovators through increased productivity and cost advantages leading to 'imitation effects' among competitors, although in limited markets these 'monopoly profits' successively disappear, resulting in 'dwindling investment opportunities'. Product prices and revenues or profit opportunities tend to decline, leading on the one hand to corporate concentration and attempts to expand the market, and on the other to yet more innovations aimed at generating new 'monopoly profits'. According to innovation theory, it is these new innovations that initiate a new cycle.

In Schumpeter's innovation theory, which he developed on the basis of historical observations, the 'innovative' or 'creative entrepreneur', a subspecies of 'homo economicus', appears as the decisive actor. His or her function essentially consists in the 'creative destruction' of existing structures through new combinations of conventional and new elements, in other words 'innovation' by investment. The 'creative entrepreneur' is not necessarily envisaged as a single individual but may take the form of an institution. 'Creative entrepreneurs' act within a complex economic, social and political environment, which on the one hand determines the specific form their inno-

vation behaviour takes, but whose structure and development are in turn influenced by the entrepreneurs' activities. The historical dimension of innovation in this sense is not merely concerned with technological innovation and the myriad impacts it has on the systems of production, labour and distribution. Technological innovation affected the entire economy and determined its development, but it was also accompanied by a multiplicity of economic and social, not to mention political innovations as a result of the growth cycles it initiated. Innovation as a concept must thus be understood in the broader sense of economic and social 'modernization', not mere technological innovation. In this sense, innovation is a socio-historical and ultimately a socio-political concept (Gilomen, 2001; Pichler, 2001; Reith/Pichler/Dirninger, 2006).

This very broad understanding of the concept of innovation appears to play a role in current discourse, for instance when there is talk of a need for 'change in every area' in response to the persistence of the recent economic crisis (Reinhold Mitterlehner, Minister of Trade and Commerce, at a conference of the Vienna Chamber of Labour 'Austria as an Industrial Country - How to Proceed?' held on 24 November 2014). There is a feeling that innovation is needed, not only in the business sector but also as regards the role of the state in shaping the economy and society via socio-economic institutions, education, finance and welfare. It is in this sense that Hannes Androsch calls for political initiatives to encourage innovation. He sees a need for action 'to improve the general economic environment, public management and public finance', but also education and training. He considers it necessary to create 'a freer atmosphere for innovation and a spirit of entrepreneurial commitment, more "creative destruction" instead of destructive regulation and bureaucracy' (Androsch, 2014c). This is something that economic and political leaders evidently understood in the past. Androsch refers, for instance, to Wenzel Anton von Kaunitz, Chancellor under the Austrian Empress Maria Theresia, who once said that many things seem difficult only because they have not yet been accomplished, and that when the wind of

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change blows, we must set sail for new shores (Androsch, 2014a). Similarly, Mariana Mazzucato has recently caused a stir with her book *The Entrepreneurial State – Debunking Public vs. Private Sector Myths* (Mazzucato, 2013), which points out the key role played by the state in fostering innovation.

FACTORS IN INNOVATION SCENARIOS

The role of the state and its innovation policy draws attention to a specific aspect of the complexity of innovation whose relevance is highlighted by the historical perspective, namely the ripple effects of innovation and the emergence of various interacting factors. Here it is helpful to consider specific historical innovation scenarios, including specific historical perspectives on the phenomenon of ‘innovation’, in order to gain insight into modern innovation scenarios. Such insights into the form of ‘experiential knowledge’ or ‘orientation’ can be a useful resource for our modern knowledge-based society. By considering different historical innovation scenarios, it is possible to identify a number of factors which are specifically relevant to the emergence and implementation of innovation and which have had different individual effects. These factors can be integrated as generalizations into the previously mentioned theoretical model of the sequence invention – innovation – diffusion, particularly with reference to the transitions between these stages.

For instance, an essential prerequisite for the transition from invention to innovation is the existence of sufficient demand as a motive for investment. The existence of such a demand applies not only to product and process innovation but also to institutional innovation within the socio-economic system, insofar as new ‘institutional gaps’ arise as a result of new needs. In many cases the action of initiators is crucial for the transition from invention to innovation. Initiators pick up on inventions and communicate them either to investors or to policy makers within the economic and socio-political system who can take the necessary decisions. An analogous role is

played in the transition from innovation to diffusion by promoters, who spread the news about specific innovations along the communication channels at their disposal. As a rule, government subsidies or direct measures to foster innovation are closely connected to the activities of initiators and promoters at all three stages. At the invention stage, this applies specifically to the area of research and development, and at the stages of innovation and diffusion to investment and infrastructure. The normative regulation of innovations and their impact on the economy and society is particularly relevant as a factor at the diffusion stage.

If we consider the question of the cause (potential demand) of innovations from a historical perspective, three relationships seem to be of fundamental importance and worth discussing with reference to the historical dimension. The first is the relationship between government innovation policy and private entrepreneurial initiative, with particular focus on innovation as part of the agenda of economic policy. An important aspect is the creation of an appropriate investment and innovation climate and here, the confidence of innovators and investors in political and economic stability is a significant factor. Hansjörg Siegenthaler has developed a theoretical approach which illuminates the significance of confidence for investment decisions in periods of uncertainty following the destabilization of social and economic structures. He explains that innovative investments and a new growth phase can only be expected when confidence has been re-established as the normal state of affairs (Siegenthaler, 1993; Siegenthaler, 1984).

The second relationship is that between innovation in the real economy and innovation in the financial system of the national economy. The third is that between innovation in the system of production and its social consequences, including the innovations that result in social policy.

The examples of historical innovation scenarios which follow can only be described in outline, but I shall nevertheless attempt to distinguish several historical types.

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Chronologically, these scenarios were part of the 'classical' process of industrialization, often referred to as the 'first' industrial revolution, which taken as a whole can be interpreted as a single complex innovation process spanning the late eighteenth and nineteenth centuries.

SPECIFIC HISTORICAL INNOVATION SCENARIOS

INNOVATION AS A FACTOR IN SOCIAL TRANSFORMATION IN THE EIGHTEENTH CENTURY

Bauer/Matis argue correctly that the cameralist, mercantile economic policy of the eighteenth century absolutist state was a decisive factor in the emergence of 'modern capitalism' (Bauer/Matis 1988). Considered from the point of view of technological innovation or innovation in operating systems, this transformation, so fundamental to the modernization of the socio-economic system, is a matter of a change from so-called 'proto-industrial' to industrial structures, in particular in textile manufacturing, due to increasing use of spinning machines and mechanical looms. Linked to this is the transition from 'cottage industries', that is to say from spatially concentrated mass production with internal division of labour, to 'the factory' equipped with machines. The invention of the relevant technology created the possibility of increasing productivity by its incorporation into the production process, that is to say by investment – a possibility which presupposed certain economic, social and political conditions and also had an impact on all of these domains. Sufficient willingness to invest is a crucial factor in the transition from an invention to an economically significant innovation as well as in its subsequent diffusion, and the degree of willingness was primarily due to several factors that constituted this specific innovation scenario. One of these factors was undoubtedly increasing demand. This came on the one hand from the state (both the military sector and the growing state bureaucracy) and on the other from society (the aristocracy, the middle class and the growing population).

However, it also arose from the expansion of supra-regional trading markets and from colonialization. Another decisive factor was the existence of investment capital. This precondition was met by what is referred to as the 'primitive accumulation of capital' in farming, trade and proto-industries such as publishing and cottage industries. Innovations in the financial system, for instance the introduction of loans as a common means of financing investment, played a key role in the transfer of this accumulated capital into industrial investments, in other words in the transition from mercantilism and agricultural capitalism to 'industrial capitalism'. A third important factor was the existence of entrepreneurial potential, which was provided by the establishment of a mercantile middle class within a society that was still essentially organized on a feudal and class basis. The fourth and most significant factor in the state's capacity to foster innovation was the state itself, in the form of the enlightened absolutist regime, which had an interest in strengthening the economic and financial bases of its political power both internally and externally. Its contribution took the form of state subsidies and a policy of allocation within the framework of a mercantile and cameralist economic policy that encouraged innovative investments with reduced taxes and duties as well as providing subsidies and privileges with respect to products and markets. However, it also created a 'collective monopoly' of the guilds (Bauer/Matis, 1988), a ground-breaking legal framework for entrepreneurial and hence also for innovative initiatives. All of this added up to an extreme form of interventionism and political control of the economy that at times amounted to a planned economy, for example in the idea of 'universal commerce' introduced under Empress Maria Theresa, which aimed to establish a local commercial and industrial production structure.

At all events, state economic policy included a policy of innovation in various ways, including the recruitment of innovative entrepreneurs from abroad, the establishment of teaching and research facilities, educational reforms (the introduction of compulsory schooling, the establishment of schools to teach manufacturing, spinning and

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weaving), the institutionalization of science (the Académie royale des sciences in Paris, the Royal Society in London) and the study of innovations in foreign countries in the course of investigative tours (Bauer/Matis, 1988).

In one particular respect, the close link between economic innovation and the political system in this early modern innovation scenario had far-reaching consequences, namely the development of a coalition of interests between the absolutist regime, concerned with furthering the state's economic prosperity, and the emerging mercantile middle class (the 'third estate'). The latter began to demand a much greater say in politics as a result of its increasing economic importance; it played a significant role in the early stages of the French Revolution as well as in the course of the economic reform policies of the Austrian Emperor Joseph II.

Another function of the state in the innovation scenario, however, was to offset insufficient private enterprise (or private capital) and 'market failure' in the form of state-owned businesses, most frequently in the area of manufacturing. One example among many is the Linz woollen mill, which was at first privately owned but then acquired by the state in 1754. By the late eighteenth century it had become one of the largest businesses in Europe.

PRO-INNOVATION POLITICIANS IN THE NINETEENTH-CENTURY MONARCHICAL SYSTEM

The process of economic and social modernization that began in the first half of the nineteenth century rapidly gained momentum. It is notable that during this period certain high-ranking representatives of the political elite quite deliberately introduced and pursued political initiatives to foster innovation. As initiators and promoters they were a driving force behind all three stages – invention, innovation and diffusion – of the innovation process. Their efforts took the concrete form of acquiring and promoting knowledge of promising new production and economic systems, which they

then formulated as economic projects and objectives. In other words, their role was the identification and enhancement of innovation potential. They also encouraged potential entrepreneurs who were willing and able to innovate, and they endeavoured to create the necessary conditions for innovation in infrastructure, institutions and the regulatory and financial framework, combined with efforts to create a greater openness to change and innovation within the political system. They also promoted the diffusion of innovation within the socio-economic system.

A notable example of this kind of pro-innovation politician is Archduke Johann (1782–1859), known as the 'Styrian prince', the brother of the Austrian Emperor Francis I. The pursuit of economic and social innovation in all the forms mentioned above was a central aspect of his life (Magenschab, 1981; Theiss, 1982), but only a few of his most important initiatives can be mentioned here. In 1811, he founded the Joanneum in Graz as an institute for gathering expert knowledge (above all in the natural sciences) and developing practical economic and technological applications. The Joanneum was conceived as an educational institution for all social classes. During a stay in England in 1815, Johann studied the innovations that had taken place there in the iron and steel industries and the use of the newly invented steam engine, and met its inventor, James Watt. In the course of this visit, he learned of the beginnings of the railway system and would later be an enthusiastic supporter of the introduction of railways to Austria. In the 1830s, for instance, he was involved in the planning and construction of a railway line linking Vienna and the thriving Adriatic port town of Trieste via Graz. Johann's chief interest, besides railway construction, was the expansion, maintenance and improvement of the Styrian road network, which he realised very early on was key to the region's economic development.

The impressions and experiences that the Archduke brought back with him from England formed the basis for numerous innovative measures that he introduced to the Styrian mining industry on his return. In 1828, for instance, he acquired a blast

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furnace in Vordernberg and personally ensured that it was operated according to the latest management methods. In 1829, on his initiative, the master blast furnace workers in Vordernberg formed a co-operative to procure the technical equipment (winding engines, mine railways) necessary to mine iron ore efficiently from the Erzberg. This enabled crucial operational innovations which increased their international competitiveness. Archduke Johann's numerous contacts at home and abroad were a major contributing factor to winning new markets.

To provide the necessary scientific and educational foundation for industrial innovation, Johann initiated the founding of a 'Mine and Furnace School' in 1833, which eventually became the University of Mining and Metallurgy in Leoben. He also founded the 'Geognostic Mining Society for Inner Austria and the Country above the Enns', and initiated the 'Exhibition of Industry and Commerce' held in Graz in 1832/33, as well as the founding of the 'Society for the Encouragement of the Commercial Spirit and the Promotion of Commercial Industriousness', two initiatives which encouraged the diffusion of innovative products and means of production. Another of his initiatives was the 'Society for the Promotion and Support of Industry and Commerce in Inner Austria', founded in 1837 and directed by the Archduke himself. It organised exhibitions and gave awards for exceptional work in handcrafts and industry, as well as providing the authorities with expert advice. Social welfare was another aspect of the Archduke's program of innovation, for instance the founding of a form of social insurance for miners and furnace workers in case of accident or disease (the 'Bruderlade der Berg- und Hüttenarbeiter', founded in 1838).

A further focus for Archduke Johann's innovative activities was agriculture. He understood the vital importance of persuading peasant farmers to introduce modern innovations to their traditional methods of farming if they were to compete and hence to survive in the future. With this in mind, he initiated the founding of an agricultural society in Styria in 1819, laying particular emphasis on combining the farmers'

practical knowledge and their own innovative ideas with the latest findings in scientific research. In his capacity as president of the society, he was himself in frequent contact with farmers. This enabled him to introduce many innovations, not only in crop cultivation and animal husbandry but also in the design and construction of farmhouses. These efforts were furthered by an experimental model farm founded in Graz in 1822, by the creation of a Chair in Agricultural Economics at the Joanneum, and by the founding of the Mutual Fire Damage Insurance Company ('Wechselseitige Brandschaden-Versicherungsgesellschaft'), which would eventually become the modern insurance company Grazer Wechselseitige Versicherung.

An important and often tiresome aspect of Archduke Johann's efforts at innovation were his stubborn attempts to convince the central government, not least his brother, the Emperor, of the necessity for state support in the form of financial and regulatory measures. The objections and delaying tactics he encountered in the process only serve to underline the importance of his role as an initiator and promoter of innovation.

INTERACTION BETWEEN THE PUBLIC AND PRIVATE SECTOR IN INSTITUTIONAL INNOVATION

In the early nineteenth century, the so-called 'social question' acquired a particular urgency. In response, an institutional innovation of major importance took place in the field of finance and welfare in many European countries in the form of the savings bank (Pix/Pohl, 1992). An example that can be considered representative was the founding in 1819 of the Erste Oesterreichische Spar-Casse, which played a pioneering role in Central and Eastern Europe (Thausing, 1919). Since the feudal and absolutist regime was evidently incapable of solving the 'social question', there was an urgent need for institutions that could do so. In other words, an institutional gap had opened up. As a result, innovative private initiatives emerged in the form of savings societies modelled on French and British examples. The government took up these initiatives,

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and by establishing and promoting the savings bank as an institution, transformed these private initiatives into an institutional innovation. A significant driving force here was the growing demand for small-scale, low-interest loan and credit financing, to be met from the interest. The rapid diffusion of this innovation across the whole of Europe resulted in the development of a banking industry with regional structures that ultimately laid the historical foundations of retail banking.

In the second half of the nineteenth century, this development was extended by a system of cooperative savings and loan associations (Faust, 1977). The innovation scenario that emerged here was profoundly influenced by the existential threats to their livelihood faced by large numbers of peasant farmers and cottage industries as a result of the emancipation of the peasants, which had an impact from the mid-nineteenth century onwards, and the liberalization of trade regulations. The cooperatives which arose as a response to this need were in essence non-governmental initiatives, conceived, championed and created by individual innovators, although they soon received state support. Friedrich W. Raiffeisen and Hermann Schultze-Delitzsch were two such innovators and promoters whose innovations were subsequently taken up by the state and given a specific legal framework in the form of the Cooperatives Acts ('Genossenschaftsgesetze'), thus becoming part of the economic system.

INTERACTION BETWEEN THE PUBLIC AND PRIVATE SECTOR IN INFRASTRUCTURE INNOVATION

The classic example of an infrastructural innovation scenario is the railway, an innovation that had far-reaching consequences for the economy and society. Three areas in which the state and the private sector interacted, in real economic terms as well as with respect to financing, were the planning of the railway lines, the construction of the lines and stations, and the operation of the lines, including the rolling stock (Dirninger, 1993).

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As far as planning was concerned, the primary initiative came from the state. Research in this field has shown that the main focus was on military objectives and considerations, at least at the beginning, although economic and political factors soon became more important, for instance creating transport access to industrial zones, and the economic integration of peripheral regions. In the construction and operating stages, that is to say the phase of actual investment, the interplay between public and private investment becomes particularly clear, beginning with the question of financing. The example of the Austrian railways is a good illustration of the roles played by the public and private sector in the diffusion of this particular innovation that more than any other may be said to characterize the industrial revolution.

The Vienna-Gloggnitz line (the first stage in the construction of the 'Südbahn', the main railway line running south) was licensed in 1839 and opened in 1842. It was initially funded by private investors, but the state soon stepped in and became the key player in the development of this particular innovation. The government had realised that a railway network could only be built up with direct state involvement, above all where financing was concerned. The age of state rail in the Habsburg Empire lasted from the early 1840s to the mid-1850s. It originated with a document of 23 December 1841 entitled 'Provisions of the State and Private Railways', which established two of the state's essential functions as promoter of the railway and of its development through a combination of public and private investment. The provisions foresaw an extension of the geographic range of the rail network along a north-south and an east-west axis in order to make the Empire's peripheral regions accessible. Vienna would be the central junction, and there were to be cross-border connections to the rail networks of the various neighbouring countries. This required building main lines, the so-called 'state railway lines', from which regional connecting lines would branch out. The provisions were also concerned with the relationship between private and public financing of the development process. 'Where no private ventures exist, or

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where existing ones are unable to fulfil their obligations with respect to the construction or completion of the state railway lines, the cost of constructing the aforementioned state railway lines is to be met by the government.' The provisions also allowed for the leasing of the state railway lines to private operating companies.

The mid-1850s to the mid-1870s were the age of private rail. This was partly because a great deal of international capital was available to be invested in the expansion of the rail network, whereas state finances were in rather a precarious state. However, the state retained its leading role by virtue of the 'licensing norms' of 1854 and the associated railway construction programme, and by a state guarantee of returns of 5.2% on invested capital.

The construction of the main lines running west, south and north became a crucial factor in the economic boom of the *Gründerzeit*. However, the future prospects and conditions for the spread of this particular transport innovation were fundamentally altered by the great stock market crash of 1873. Private funding declined sharply, necessitating more state involvement. The resulting 'Sequestration Law' of 1877 nationalized railway construction to a great extent. Further development was above all determined by the policy of wholesale economic integration of the regions of the Habsburg Empire, in the course of which the innovation spread further and further into peripheral regions. It was for this purpose that the state built the great Alpine railways (the Arlberg line, the Tauern line and the Karawanks line).

The innovation scenario of the railways had specific economic and social consequences, especially in the regions. The advance of the railways led to an expansion of markets, which disrupted small-scale regional economies as well as threatening the livelihood of providers of traditional forms of transport, such as river traffic. On the other hand, thanks to the supply sector, new development opportunities opened up in transport, while the railways created large numbers of jobs and thus brought new elements to the social and employment situation in the regions.

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As an innovation in transport and infrastructure, the railways had an impact on many areas of life. One specifically regional change was the shift from wood firing to coal firing in the salt industry from the mid-nineteenth century onwards, which was made possible by the railway's increased transport capacity. While this was undoubtedly an extremely important innovation, affecting both the productivity of the salt industry and its means of production, it also had serious consequences for the economic structure of those regions dependent on the salt industry. For centuries, the salt production centres, built around salt mines, salt flats and trade in salt, had had an interdependent relationship with the forestry and timber supply regions. The shift from wood to coal firing deprived these regions of much of their function and their sales. As a result, the regional supply chains were disrupted and a system of interdependence dissolved. On the positive side, however, the former supply regions also benefited from a trend towards economic emancipation thanks to the railways, which enabled them to transport their timber and agricultural products to a wider market area.

INNOVATION AND SELECTION IN THE FINANCIAL SYSTEM OF 'INDUSTRIAL CAPITALISM'

By the mid-nineteenth century at the latest, the demand for capital, and the transformation of capital derived from agriculture and trade into 'industrial capital' by investment in industry, made innovations to the financial system necessary. Specifically, ways were needed of focusing and channelling large amounts of capital into the industrialization process, including production, transport and distribution. However, the banking system that had been developed under merchant capitalism lacked suitable institutions. Once again, an institutional gap opened up, creating a need for an institutional innovation. This was met by the establishment of investment banks, whose organization was modelled on stock companies. The innovators and promoters here were individual representatives of the financial system of merchant capitalism,

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in particular the brothers Émile and Isaac Pereire who founded the *Crédit Mobilier* in Paris in 1852 as an innovative kind of joint stock bank aimed at industry and equity financing. The diffusion of this particular innovation is a specialized example of how competition produces an imitation effect, as the Pereire brothers diffused their type of 'entrepreneurial bank' (Cassis, 2007) by participating in the founding of banks modelled on the *Crédit Mobilier* in other European countries. In the process, they became heavily involved in the financing of railways. All this was done as a deliberate challenge to the established banking system and in particular to the Rothschilds, who up until then had dominated the banking world. The Rothschilds, in turn, despite initial reservations about these 'new banking practices' (Cassis, 2007), began to found banks on the Paris model themselves. One of the most notable was the *Credit-Anstalt für Handel und Gewerbe*, founded in Vienna in 1855.

During the *Gründerzeit* there was a boom in speculative investments and the liberal licensing practices in the corporate and banking sector led to a growing potential risk to the capital markets and to the banking sector. This came to a head in the financial crisis of 1873, which resulted in the introduction of a selection process to this sector of the banking system. Those parts of the system that had a solid financial basis were able to consolidate, in part via state regulation, thus permanently cementing the position of this particular innovation as a central element of the 'industrial system'.

INSTITUTIONAL INNOVATION IN SOCIAL SECURITY

In the last third of the nineteenth century, the expansion of industrial means of production and factory working conditions made the 'social question' ever more urgent, particularly in densely populated industrial areas, until it began to constitute a threat to the government, especially in the form of the labour movement and other politically motivated and organized protests with revolutionary potential. This potential threat compelled the government to introduce innovative initiatives aimed at institution-

alizing social security to at least a rudimentary degree. These institutional innovations took the form of social security systems. The Bismarckian system is a prototypical example, providing financial security in case of sickness, accident and old age, and it served as something of a role model in the development of this particular institutional innovation (Eichendorfer, 2000). A rather remarkable characteristic of these institutional innovations and their diffusion is that older institutional innovations that had arisen regionally, such as local health insurance schemes or the insurance schemes of particular branches of trade and industry, were taken over by the state and given a legal framework.

REGIONAL IMPORT OF INNOVATION

Two features of the nineteenth-century process of modernization are the advance of innovative elements into the regions, particularly rural areas, and the resulting changes in the regional economy and society. Taken together, these changes had a long-term impact. A scenario that frequently occurs in this context is the transfer of innovation into a region and its establishment there, by innovators from outside the region. From a historical perspective, the scenario of regional import of innovation can be identified as a symbiosis of various agents whose interaction functions in principle like an 'innovative entrepreneur' in Schumpeter's sense, bringing various different factors together in an innovative fashion.

One specific example among many is the founding of spas, which opened up new dimensions in tourism and the tourist industry. Historical analysis shows that the actual process of importing this innovation into the regions followed a general pattern with specific regional variations. The founding and establishment of spas in the area of Austria known as the *Salzkammergut* is an example of one such regional variant. It took the form of a symbiosis between a physician, frequently an incomer from Vienna, who had the necessary medical knowledge and the project idea, and the financiers,

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investors in the narrow sense, mostly incoming members of the urban upper classes. In the same way, state officials who frequently holidayed in the region were able to arrange for the necessary permission and legal arrangements. Local officials and interested parties were also recruited, who ensured that the local authorities took the necessary decisions and helped spread acceptance among the local population. The new branches of industry and employment opportunities the spas brought with them meant that this particular innovation had a significant economic and social impact on tourism in the places that were elevated to the status of 'spa towns'.

Bad Ischl was in many respects the prototype of the spa town in the Salzkammergut region. The Viennese physician Franz Wirer founded a spa here in 1823 (Prohaska, 1924) which, together with the attraction of the Emperor's summer residence, quickly brought noticeable economic prosperity to the town, indicated not least by a significant population increase. During the second half of the nineteenth century, this recipe for success was followed by other towns in the Salzkammergut with suitable geographic features. The construction of saltwater pools and spas is thus an example of the regional diffusion of an innovation. One specific instance is the spa in Aussee, the central town in the Styrian part of the Salzkammergut, which opened in 1870 (Pohl, 1871). Here, too, the spa led to an economic upturn and increase in population that lasted until well past the turn of the century. The same applies to Gmunden in the north of the Salzkammergut, where a similar spa was built in 1861 (Schießer, 2011). A further innovative step in the development of tourism in the Salzkammergut in connection with the spas occurred in the late nineteenth century with the invention of summer resorts (Burkert, 1981).

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INNOVATION FETISHISM AND SCHUMPETERIAN CREATIVE DESTRUCTION

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CREATIVE DESTRUCTION HAS BECOME MORE DESTRUCTIVE

Joseph Stiglitz, the Columbia University Nobel Prize winner – arguably the economist with the broadest vision among living practitioners of the profession –, popularized the notion of ‘GDP fetishism’ in order to highlight the propensity of our culture to attach almost religious importance to GDP numbers instead of other (non-monetary) measures of welfare such as life satisfaction, happiness, longevity, school performance, poverty rates, or even incarceration rates (Stiglitz, 2012; Stiglitz et al., 2010). In fact, ‘disruptive innovation’ is celebrated to such an extent that the Nobel Prize winning Princeton economist Paul Krugman thinks that it ‘glamorizes business’ (Krugman, 2014). Given that economic growth is fueled primarily by innovation, behind the hype over GDP is a hype about innovation that permeates so much of our overarching mental attitudes. In 1942 Joseph Schumpeter, the Austrian-born Harvard economist, famously dubbed the process of innovation of larger-than-life entrepreneurs ‘creative destruction’ that provided the mainspring of capitalist economic development (Schumpeter, 1942; Aghion/Howitt, 1998). In his novel dynamic conceptual framework entrepreneurs invent new products or new ways of doing things in order to increase efficiency, improve quality, or lower price, thereby bringing about the obsolescence of their counterparts who lagged behind and failed to seize those opportunities. The ancient is destroyed in the process of creating the new in a Darwinian – or perhaps even more appropriately – in a Spencerian competitive process of survival of the fittest – or the most profitable (Hodgson, 2002). Thus, crea-

¹ A version of this essay appeared as “Disruptive Innovation. Glass Half Empty” in Milken Institute Review, 17(1), 28–35.

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tivity in Schumpeter’s conceptualization is at once constructive and destructive: evolutionary progress is not painless by any means (Tanner, 1996). Not at all: there are not only gainers but also losers, as he himself recognized (Witt, 1996). Nonetheless, Schumpeter and those who followed in his footsteps stressed confidently that creative destruction was, in the main, welfare-enhancing in the long run (Witt, 1996). The goal of this essay is to argue that there are two sides to ‘creative destruction’ (CD) and that the ideology of our Western societies is biased insofar as it focuses almost exclusively on the gainers and ignores the losers, cheering and celebrating creativity while benignly neglecting its concomitant destruction. This attitude will not do any longer.

CREATIVE DESTRUCTION

The destructive (D) component of innovation – or that of the process of technological change – can be viewed as a negative externality: a cost that is imposed on third parties without their consent (Witt, 1996). Note that D can impact NNP, employment, or welfare, and it can fall on producers or on consumers. An example of an externality that falls on producers is an innovation such as a camera built into a mobile phone (by firm A) that ultimately leads to the decline in demand for traditional digital cameras and the bankruptcy of Kodak Inc. (firm B). Suppose that A’s output at time $t = 1$ is valued at $C = \text{US\$}10$ and that at $t = 0$ (i.e., prior to the innovation) firm B’s output was $D = \text{US\$}4$ which suddenly becomes obsolete so that its value declines to 0 at time $t = 1$. Suppose that B’s capital equipment loses all of its value, because it cannot be put to other uses, and that many of its employees will not be able to find work in other sectors and therefore become unemployed. This implies a loss to the economy since these factors of production are no longer producing the $\text{US\$}4$ per annum that they did prior to the innovation. Hence, firm A’s output of $\text{US\$}10$ is the creative component which we are fond of celebrating. However, the $\text{US\$}4$ destructive element – the negative externality valued at $\text{US\$}4$ a year – tends to be utterly forgotten. Hence,

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we celebrate the innovation as though it were worth US\$10 in spite of the fact that its actual contribution to NNP is but US\$6, because in the absence of the innovation firm B would have continued to produce US\$4. Thus, overlooking the negative externality magnifies the importance of the innovation in our eyes out of proportion to its true contribution to NNP.

Another kind of externality is the kind that falls directly on consumers. In this version of CD, firm A introduces a new product that does not bankrupt another firm but instead unexpectedly renders a consumption good obsolete. The obsolescence can be planned or not; the depreciated good can be produced by firm A or another firm. Of course, planned obsolescence is a favorite strategy of oligopolies for products such as video games, textbooks, software, consumer electronics where upgrades and the latest versions are introduced periodically with the aim of convincing the consumer of its superiority in spite of only minor improvements. Such a strategy depreciates the value of the predecessor version and increases the profits of the corporation. Thus, new versions of existing products frequently do not add a lot of net value to the consumers' welfare in proportion to the amount by which they increase NNP.

This strategy is immensely profitable, because the quality of a new product is not immediately obvious and because firms can instill in the consumer the feeling that they need the newest version as a status symbol, although the older one is still functioning well. Moreover, there are hidden qualities which are not apparent until one has some experience with the product. Then there is a tendency to force consumers to switch by not providing compatibility with connectors or programs and not providing support indefinitely. Microsoft often forces upgrading by making older file versions inaccessible and inoperative.

The fashion industry is another example of a sector in which new products mostly replace existing products for which they are close substitutes and which would not have been devalued had it not been for the creation of the new products. By creating

and promoting new fashion part of our inventory of clothing is rendered obsolete. That means that we do not obtain as much utility from the clothing we now have as we anticipated at the time of purchase or that we could have obtained in the absence of the negative externality.

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INNOVATION'S DESTRUCTIVE POWER HAS BEEN INCREASING

In his apotheosis of the innovating entrepreneur Schumpeter was undoubtedly thinking of the significant disruptive innovations associated with the First and Second Industrial Revolutions: the steam engines, railroads, steam boats, iron, steel, interchangeable parts, petroleum, chemicals, electrification, telegraph, telephone, radios, automobiles, airplanes, filmmaking, papermaking, plastics, rubber, and machines and engines of all sorts. The negative externality associated with these technologies was small or even negligible while the gains in productivity were enormous. The reason is that many of these were completely new products and some were general purpose technologies with substantial impacts on the productivity gains of other sectors that rippled through the economy. Moreover, all of them were capable of capturing economies of scale previously undreamed of and all satisfied a basic need innate to human nature so consumers did not need much convincing to adopt the new products. Most importantly, the non-mechanized firms that were replaced were generally small-scale operations working with little capital. What's more, the new technologies mentioned above used labor on a massive scale so that the workers displaced by the innovations could easily find employment in the new sectors of the economy as skills were transferable across industries. Hence, the destructive force of those innovations was not only small but waned in significance relative to the creative component.

For instance, innovations such as the incandescent bulb replaced the kerosene lamp, and the value added to NNP as well as to welfare in terms of reliability, convenience, health, and safety was enormous. The destruction of the kerosene lamp industry was

not a major loss to the economy. Similarly, the telephone was a new technology that replaced nothing but the pigeon carrier and perhaps some mail. Hence, the gains in productivity were gigantic. Clearly, the closer the substitutability between the new and the old product (or the new and old ways of doing something) the higher the negative externality. However, during the First and Second Industrial Revolutions the degree of substitutability between the new and the old products was very low or even non-existent, implying that the creative component of innovation must have been extremely high relative to the destructive component. However, that is no longer the case.

WELFARE AND CREATIVE DESTRUCTION: PAST, PRESENT AND FUTURE

However, by the end of the twentieth century the destructive component of innovations has increased substantially for several reasons. Recent innovations have had substantial substitution effects between the new and the old products. The iPhone 5 is a very close substitute of its predecessor iPhone 4 and Windows 8 is also a very close substitute of Windows 7. That means that the incremental gains produced by the innovation tend to be tiny. Another reason is that all our innate basic needs have been satisfied with the already existing technologies so that firms have to expand much more money on marketing in order to induce consumers to buy the new products. Thirdly, the old products were already produced by modern firms efficiently on a large scale so that gains due to economies of scale were not forthcoming. Hence, new firms may be able to destroy competing firms due to a slight competitive advantage or because of novelty but nonetheless fail to increase productivity, employment, welfare, or NNP by leaps and bounds as in previous centuries. Consequently, the benefits reaped from creative destruction – net of the negative externalities – have declined substantially over time and are likely to remain at a low level.

Consider that tablet computers expanded at the expense of laptop computers; Wikipedia destroyed Encyclopaedia Britannica; Amazon replaced countless local book-

stores as well as Borders, which in 2003 had more than 1,200 stores. Furthermore, the smartphone replaced simple cell phones and traditional cameras. The 'selfie' replaced the 'Kodak moment', but Kodak employed 86,000 in 1998 and 145,000 at its peak (and paid them mostly middle-class wages), while in 2014, after emerging from bankruptcy, it had a skeleton workforce of 8,000. The bankruptcy of Kodak was likely more substantial in terms of depreciation of plant and equipment than the destruction of handloom weavers, kerosene lamp makers, or horse-and-buggy makers.

In contrast to the peak employment at Kodak, Apple – one of the iconic corporations of the information era – has but 47,000 employees, two-thirds of whom are earning below middle-class wages. No wonder we are experiencing a 'jobless recovery'. Consider that U.S. employment in the 'internet publishing, broadcasting and search portals' sector increased in the fifteen years from March 1999 until March 2014 from 64,000 to 151,000 (or by 87,000); at the same time, however, the number of jobs in the newspaper publishing industry was halved from 424,000 to 212,000 with a decline of 212,000 jobs. Hence, the net loss of jobs in this process of creative destruction was around 125,000 in fifteen years.

Moreover, because of the internet revolution, many traditional newspapers are decreasing their print edition or discontinuing them completely and going digital – including the *Christian Science Monitor*, with a concomitant loss of jobs. Many newspapers succumbed to bankruptcy, such as the Tribune Company and the Sun-Times Media Group. With the expansion of the internet, advertising revenue of newspapers plummeted by two-thirds of its 2001 peak of US\$65 billion to US\$24 billion in 2013, while internet ad revenues increased in the same time span from US\$7.2 billion to US\$42.8 billion, essentially replacing the amount lost to newspapers, with total advertising revenue remaining unchanged.

While social networking facilitated by Facebook is a popular feature of the internet, basically it merely replaces older ways of socializing without adding much to our

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feeling of well-being. It monetized activities that were for the most part left previously outside of the market's purview. Market capitalization of Facebook is inching toward US\$ 200 billion, and Twitter, WhatsApp, Instagram are all household names worth billions but probably add much less value to real NNP, welfare and employment beyond the technologies and firms they replaced. This is the case, because the needs they respond to were satisfied for the most part prior to their existence. They destroyed old forms of communication to which they are close substitutes. Besides, Facebook has merely 7,000 employees.

The current list of 'disruptive technologies' that are likely to usher in future waves of innovation include such fields as education, information, nano- and biotechnology including genetic engineering, cognitive science, robotics, and artificial intelligence. These are not likely to offer major consumer goods which make up the most important part (70 %) of US NNP, and even those that might be forthcoming are not likely to satisfy a basic need that is not already satiated. Therefore, it appears that the innovations of the foreseeable future will probably not create substantial net gains in NNP; rather, they will be mostly close substitutes for already existing technologies implying that CD will probably be fairly small, as with 'Google Glass', the driverless car, or drone delivery. These might become trendy gimmicks, might even become useful in some circumstances but do not promise great gains in welfare, employment, or NNP. After all, one still has to sit in the car even if it is driverless, and the gains in productivity from switching from listening to music to texting or answering email are likely to be negligible. Similarly with genetic engineering: we might be able to increase life expectancy, but I doubt it will add much to NNP per capita. Furthermore, they all will destroy jobs in large numbers.

So far we have been discussing the immediate destructive negative externalities of innovation, but there are longer-term ones as well which are not directly evident. Joel Mokyr, the distinguished historian of technology at Northwestern University,

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acknowledges that technological change is by no means a free lunch; one needs to consider the 'bite-backs' as well. Innovations such as DDT, chlorofluorocarbons, carbon fuels, leaded gasoline, fast food, asbestos, lead-based paint, generated negative externalities whose true costs were discovered long after they were implemented and therefore created an illusion of productivity increase, not to mention the technological causes of global warming. Thus, we should subtract these unanticipated costs from the NNP figures. That would give us a much better sense of economic performance and improve our ability to frame policy going forward.

Furthermore, not all innovation enhances productivity as many are designed for rent seeking purposes. That is also Paul Volcker's assessment of the innovations associated with the financial crisis. The myriad of so-called financial innovations culminated in an immense 'bite-back' which added up to about US\$7 trillion support from the government and an annual loss in output in the U.S. alone of about US\$1 trillion. Another often neglected controversial aspect of technological change is that it is not at all democratic, insofar as entrepreneurs impose their will on society and thereby redistribute income. It is inconsistent that we celebrate such a process even though it hurts people by redistributing income, while at the same time we generally argue against the government redistributing income for exactly the same reason, i.e. that the redistribution hurts the people who are taxed. It is not at all clear why the entrepreneur should enjoy privileges that do not accrue to the community as represented through the government.

This is a major incoherency in economic theory and we need to think about laws and institutions that will protect those who are in the danger of being hurt. The goal of such institutions would be to ensure that the suffering of the losers would be minimized in the process of creative destruction. The immense destructive forces of the financial innovations should provide a powerful incentive to develop institutional mechanisms to assess the riskiness of innovations and to foster those innovations

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that minimize the amount of pain it produces in the economy. After all, the FDA tests drugs before they can be used commercially; there is no reason why we cannot test other products for their side effects in order to be able to make informed choices about their desirability. Several European countries have come to the rescue of local bookstores by limiting the amount of discounts that Amazon is allowed to grant as a defense mechanism of Amazon's destructive forces. Other such policies could be and should be developed. Another example comes up in English common law in which the owner of a building with windows that has had natural daylight for at least twenty years enjoys a 'right to light' so that new construction is not allowed to impinge upon it. This is an example of economic growth that attempts to minimize the destructive forces and should be more widely adopted.

CONCLUSION

In sum, creative destruction has become more destructive than ever before. Yet, we live in a culture that continues to celebrate the 'gospel of innovation' without acknowledging forthright the deleterious effects of the concomitant negative externalities or caring much about the suffering they cause (Lepore, 2014; Stiglitz et al., 2010). Yet, innovation's net value added to NNP, to employment, or to welfare – net of the negative externalities – has diminished substantially by the 21st century. The destructive forces of creative destruction have gained the upper hand. The implication is that instead of innovation fetishism we should scrutinize seriously the extent to which a particular innovation will improve the human condition before it is allowed to unleash its destructive forces. Given the kind of innovations in the pipeline this trend is most likely to continue.

The transition to a postindustrial economy has been far from advantageous to the well-being of a substantial share of the population. Just because we have been innovating and growing successfully for a quarter of a millennium by no means implies

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that the process will, or should, continue indefinitely. No such economic law exists and the historical record indicates that there are times when economic regimes reach a tipping point and abruptly change direction. That is exactly what our economy has done. It is time to acknowledge it.

The increase in the destructive forces of innovation dovetails with several pessimistic prognoses of the future of the US economy, insofar as many prominent economists are arguing that economic growth is going to be slow into the foreseeable future. Harvard economist Larry Summers suggests that the economy has morphed into one of secular stagnation on account of inadequate aggregate demand, while Krugman has been blaming pervasive political dysfunction for our malaise, and Stiglitz points to pervasive inequality as the culprit (Krugman, 2008; 2013; Stiglitz 2012; Summers, 2013). Moreover, Northwestern economist Robert Gordon points out that slowdown in the growth in labor productivity since 1972 is another reason to be pessimistic about our future economic prospects, and forecasts that the real disposable per capita income of the bottom 99% of the income distribution will grow at a negligible rate of 0.2% which will be very difficult to distinguish from zero (Gordon, 2014). In other words, the postindustrial service economy is going to be stuck in low gear as far as the eye can see.

The scholars mentioned above are doubtful about our ability to continue on the path forged since the First and Second Industrial Revolutions. The new technologies might well be brilliant and create immense wealth for a select few, thereby continuing to exacerbate socio-economic inequality and exclude an ever increasing share of the population from the middle class. Yet the numbers of underemployed and working poor will probably swell as technological unemployment is going to be an endemic problem from now on, as the MIT economists Erik Brynjolfsson and Andrew McAfee suggest (Brynjolfsson/McAfee, 2014). Since the Meltdown of 2008, the employment/population ratio has declined by some five percentage points, and 12.5% of the labor

force is still underemployed 6.5 years after the start of the recession. This implies that GNP growth has been decoupled from employment. Low-skilled workers – and there are many of them – are becoming increasingly redundant through automation; hence, endemic underemployment is here to stay.

According to the University of Texas economist James Galbraith, the best is behind us as we have entered a new age of a new normal (Galbraith, 2014) that will resemble more closely the social structure of the *Ancien Régime* than that of an ephemeral ideal economy (Piketty, 2013). We have argued similarly that there has been a shift in the destructiveness of new technologies, and this effect has so far not registered adequately in the economic statistics that we use to gauge the performance of the economy and to formulate policy.

Thus, we need to pay more attention to the destructive forces of new technologies. The 'low hanging fruit' have been picked so that the negative externalities of innovations have been increasing. Yet, these negative externalities are not adequately understood by the public or by policy makers or by the media so that our evaluation of the contribution of the innovation to NNP, to welfare and to employment is overestimated. This is the case, we have argued, because the destructive power associated with Schumpeterian creative destruction has increased markedly relative to their creative component, in stark contrast to previous epochs. Creative destruction's gentle winds have mutated into cyclones of destruction. Thus, our life satisfaction will probably be decoupled from even the slow economic growth being predicted by Gordon and Summers. While the economy will be growing, albeit slowly, our sense of well-being will be mysteriously lagging well behind unless we are able to tame the destructive forces of Schumpeter's gale.

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CHAPTER 2

THE ECONOMIC AND SOCIAL SIGNIFICANCE OF INNOVATION TODAY

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INNOVATIONS, KNOWLEDGE ECOLOGIES AND ACADEMIC TIMESCAPES

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In contemporary societies, any credible reflection on future developments has to engage with scientific and technological innovation as a crucial force, driving and shaping change. The importance of innovation seems to be the undisputed starting point when considering what can or must be done in the present in order to achieve whichever bright future is being proposed. The claim that 'Europe's future is linked to its power to innovate'¹ has become an established element of research policy discourse at the European level, as has the call to create an 'innovation-friendly environment'. The hope is being expressed that we can 'innovate Europe out of the crisis' (ERAB, 2012) or that key technologies will be our 'ticket to the future' (German Federal Ministry of Education and Research, 2010). While in the 1990s, 'knowledge society' was the central buzzword characterizing Europe, this concept has been replaced virtually seamlessly by 'knowledge economy', which, now, in turn has given way to the notion of an 'innovation union'. It is thus no longer the creation of knowledge that occupies centre stage but the increased production of innovations in the face of unrelenting global competition. Even universities are increasingly required not merely to focus on what have hitherto been their core activities – basic research and higher education – but to consider the potential applications of their research more thoroughly and at an earlier stage than ever before.

However, this optimism about the role of innovation is always accompanied by an anxiety that the 'general public' might not fully understand and appreciate its significance and consequently might not support it adequately. This fear explains why so much emphasis is laid on the importance of integrating innovations more firmly

¹ http://ec.europa.eu/research/innovation-union/index_en.cfm

in society. Concretely, this concern can be traced in the *Horizon 2020* programme 'Science with and for Society', whose stated goal is 'to build effective cooperation between science and society, to recruit new talent for science, and to pair scientific excellence with social awareness and responsibility.'² More than ever, research is required to take societal expectations and values into account. These requirements include the demand for better communicating research and its results (researchers are supposed to be the proactive ones here), closer cooperation between science and societal actors (for example, Citizen Science, but also co-operation of academia with various civil society organisations), and the demand for a greater degree of sensitivity towards societal values. This shift is well-illustrated by the call for science to follow the paradigm of 'responsible research and innovation' and thus to produce knowledge and innovations which could be regarded as 'socially robust' (Nowotny et al., 2001). Given the importance ascribed to innovation, it would seem not only legitimate but essential to pursue the question of how science policy envisages and implements the ideal conditions for encouraging innovation, and how well this translates into actual production contexts, in particular as regards academic research. The latter is crucial, for unless a society gives thought to the medium and long-term conditions necessary for producing innovations, and adapts and develops these correspondingly, it will not succeed in achieving sustainable innovations to address complex, constantly changing problems.

Although numerous aspects of innovation have been the subject of analysis and continuous readjustment, the role that time plays in innovation processes has received relatively little attention. If we take seriously Jeremy Rifkin's assertion that 'time is our window onto the world' (1987, 7), and if we consider the extent to which time is connected to issues of power and control, then it seems astonishing that we tend to

² See: <http://ec.europa.eu/programmes/horizon2020/en/h2020-section/science-and-society>

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simply accept temporal structures as a given 'without ever stopping to think what a crucial role [they] play in defining the social order' (Adam, 1998). This non-reflexivity effectively makes time an invisible part of our society's infrastructure. We thus find ourselves confronted with a fundamental contradiction – on the one hand we know that time is a social construct, even physical time as measured by clocks, and on the other we behave as if it actually is a given fact (Rosa, 2013).

The temporal structures we inhabit thus play a significant role in shaping the conditions for research and innovation without ever being subject to systematic critical scrutiny, even though time in its various aspects is one of the basic materials that give rise to innovations.

This essay will therefore reflect on the temporal structures and horizons within which we conceive of and develop innovations. It will examine how these temporal dimensions materialize through funding programmes and structural measures, and eventually consider the research practices giving rise to innovations. Particular attention will be paid to universities, as these lay, through the combination of education and research, the foundations for an innovation society.

TIMESCAPES

If time is understood as a formative factor in the development of innovation societies, it is essential to consider the various forms in which time manifests itself, such as tempo, acceleration, rhythm, temporal horizons and development trajectories, to name but a few. The multifarious connections between these different forms of time give rise to what Adam (1998) aptly called 'timescapes' which in turn shape the genesis and development of innovations. Capturing these interactions of different forms of time through an analogy to the notion of landscape draws attention to the simultaneous superposition and fusion of physical elements, cultural dispositions and personal perception (Rosa/Scheuerman, 2009). The timescapes in which we live and create

innovations are therefore always to be understood as both real and subjective, individual and collective, past and present. Timescapes also have an internal temporal dimension; they are composed of what Koselleck (2000) aptly describes as 'temporal strata'. The future and various strata of the past encounter each other in the present, giving rise to frictions or convergences, collectively creating an impact and allowing particular visions of the future to emerge while others remain inconceivable.

The present thus becomes a central space of negotiation in which ever new arrangements between past and future have to be found. Taking the Austrian context as an example, we can see that there is hardly any technological innovation which is not evaluated against the background of past experiences of rejection, for instance those of genetically modified organisms or nuclear power as an energy source. The discussions around nanotechnologies serve as an excellent example (Felt, 2015).

Examining innovation through the lens of timescapes therefore means paying attention to different simultaneously operating temporal logics and to the contradictions and mutual reinforcements they create. Two perspectives are particularly important. The first addresses innovation policy making and means analysing the attempts being made to implement specific temporal structures for research in order to increase the flow of innovations. The second reflects on how these temporal structures, created by different policy actors, relate to each other within academia, what tensions and potential fault lines arise in this context, and where first signs of unexpected side effects begin to emerge. The conclusions will then consider the insights provided by the time-sensitive analysis and elaborate on what this means for an appropriate future-oriented and sustainable innovation governance.

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BETWEEN INNOVATION POLICY AND RESEARCH PRACTICE: TRACING HETEROGENEOUS TIMESCAPES

In order to fully understand the interrelation between innovation and society, it is essential not only to engage with political visions, discourses and programmes, but to ask what impact these have on research practice and on the lives of academic researchers. If we look at the development of post-war academic research from a time-sensitive perspective, we observe a multiplication of so-called 'time generators' (Rinderspacher, 1988). 'Time generators' are key-sites which create binding temporal requirements and regulations – in our case for research. The establishment of project funding, the implementation of more or less regular evaluations, the creation of specific academic career models, the average frequency of publications and the time it takes, but also the establishment of temporal horizons in science policy (for instance, *Europe 2020*) are such sites where research-specific time structures take shape.

In what follows, four time structures created by such time generators will serve as examples. For each of them I will show how they impact research practices and as a consequence also the conditions for creative thinking, and thus shape potential innovations. I have labelled these time structures as anticipation, acceleration, tempo, and temporal fragmentation.

ANTICIPATION: INNOVATIONS FOR TOMORROW

Our age, it is often said, is characterized by an 'unquenchable thirst for the future' (Sloterdijk, 1989), or by tireless efforts to 'colonize the future' (Giddens, 1999). As suggested in the opening section of this essay, science and technology policy discourses and associated measures more than ever before revolve around the concept of 'the future'; a future which must be actively brought about and shaped; a future which contains the solutions to present-day problems. Contemplating the future is nothing new, but the intensity of this preoccupation and the increasing significance ascribed

to our ability to anticipate it are characteristic of contemporary innovation societies. There is a broad spectrum of agents continuously producing new visions of the future and disseminating them via the media, futures which are to be achieved or prevented by the suitable innovations. The extensive efforts invested in envisaging the opportunities and limitations of society in 2020, 2035 or 2050 and in making the right techno-scientific choices form the essential elements in the expectation dynamics at work. As a result, depending on the directions chosen, societies are either categorized as 'future-able' or are accused of impeding a promising future. We speak of being 'on the way to a better future' or describe certain developments as having 'no future'. Reflections on the future potential of innovations must thus always be understood as entangled with potential societal futures.

In recent years, numerous studies have pointed to the fact that our orientation towards the future has ceased to be based on a simple belief in progress, as was the case up to the 1970s (Adam/Groves, 2007). We no longer assume that any and all investment in research will automatically produce innovations. Instead, today's researchers, even those engaged in basic research, are expected to assess the potential future contexts of application of their work at a far earlier stage than previously. Innovation policies, for their part, employ clearly focused funding strategies that are predominantly linked to expectations and problems of societal, mostly economic, nature.

Connected to these developments, two problem areas arise. On the one hand, we can identify the emergence of an 'economy of promises' (Felt et al., 2007). Not only are scientific products, patents and publications subject to market-like evaluation mechanisms, but a form of symbolic economy has been established which 'trades' techno-scientific promises for the future. Such promises range from new medical treatments, over new materials with revolutionary characteristics, new means of providing food security, to hitherto unsuspected sources of environmentally friendly energy, to mention but a few. Possible futures thus play a rather active role in present

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innovation spaces, being used as symbolic resources to gain headway in the competition for funding.

The design and dissemination of promises of potential future applications is no longer a marginal by-product of academic science but an integral part of research-related core activities. Future scenarios are both a resource and a creative space for imagining potential developments, and thus they always affect the shape innovations take. Funding policies in particular show an often quite narrow focus on 'promising' areas of innovation – the fact that since 2000 almost every country has developed a 'nano-action plan' and specific funding measures for nanotechnology is just one of numerous examples of the impact of such a promissory logic.

This focus on the realization of specific futures, however, misleads us into thinking the development of our societies in terms of clear socio-technological trajectories. Indeed, this mode of thinking has become a deeply rooted habit of modernity (Appadurai, 2012), which assumes that change can almost always be described in terms of cumulative lines of development from here to there and from the present to the future. This carries with it the risk that, if we have a particular vision of a desirable future, we tend to predominantly invest in those areas which appear to support this goal. An example is the European research funding programme *Horizon 2020*, whose funding lines are mainly directed towards clearly defined 'grand challenges', and within each of the funding lines even the formats of potential projects get prescribed. Although this is not a problem per se, research which goes beyond the quite narrow confines of this vision is now effectively without support at the European level (with the exception of the excellence funding schemes). Often anecdotal success stories demonstrating that this kind of rather focused approach can produce innovative solutions are used to "prove" that this approach to funding works. Yet, imposing a strategic agenda and significant limitations at a very early stage in techno-scientific development might lead to permanently excluding vital alternative potential directions of innovations. Funding

structures which are too tightly focused on anticipated gains thus pose a twofold risk: firstly, if funding is too strongly tied to specific expectations, striking off in the wrong direction has much greater and longer-lasting consequences than under more open funding conditions; and secondly, this kind of approach might lead to the fact that explorative, socially inclusive research receives less support.

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ACCELERATION PHENOMENA: RESEARCH IN THE FAST LANE

Our orientation towards the future goes hand-in-hand with the supposedly necessary acceleration of the processes which (are compelled to) produce and disseminate innovations. Both within the world of science and beyond, a race against time is staged, in which every researcher is required to produce more and faster results than any of his/her competitors at other research institutions. It seems to have become of vital importance to be ranked among the best and to retain this position. For Europe, the competition with the US is at the core, even though in the last decade concerns about competition from new scientific and technological powers such as China and India have been rising. At the same time, competition for relatively limited funding resources (for instance for the lucrative European Research Council grants), for offering better quality environments in terms of economic and physical infrastructure, and for being attractive to 'the brightest minds' prevails within Europe.

Under these circumstances, any kind of pause to reflect on exactly what innovations we should be trying to achieve is interpreted as a potential danger to fall behind (Adam/Groves, 2007). Researchers thus feel themselves subject to a great pressure of expectation, in part institutionally imposed, which manifests itself in performance agreements between academic institutions and the state, but also within institutions, for instance in evaluations of individual researchers and of research units. In order to ensure that the desired acceleration actually occurs, benchmark indicators are usually established, allowing to track progress. The number of patents, spin-off

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companies, publications and cooperations with industry that result from research are cited as evidence that we are heading in the right direction. Thus our culturally conditioned faith in numbers is invoked (Porter, 1995) and at the same time the assertion made that the use of indicators can objectively determine whether a development is moving in the right direction. This in turn allows for an apparent de-politicisation of what are in fact highly political decisions.

The introduction of these kinds of indicators for self-monitoring and comparison fits perfectly with the diagnosis that we live in an 'audit society' (Power, 1997). In science, as in many other societal domains, researchers and their institutional units are obliged to present their own work in accordance with the logic of indicators. However, within a context of constant competition this also causes a shift in researchers' perception and evaluation of their own performance. The pressure to be ever more productive within relatively short temporal horizons creates a feeling of time scarcity (Rosa, 2013) and the persistent impression that the ratio of available time for tasks to be accomplished is no longer balanced. The logical consequence appears to be either to think about ways to save time, or to re-assess whether simply trying out new things is still a feasible approach to research. This change not only is noticeable in science but also in society as a whole. While previously, there were relatively clear time frames within which specific types of activities were to be carried out, e.g., when it was clear where work time ended and free time began, now these time frames are becoming ever fuzzier and each individual is expected to react to numerous very different demands all at the same time. This creates, quasi unavoidably, the feeling that time is always in short supply, and sooner or later it carries the danger of researchers' alienation from the structures and places in which innovations are supposed to be created.

This pressure also means that the call for engagement with society alluded to at the beginning of this essay, starts to be seen as a potential problem, something that

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might hinder the flow of innovation, or at least delay it, and not as something that could lead to better, more socially-inclusive forms of innovation. In the end, accelerated research will not have more but rather less time for addressing questions of societal expectations and assessments, in spite of the growing discourse about the importance of these. This accords with the observation that although the number of communication events directed towards the public (news reports and other communication formats focusing on science) has increased, there is less room and less time for a thorough examination of a problem at stake or for democratic decision-making processes when it comes to complex techno-scientific issues. Therefore, as far as the democratization of innovation societies is concerned, it is essential to focus consciously on deceleration if we want the diversity of our societies to be reflected in our decision-making processes. This in turn means creating spaces in which we can both think and act without constantly hearing at our backs 'time's winged chariot hurrying near'. Because in the end, it is the direction in which innovations lead which is a much more important issue than the frequency with which they are produced (Felt et al., 2013).

THE RHYTHM OF RESEARCH – OR THE DREAM OF EFFICIENCY

Tightly coupled with anticipation and acceleration, recent decades have also been characterized by a fundamental change in research organisation and practice, which can be described as 'projectification' (Ylijoki, 2014). The development of project logic, that is to say the conviction that the production of knowledge and innovations can be planned and organised in discrete temporal units of only a few years' duration, is building on the belief in time as a straight-forward physical quantity. It is this, according to Manuel Castells (1997), which allows us to succumb to the illusion that we can pack an ever-greater number of activities into the same unit of time, thereby fulfilling the ideal of efficiency that modern societies consider a mark of success.

Indeed, these days research is barely possible if it is not funded through so-called projects. This has permanently altered scientific practice and in particular the temporal logic of research. As part of the endeavour to achieve not only quality control but also an appropriate use of resources and new forms of efficiency, any research must now run through the project approval machinery, which in concrete terms means that only ten to twenty-five per cent of research applications (depending on the funding structures) actually get funding. The long-term pursuit of greater questions seems no longer the central focus of research. Instead, only those questions can be and are explicitly posed which fit the temporal structures of the project logic. As a consequence, there is a much more intense focus on smaller-scale questions, which is not problematic in and of itself, but which can potentially become so if this logic manages to push broader approaches to issues at stake into the background. The format of project funding further reinforces the economy of promises as outlined above, as every project that is in competition with other projects has to provide an appealing narrative, promising usefulness of results well beyond the bounds of the project itself. This means that potential successes have to be listed before the project has even begun, so that in essence there seems less and less room for surprises, while at the same time every project has to aim to do something fundamentally new. This in turn means that the project logic encourages research to stick to the safety of the mainstream, and it is harder to attract funding for rethinking or combining existing insights and technologies. Furthermore, constant risk management is necessary to ensure that sufficient results are produced with a fit to the evaluation machineries in place.

However, projects also create the impression that a specific order prevails. They reinforce the illusion that knowledge and money/time can be brought into a straightforward relationship with each other – an illusion that has become firmly rooted in our minds by the ‘Milestone and Work Package Logic’ of EU projects and bey-

ond. Even though every researcher would emphasize that this kind of planning has little or nothing to do with the actual epistemic rhythms of knowledge production, it is nonetheless implemented. Deviations from this norm require explanations and create the deep-rooted impression that it is or should be possible to optimize research organisation in this direction. The associated use of time sheets also triggers a medium-term change of perceptions of time, as well as of temporal routines. We talk more than ever about ‘purposeful use of time’, which ultimately leads to each individual considering where best to invest his or her time and whether it is worth investing time in (essential) work that does not directly contribute to their own production of knowledge/output.

Furthermore, projectification creates an academic job market that is highly temporalized, one in which numerous young people are offered the opportunity to engage in research. In recent years, however, voices have been repeatedly raised describing this kind of organisation of short-term academic labour in terms of ‘traps for idealists’ and other negative epithets (Haug, 2013). Recurrent articles on the topic in leading journals such as *Science* and *Nature* bear eloquent witness to the problematic nature of the situation. While the number of PhD students required for doing the planned research has risen considerably, the number of tenured positions has not grown proportionally. This has led to a significant sense of insecurity and an extremely high level of competitiveness and selectivity among young researchers, as well as causing numerous young people to question whether, given the lifestyle contemporary research necessitates, it is worth continuing to invest in a scientific career. In a recent article, leading researchers also warned that this situation could suppress ‘the creativity, cooperation, risk-taking, and original thinking required to make fundamental discoveries’ (Alberts et al., 2014). While this obviously has consequences for researchers who fail to find a job after a series of short-term contracts, the fact is often overlooked that this kind of industrialization of research has an

impact on the production and quality of innovations as well. The question actually to be posed is, who is willing to hang on in such a system and for how long, in the hope of eventual success, and whether this very early pressure to succeed does not encourage researchers to remain in the safety of the mainstream rather than trying to establish themselves outside of it.

THE FRAGMENTATION OF ACADEMIC LIVES

The pressure to anticipate, the acceleration and ever-increasing rhythm of research, as well as the changing academic career structures have together led to a profound fragmentation of academic lives. Since rhythms of life, career progression, project duration, evaluation cycles (both individual and collective), publication frequencies and so on are following different temporal logics, researchers are required to perform significant synchronization work. They are the ones who have to align very different demands in such a way that they have enough space to be innovative in their work. They have to ensure that the individual elements of academic life cohere in order to transform their career into a scientific biography, i.e. into a research life worth living. A closer look at the impact of this dense temporalization of research allows for a number of relevant observations. The need to document the use of one's time demanded by project logic, for example in the form of time sheets, alters our perception of time. It renders the amount of time spent on a specific task visible and almost automatically leads to the implicit weighing up of how much time must/should be spent on what. While we could describe this with positively connotated catchwords like transparency of achievements and resources, these changes simultaneously have the effect of making researchers consider carefully how much time, if any, they are prepared to invest in working for the community, the lab or the research team. This gives rise to classic time conflicts, specifically to conflicts between shared time and personal time, between process time and project time, and between continuous time

and fragmented time (Felt/Fochler, 2010; Ylijoki, 2014). The first conflict addresses the fact that researchers have to reflect ever more strategically on how much they should engage in shared knowledge production processes, which are seen as essential to solving complex problems, and how much on advancing their personal careers. Thus how to structure the balance between the researcher's own time and shared collaborative time, and who controls this relationship, has become a significant issue in innovation policy. From a gender perspective, the question arises as to what kinds of central, collective tasks that help maintain the system as a whole – for instance caring for infrastructure, teaching/supervision and so on – are valued as academic achievements and count in career advancement (Felt/Fochler, 2010).

The tension between process time and project time, as described by Ylijoki (2014), then sheds light on the often complex relationship between longer-term processes of reflection and development and the more bounded logic of an individual project. This relation is particularly challenged when important follow-up projects are not approved on the grounds that they are no longer regarded as new enough – a scenario frequently reported by researchers. Projectification also threatens to unbalance the relationship between 'timeless time' (Ylijoki/Mäntylä, 2003), i.e. time that is not dedicated to the production of a particular output, and 'goal-oriented time'. This raises the question of how, within the framework of policies which have defined the project as the basic organisational unit for research, we can nevertheless create spaces which foster innovation outside pre-set paths.

Complaints about the lack of large stretches of time or anecdotes about the constant need to juggle different demands on one's time, i.e. interrupted time (Bittman/Wajcman, 2000; Rosa, 2013), constitute a fourth source of tension. The increasing temporalization and periodization of academic work described above and the new tasks imposed by auditing and management structures result in a deep fragmentation of time in academic life. In many cases this fragmentation is not necessarily caused by an

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increase in direct interruptions to work – although this often occurs – but by the constant anticipation of being potentially interrupted by unexpected events in academic work. A larger feeling of coherence thus might get lost – and the rise in efficiency that increased attention to time is supposed to achieve might turn into its opposite.

This feeling of being permanently under pressure is a recurrent element in many descriptions of lives in science. And even if researchers are successful and thus perceive this as a reward for their efforts, the question still remains of whether these investments in juggling with time do not lead to wasting a considerable amount of creative energy, so that the imagined efficiency is in fact much lower than counting exercises might suggest.

KNOWLEDGE ECOLOGIES AND CARE FOR TIMESCAPE: A REFLEXIVE VIEW

Living in a deeply economised culture, time is being almost inevitably seen as a resource that can be evaluated in economic terms. This is visible in all four perspectives addressed above, indicating very clearly also the limits of any innovation policy that is temporalized in this fashion. However, analysing timescapes of innovation does not necessarily lead to questioning the very idea of an innovation-driven societal development. On the contrary, if today's industrialized nations believe that innovation is and should be a central creative force shaping our societies, then we should more closely reflect on these complex and invisible temporal structures and envisage new modes of dealing with and possibly rearranging them. Only in this way can innovation fulfil its potential in a sustainable manner, and in line with societal visions and values.

Which conclusions, then, can and should be drawn from the analysis offered so far? More than ever before, we need to aim at understanding any innovation as the outcome of longer-term developments and as part of broader contexts of knowledge production in which temporal structures – although largely invisible – play a significant role. To foreground the developmental aspects of innovation in our reflection the me-

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taphor of a 'knowledge ecology' might prove helpful. The central goal of a knowledge ecology would be to preserve the diversity of knowledge not only for the present but also for future generations. Yet embracing this conceptualisation would also mean promoting a balanced relationship between various forms of knowledge as well as the diversity of researchers who live and work within the science system. Further, it is not enough to safeguard free access to knowledge, but we need to make sure that the tendency towards commodification of knowledge does not induce an artificial knowledge shortage. The metaphor of knowledge ecology should finally remind us that sustainability is an essential quality of any knowledge system. Contemporary innovation societies largely live off the knowledge resources that were created decades ago by open funding, less tightly structured timescapes and a less pronounced need for focusing one's research. It is therefore no longer only a matter of anticipating what the world we live in will look like in twenty years, or in fifty, but of asking whether we support today the creation of diverse enough knowledge resources and secure "epistemic living spaces" (Felt, 2009) for researchers that will also enable us in the future to develop solutions to problems that we are unaware of as of yet.

The central thesis, however, is that – due to the kinds of timescapes of innovation in place – these knowledge ecologies have become relatively fragile and are under threat. It is the invisibility of these temporal structures that allows the tensions and dysfunctionalities they create to remain largely unaddressed. Thus, if we are to achieve innovations at the rate required in the long term, we need to care more closely about these timescapes. We should be more aware of the consequences of particular temporal logics for our innovation system and of the necessary adaptations and countermeasures. This is, in other words, a new challenge for the governance of innovation systems: how can we harmonize the often exaggerated short-term demands made on the rate of innovation with the medium and long-term demands that cannot be fully anticipated but will be made in future times on our skills and knowledge?

How can we shape the temporal structures of research in order to escape the tight temporal corset and the sense of constant asynchronicity in order to open up new spaces for innovation? At stake is thus our capacity to free ourselves from our rather naive ideals of time economy that we like to call 'efficiency' and thereby to create time for innovation.

For if researchers submit to the ideals of an audit society as described above, more output units will undoubtedly be produced, but they will also become progressively smaller and disregard more complex connections, if they are capable of addressing them at all. We may be able to justify ourselves by pointing to the innovations we have produced. Yet, it remains unclear if these innovations will be really able to provide answers to urgent problems and whether these will actually correspond to the needs of the societies they were allegedly produced for. If we do not manage to shape the temporal structure of academia in such a way that the more innovative minds choose to stay in it, we shall find ourselves heading for a major human resources shortage – not, as is often feared, in terms of the number of researchers but in the quality of truly innovative thinkers. Furthermore, in a highly paced research environment, there will hardly be space to pursue the ideal of responsible research and innovation, nor to seek a serious engagement with societal values and expectations as far as scientific and technological innovations are concerned – for within tightly structured timescapes, both are in danger of being seen as a luxury rather than a necessity (Felt et al., 2013).

Successful innovation policy therefore also needs a careful temporal policy, a fact which, given the invisibility of temporal structures, needs to be constantly reiterated.

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INNOVATION AND BUSINESS GROWTH

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INTRODUCTION

Innovation and the pursuit of new business opportunities is essential for growth at the firm level; moreover, it provides the foundation for an economy to achieve new levels of technological prowess, productivity, and ultimately prosperity. This chapter describes recent work in economics and management scholarship on how firms grow. Given the other contributions in this collection, we focus specifically on questions surrounding the types of innovations that large and small firms pursue and how it impacts their relative growth rates. Developing evidence suggests that as firms become larger they have trouble maintaining the external innovations that are most powerful for growth, instead focusing increasingly on internal work and enhancements. Section two outlines a theoretical model about these dynamics to fix ideas and highlight some key economic considerations. In some cases the growing internal focus with firm size is optimal, but in most cases it is not and reflects struggles of larger companies to maintain dynamic capabilities that they otherwise desire. Section 3 then provides a case study of IBM, how it observed these limitations within itself in the late 1990s, and then the actions it took to correct the gaps. We use the IBM story to highlight in section four several emerging best practices on how firms can best structure themselves to maintain the innovations that are important for their growth.

THEORETICAL BACKGROUND

One model of corporate choices toward innovation and the underlying heterogeneity in these processes is depicted by Ufuk Akçigit and William Kerr (2015), who build upon prior micro-macro work like Klette and Kortum (2004) and Lentz and Mortensen

(2008). The model considers why types of corporate venturing and innovation vary along the firm size distribution; this provides an important input to understanding the relationships between innovation and business growth for firms. The Akçigit-Kerr model draws a distinction between two types of innovation that companies may perform – internal innovation vs. external innovation. Internal innovation, sometimes called ‘exploitation’ innovation by organizational behavior scholars, concentrates on improvements to a company’s existing product lines, enhancing the capabilities and offerings that the company already has to increase profits. External innovation, sometimes referred to as ‘exploration’ innovation, focuses on creating new ideas to add to the company’s product range. In the Akçigit-Kerr model, this exploration process can be understood as improving upon and taking ownership of product lines belonging to other companies.

Figure 1 below depicts an illustrative firm in this model, that we label f , and how this firm engages in these two types of innovation. Each product line is represented by one of the vertical lines on the graph, and every possible product line in the economy falls somewhere on the 0-to-1 continuum. There are infinitely many possible product lines, and each firm owns some finite subset of these lines. The ‘quality’ of the underlying technology for each product line is represented by the height of the line in this figure, following classic ‘quality ladder’ depictions for studying technological progress (e.g. Aghion/Howitt, 1992). A higher quality product line brings in more profit than a lower quality one.

To the right of the figure are the four product lines originally owned by the firm (i.e. the lines shown in black and with z_j at their base). The firm can engage in internal R&D and innovation to improve the quality of the lines it holds. Firms have profit incentives to improve these technologies but they also face costs for doing R&D. The rate at which they make these investments is z_j , with some probability of success in each period thus determined (innovation outcomes are stochastic). A firm will invest

money up until the costs outweigh the expected benefits. If an innovation is realized, the quality of the product line is incremented by an amount λ , and the company gains more profits from the improved line. In the figure, two of firm f ’s internal R&D attempts have been successful as an example.

Companies may also undertake external R&D to ‘capture’ a product line owned by another company. As with internal R&D, exploration R&D efforts succeed with a probability that depends upon the amount of the investment being made. The firm will spend an amount of money x on exploration R&D up to the point that costs equal expected gains. If a company’s attempt is successful, then it acquires a new product line, chosen at random along the 0-to-1 interval, at the quality level that said product line has reached prior to this acquisition. The firm then increments the quality of this product line by an amount s_k . This is shown in the figure by the line on the left, with the x at the base. The black section represents the quality of the product line at the time that firm f ‘captured’ it, and its quality is then incremented by s_k as a result of the innovation undertaken by firm f . The magnitude of s_k is determined in the model by a number of factors, including technology waves, how long a product line has existed, and various other inputs that are beyond the scope of this note. This form of innovation is also sometimes called ‘horizontal innovation’ and closely relates to the frequently discussed concept of ‘creative destruction.’

Firms are constantly pursuing both forms of innovation, thus competing with each other on two fronts: trying to improve the quality of the product lines that they already own, and trying to capture product lines away from other companies. The model also takes into account entrepreneurs or new entrants by modelling individuals who own no product lines but wish to enter the industry by engaging in this creative destruction. The ability to consider both internal and external innovations and jointly model them in a fully-specified, general equilibrium setting is one of the major theoretical contributions of this model. This is an important step as it begins to allow economic

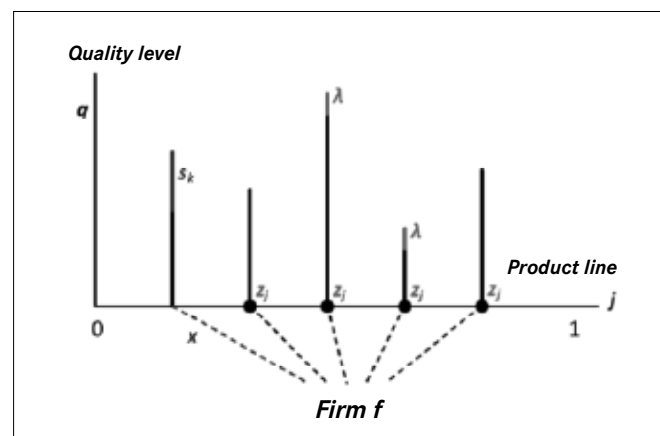


FIGURE 1

Internal and external innovation: the Akcigit-Kerr Model (2015)

models to take better account of why differences in the number of small firms vs. big firms might matter for the types of innovations undertaken and the economic impact observed.

The key feature of this model is the manner in which the different types of innovation scale up as firm size increases. In particular, the model predicts that *internal* innovation scales with firm size much more than external innovation does. As firms grow larger, the proportion of their R&D budget that they allocate to internal R&D will scale in a linear fashion as more product lines are added. However, external R&D does not scale up with company size as completely. This observation has been made at times in the empirical literature regarding innovation and is being applied here to theory; the full version of the model also undertakes a more complicated quantification analysis to formally measure these properties.

As an example, consider the extremes of firm size: a new entrant or entrepreneur starts with zero existing product lines, so they cannot, by definition, engage in internal R&D – the entire budget will therefore be allocated to external innovation. Similarly, a

very small firm with only one or two product lines still has a very limited opportunity to spend money on internal innovation, but there is considerable opportunity for external R&D. At the other end of the scale, a firm with 1,000 product lines has a much greater opportunity to spend money on internal efforts, and we see the proportions shift in that direction. It is important to note that this does not reflect the absolute amounts of money spent – a large firm may spend more in aggregate on external R&D than a small firm does, but these exploratory expenditures will account for a smaller proportion of their budget than at a small firm.

Data collected from the US Census Bureau and the NBER Patent Database on firm R&D and patenting behavior exhibits the scaling that the model predicts. For example, using the 2008 Business R&D and Innovation Survey, there is a -0.16 correlation between firm size, and the share of R&D that the firm reports is directed towards business areas and products where the company does not have existing revenues. Similar negative correlations are found for questions about the share of firm R&D being directed to technologies new to markets. Similarly, using the citations that firms make on the patents they file, there is a 0.11 correlation between firm size and the share of backward citations that are made to a firm's own prior work. Firms with larger past patent portfolios are mechanically more likely to self-cite, and the paper shows that larger firms are more likely to exhibit abnormal rates of self-citations compared to Monte Carlo simulations of their expected self-citation rate. Other evidence is also provided.

By itself, these differences in innovation behavior over the firm size distribution might not result in important economic outcomes, but the study by Akçigit and Kerr (2015) goes further and shows how external innovation is associated with greater employment growth than internal innovation. That is, the average firm growth impact that comes from exploratory work is larger than when firms focus on just enhancing their existing product lines, and moreover the growth spillovers into the broader economy

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are larger. The data thus indicate that firm growth rates depend on the kinds of innovation undertaken, and that firms that engage in greater proportions of internal innovation have slower growth rates than firms that spend proportionately more on external efforts. Thus we often see larger firms growing at a slower rate than smaller firms or new entrants, and we also find that these smaller, newer firms make disproportionately large contributions to major innovations. This again connects back to allowing for a model that can link firms of different sizes to different types of innovation investments and ultimately to growth consequences, for the firm and the economy as a whole. This is where the academic literature is currently pushing and starting to make substantial traction.

With this model in mind, the sensible next step is to examine the choices that firms make to see why they engage in the types of innovation that they do. The fact that larger firms devote less resources to external work can have both 'efficient' and 'inefficient' underlying reasons. The model can operate the same in both cases, but the business and policy prescriptions would be different. Why might larger firms engage efficiently in less external R&D? The paper describes several reasons, with the most intuitive one being limits on the effectively used manager time. If a skilled CEO does not have the time or resources to add another product line to their workload, it would be a reasonable decision to focus on the existing lines rather than trying to add new ones. In this setting, because new entrants and small firms have fewer product lines, they have competitive advantages for pursuing external-oriented work.

On the other hand, many management scholars have noted inefficient reasons for why larger companies do less external R&D or are generally less successful at achieving external innovations. Among the issues discussed in the paper are overly bureaucratic organizations and short-term stock market pressures. In these settings, the CEO of the large company may in fact want to obtain more product lines and the associated growth but struggles to do so. This is the scenario in which IBM found itself in the late

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1990s, and we will use this case study to describe the setting further. After a successful turnaround following a near bankruptcy at the beginning of the decade, IBM's new CEO was horrified to find that the innovation initiatives that he had set up at the company were failing because IBM's culture and organization were not conducive to that sort of exploratory R&D. We will use this case study to describe some reasons why large companies can struggle with external innovation and also identify how one firm sought to change itself to allow for better innovation outcomes and dynamic growth.

THE IBM EBO STORY¹

Founded in 1911, IBM focused for most of the second half of the twentieth century on creating and selling computer mainframes and minicomputers. In the 1960s and 1970s, it controlled 70% of the market share for the mainframe industry, and by the 1980s it was the most profitable company in the world. However, by the end of the decade the company had begun to decline, and by 1991 it was losing money. Between 1991 and 1993, IBM had lost approximately US\$16 billion, and its market share had dropped from 76% to 26%. This happened for several reasons. When smaller, upstart companies began to make personal computers more easily available to individual consumers, IBM leadership believed – based on past success – that they could enter and easily control the PC market. They did not recognize soon enough they needed to continue to innovate their PC platform and its marketing, and they did not realize until too late that the PC would bring about a seismic shift. While IBM's senior executives recognized that they were heading into trouble, they were unable to fix the problem. Hoping to stop their slide and turn the company around, IBM brought in Lou Gerstner in 1993 to be the new CEO. Gerstner had led American Express and had been CEO

¹ This section and the next draw extensively from Applegate and Kerr (2015). The IBM story is described in detail in Garvin and Levesque (2004) and Applegate et al. (2008), upon which this section also pulls material.

of RJR Nabisco, and he was the first outside CEO to lead IBM. When he arrived, he found that IBM had fallen victim to what Donald Sull termed 'active inertia', in which a company's set of assumptions about its core business become blinders to new ways of thinking that will promote growth.

IBM had spent the past several years focusing on existing products and short-term goals, with little attention paid to customers and their changing needs. In addition to 'mainframe blindness', Gerstner found that the processes for managing each of the individual 39 business units had continued to follow unproductive routines that rewarded existing product offerings and short-term results. Processes for starting new ventures were unclear and without a supportive infrastructure. The business units had their own profit and loss statements, but sales, manufacturing, and distribution were spread across the company. This organizational structure and the fact that there was no formal process for acquiring funding or strategy for development, made starting a new venture within the company haphazard at best. Missed opportunities were many. Finally, the culture at IBM fostered relationships that had, in some instances, become shackles that were maintained by a powerful bureaucracy, inflexible hierarchy, and interdivisional rivalries.

Gerstner's first move was to stop the steady losses of money and customers before he could start thinking about how to restart company growth. He decided to keep most of senior management on board, and strove to create a sense of urgency by requiring them to write memos describing steps to fix their department and the company as a whole. He also took steps to cut US\$7 billion in costs, shutting down underperforming departments and units, and established the 'One IBM' philosophy, setting a vision for the company as a global information business, not just a computer company, and allowing them to strategize around new opportunities like the internet. The company focused its new IBM Global Services business on value partnerships with clients and on eBusiness consulting.

IBM's Setbacks to Innovation

Gerstner's changes brought almost immediate improvement, and by 1999 IBM was on stable financial footing and looking to position itself to be able to grow and make its way back to the top of the industry. A large part of the plan to do so involved IBM being able to identify promising new ideas and directions in which to take the company, but the company was having trouble in that direction. IBM researchers were coming up with plenty of promising new ideas but Gerstner was horrified to learn that, rather than giving them the opportunity to grow, some managers seemed to be obstructing progress or allowing new initiatives to fail. After learning on a Sunday morning that funding had been cut for a promising life sciences initiative due to short-term pressures, Gerstner demanded action be taken.

Gerstner turned to Bruce Harreld, IBM's Vice President of Corporate Strategy, to investigate why things were going wrong. Harreld and his team discovered that this life science example was part of a very consistent pattern across the company, and that IBM's organizational structure was still fairly hostile to corporate venturing and the creation of new businesses, despite intentions otherwise. IBM's business units were having difficulty integrating new products and ideas that came out of R&D efforts, and managers frequently reduced budgets of growth initiatives, or, having failed to commercialize the results of research, even cut the programs altogether.

After interviewing individuals within the company who had been involved in several dozen missed opportunities and failed and struggling new venture startups, and documenting their findings in detailed case studies, Harrell and his team identified a number of high-level problems that were leading to the failure of new ventures. First, the company was mainly focused on serving the needs of existing customers, and managers were usually under considerable short-term pressures that restricted the amount of time that they could dedicate to exploring and supporting new ideas. IBM also had no useful approaches to learning about new ideas or identifying strategic

needs, and no processes in place for selecting projects or funding them. The company used a complex ‘matrix’ organizational structure that was focused on existing brands and on geographies and industries for sales and marketing, and new ventures that did not fit well into the rigid matrix were frequently abandoned. IBM also tended to rely on profit-oriented metrics to evaluate projects and business units which were ill-suited for measuring the progress of early-stage ventures that might not have reached the revenue-generating stage. This meant that R&D efforts were easy targets and often the first to be cut when a unit was having budget issues. And, the new ventures that IBM did undertake tended to be contained in separate ‘silos’, away from the rest of the company, which meant that it was difficult to effectively integrate new developments into the core business.

The Rise of Emerging Business Opportunities

In a very real sense, IBM had become too good at executing, reducing costs, and achieving short-term success. While each of these outcomes is desirable, they placed the company in a position where it struggled to undertake the longer-term exploratory innovation that would be necessary for the company’s sustained success. In short, IBM found itself in a position similar to that described by the Akçigit-Kerr model but did not want to be there! Harreld and the rest of the IBM executive team addressed this issue by suggesting the creation of an ‘Emerging Business Opportunity’ (EBO) initiative. It was based on a framework from the influential book on management *The Alchemy of Growth* (Baghai et al., 1999), which describes a three horizon model that classifies business ventures and innovations according to the length of time until expected impact, return potential and level of uncertainty, as shown in Figure 2. The book posits that a company’s sustained growth rests on what the authors call a continuous pipeline of business-building initiatives that is attained balancing short-term pressures for results with creating the space to conduct long-term and external innovation.

In the *Alchemy of Growth* conceptual model, horizons are managed concurrently within an organization, and each horizon requires its own separate management strategy. Horizon 1 (H1), situated at the lower left (low impact, low uncertainty), covers a company’s core business, the one around which a company has formed its identity, organized, and profited. H1 innovations extend or incrementally improve this business (e.g., the development of a new type of bumper by a car manufacturer for an existing line of sales). These efforts connect very closely to the *lambda* internal innovations we described earlier. While necessary to generate cash and provide resources for growth, H1 businesses – where most companies focus the bulk of their attention – will eventually flatten or become disrupted. Horizon 2 (H2) encompasses emerging, fast-rising businesses that have the capacity to eventually transform the company and become an H1 business – for example, the development and scaling up of a new type of engine that will be the basis of a new model of car. These innovations and business opportunities often have exhibited already some signs that they will work out well, but much investment remains to be done to prove out the opportunities and place them into positions for long-term

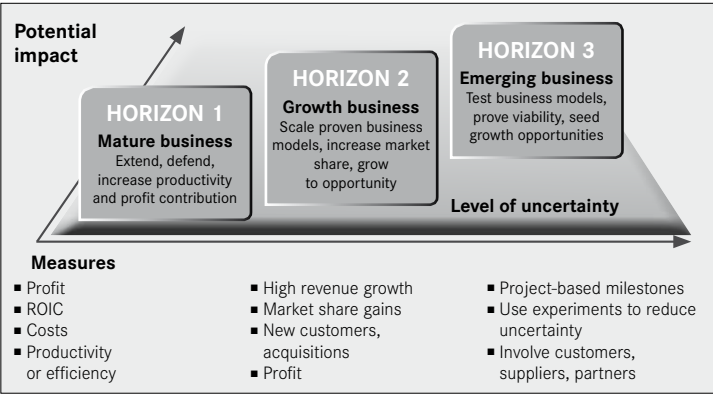


FIGURE 2
Horizons model to classify innovations; adapted from *The Alchemy of Growth* by Baghai, Coley, and White (1999)

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profitability. Located in the middle of the figure, these ventures are medium-term and have a potential for medium amounts of growth or transformation but also come with an associated level of risk.

Horizon 3 (H3) is where the seeds of totally new ideas and business concepts are created in initiatives such as research projects and pilot programs (for example, experimentation with rechargeable batteries for the purpose of developing an electronic car in the future). H3 initiatives carry with them a high risk of failure, and are often not completely aligned with a company's existing goals or product lines (and in some cases may even cannibalize current operations if ultimately launched), but they also have the highest growth potential. These are the businesses that can potentially transform a company and provide it a long-term platform for growth. Although not all of the new H3 ventures will mature to become H1 businesses, nourishing them is necessary for a company's long-term future.

Measurements, expectations, and leadership needs differ for each of the horizons. If the three horizons are managed concurrently to ensure healthy and continuous growth they 'cascade' through an organization. IBM was already well set up to handle Horizon 1 ideas and projects, which returned reliable, short-term gains and could be managed within existing business units. There was never a misalignment of incentives between the managers and these profitable investments. By contrast, Horizon 3 businesses was where IBM was struggling, as they usually required extensive experimentation or research and took a long time to realize their potential, which did not fit well with IBM's current short-term focus. These were the ideas that IBM was most interested in cultivating and were the ideas that the EBO initiative targeted. This is very common for larger companies (and very fast growing smaller companies) where the core of the company's operations can limit the ability for other ventures to take root around them. It connects to and reflects the limited scaling built in the Akçigit-Kerr framework.

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IBM quickly moved from investigation to action. To begin, Corporate Strategy and managers of individual business units worked together to identify Horizon 3 businesses. They decided upon seven EBOs that met their inclusion criteria, which included: the need for cross-business cooperation and resources; the maturity of the business plan and strategy (e.g., key market and technology risks appeared manageable, expertise was available to build the first offering and take it to market); the forecasted size of the market; and the potential for generating over US\$1 billion in three to five years. Gerstner selected John Thompson, a 34-year veteran of the company, to oversee and coordinate the EBO initiative. He was highly respected at IBM, which gave the program instant credibility. Thompson and Gerstner began rigorous monthly reviews of each of the seven initial EBOs, focusing on project milestones and developing business plans rather than meeting strict financial goals. Corporate Strategy also worked with Finance to identify expenses and revenue for each EBO, and Harreld set a goal of two points annual incremental revenue growth from EBOs. Gerstner also began using the 'horizons of growth' terminology in his speeches to the company. This helped to send the message that EBOs were not just a fad but were something that IBM was taking seriously. By 2002, 18 EBOs had been identified and shepherded through the program. One of the first challenges that the EBO group encountered was the question of where to place EBOs organizationally. If innovation was to be the foundation for success in IBM's future, it could not be delegated to a 'corporate incubator' that received separate funding and was left on its own to build businesses that would later be thrown 'over the wall' to IBM's business unit leaders, who were relentlessly focused on meeting the projections promised to Wall Street. Nor did the IBM team believe that accountability could be delegated to IBM's Research Labs. While the labs' contributions were a significant component of the company's innovation culture and brand, executives wanted to ensure that EBOs were integrated into IBM operating businesses that interacted with the marketplace on a daily basis.

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After much debate, IBM determined that both the business units and Corporate Strategy should share accountability for EBO efforts. Placement of the EBO teams within the business units facilitated the effective transition to high growth. Simultaneous oversight by Corporate Strategy, insured that the EBO initiative would secure significant senior management attention. Corporate Strategy also facilitated initial startup funding and, with business unit leaders, approved additional funding on an ongoing basis. A second challenge involved managing risk. Horizon 3 ventures, like all new business ideas, came with an inherent uncertainty and a high chance of failure. To help mitigate the risk, IBM began by first thoroughly monitoring customers' use of technology. By understanding how clients were using (or struggling with) current technology, IBM could better predict what future breakthroughs were needed and hence determine where best to place its research bets. To ensure customer involvement, IBM also introduced its 'First of a Kind' program that required that IBM researchers identify a customer willing to partner on research projects and provide minimal financing of the project. IBM also managed the uncertainty risk inherent in breakthrough research by borrowing an approach used by oil companies when prospecting for oil (i.e. 'test wells') and staging financial and other resource commitments based on specific timelines and goals for each project (Kerr et al., 2014). Finally, in 2004, IBM launched a venture capital group to help it monitor breakthrough innovations outside of the firm and serve as a technology transfer unit facilitating the commercialization of discoveries and technologies developed in IBM's research labs and businesses. By mid-2002, most of the initial EBO efforts had made considerable progress and revenues were up sharply. Equally important, there was considerable enthusiasm for the program. However, processes remained informal and success depended on Thompson and Harreld's personal interventions and networks. Financial and tracking systems, reporting relationships, review meetings, leader-selection criteria, and incentive mechanisms remained loosely defined. While this had worked for a small

number of EBO projects, the informality and intensive hands-on management could not be effectively scaled. EBO leaders differed on when to move out from under the EBO umbrella and into an H2 business. Some were concerned about how they would weather the transition from qualitative measurements such as milestones, while others argued that the tough financial goals expected of an H2 were healthy and necessary for the EBO system to be taken seriously within the company.

By now, Sam Palmisano, another IBM veteran, was CEO and he challenged Harreld and his team to come up with a way to scale and systematize the EBO program so that it did not require constant hands-on help. Harreld and the Corporate Strategy group assumed formal responsibility for the EBO process. They recognized that different categories of innovation had different risk profiles and, as a result, different approaches were needed to manage risk during implementation. The type of risk and the approach to implementation were based on the size of the opportunity and the timing and level of resources required to exploit the opportunity. These parameters defined different categories of innovation with different risk profiles. Each category of innovation also required a different leadership and organization model.

By the end of the decade, IBM's adjustments to their EBO scheme had proven their effectiveness. By 2011, the company was making US\$19 billion in revenues – 20% of their top line – from businesses that started as EBOs, and IBM seemed to have successfully positioned themselves for further growth and innovation.

Lessons from IBM and Corporate Innovation for Growth

IBM's story provides a useful example of the importance of establishing an innovative structure within large existing companies. Companies need to have the capabilities to engender dynamic growth. A number of lessons and best practices can be drawn from the successful efforts of others to jump start innovation and new business pursuit (Applegate/Kerr, 2015):

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- Innovation is necessary for a company to continue to grow and survive. Eventually, even the most productive core businesses will run out of room to grow and will face loss of market share. Disruptive innovations from other players in the same industry can create even greater pressures to find new ways to grow. The empirical work in Akçigit-Kerr confirms this point.
- As companies grow larger, it can be harder to innovate. Established patterns and processes at large companies can hinder the ability of those companies to generate new products or businesses even when it becomes clear that such a change is necessary. Donald Sull termed this phenomenon ‘active inertia.’ Managers at all levels should be aware of common obstacles that can stifle innovation or new corporate ventures:
 - Managers are frequently subject to short-term pressures, leaving them with little time/resources to devote to new ventures.
 - Corporate objectives are often misaligned with the goals of the innovative process; profit-oriented metrics that are a poor fit for early-stage innovations make these efforts easy targets for cuts during budget crises.
 - Established structures, bureaucracy, and internal politics such as interdivisional rivalries can make it difficult for changes to take root.
 - Companies can be restricted by the expectations of their customers and stockholders, both of whom are less likely to take a long-term view.
- Innovations can be broadly classified, and it is necessary for companies to be able to engage all three horizons simultaneously – what Mike Tushman calls ‘organizational ambidexterity’. If done correctly, innovations will continually cascade through the company, moving from uncertain H3 ventures to generating H1 ideas for mature ventures.
- Separate horizons have different needs in terms of management, organization, evaluation etc. Innovation or R&D units have their own unique requirements in

- terms of management, metrics, etc. different from those of established businesses or product lines. Profit levels or revenue growth may be more appropriate for Horizons 1 or 2, while Horizon 3 ventures may be better evaluated using project milestones and less rigid metrics.
- Breakdowns in the execution of a company’s strategy can provide clues to where the company needs to focus on innovation. (As a starting point, since long-term companies should be engaged in all the horizons at once to build truly dynamic organizations). Figure 3 illustrates this framework, where ‘gaps’ can occur, and how innovations in different horizons can address these gaps.
 - If a company’s or unit’s strategy is determined to be overall correct but there is a breakdown between execution and delivering value (an ‘execution gap’) then typically this is an opportunity for a Horizon 1 innovation, which mainly enhances current offerings and improves execution.
 - If the breakdown seems to occur between the setting-strategy and execution phases (‘strategy gap’) then this is more likely addressable by Horizon 2 innovations, which are longer-term and more uncertain than Horizon 1 but still adhere

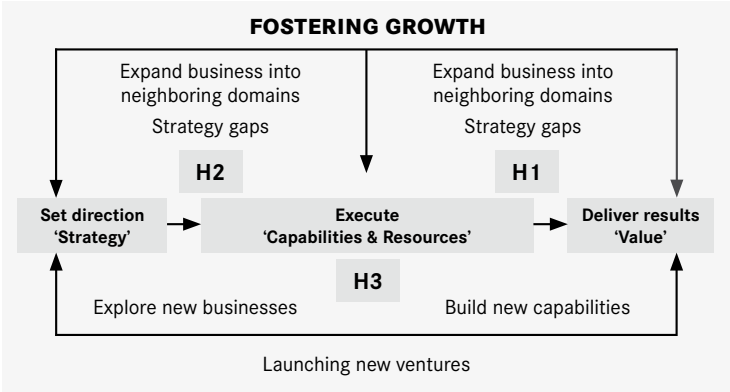


FIGURE 3

Strategy execution framework for business growth; taken from Applegate / Kerr (2015)

to the same overall strategy. The goal here is building new capabilities to deliver against the strategy.

- Horizon 3 ventures, by contrast, do not (necessarily) address strategy or execution gaps, but are attempts to expand into new businesses within a corporation or create new capabilities, possibly even creating entirely new strategic elements.
- One of the first and most important decisions encountered by IBM and other companies seeking to innovate is where to locate the new initiatives within the company. There is no 'one size fits all' solution. If there is a risk of cannibalization of time or resources by core businesses, it may be beneficial to keep a new venture separate from the rest of the company – but this risks a situation in which an innovation is not well-aligned with the company's goals and is difficult to integrate and move to an H2 business. On the other hand, while integrating new ventures into existing business units from the very start can afford them better access to funding and resources, it can also position them under managers who do not have the time or know-how to properly nurture them.
- Senior management must create a sense of 'urgency' around the changes and new initiatives, and it is responsible for ensuring that there is buy-in at all levels of the company and that innovation and new ventures are taken very seriously. It is also important to staff new ventures with some of the firm's best talent – although it is tempting to reserve the most capable workers for existing businesses with guaranteed returns, innovation efforts cannot succeed without skilled and dedicated workers.
- Although hands-on involvement from the CEO and senior management can be helpful in the early days of innovation initiatives, this may not be sustainable for the largest companies, like IBM, and it is necessary at some point to formalize the process of shepherding early-stage ideas through the stages up to Horizon 1. This includes financial and tracking systems, leader selection, processes for meetings

and reviews, and incentive mechanisms. For other organizations, the CEO may retain more direct control over the moving parts.

- Companies should involve outside parties in the ideation and innovative process to minimize risk. In particular, firms can use customers and other outsiders as 'early discovery systems' by monitoring customers' use of existing products, which can provide clues to their needs and generate likely ideas for new ventures.
- Perhaps most importantly, failure must be an option. Just as venture capital firms rely on their ability to terminate investments in projects that are not working out, large firms like IBM must be able to halt work on ideas that are not panning out and reallocate their resources elsewhere. This can be difficult for large firms: the relative availability of funding may lead to allowing struggling ventures to flounder for much too long, and managers are likely incentivized to avoid or mask failures. Proper continuation choices are essential, and some of the best companies use outsiders to obtain objective opinions about which projects to push forward vs. terminate.

In summary, the development of new businesses and innovations helps drive firm growth and that of the economy as a whole. Recent academic work is pushing the boundaries to understand better how firms differ in this regard, and we have collected empirical and case evidence of the challenges that large companies face in maintaining the pursuit of exploratory powers. In some cases, the shift towards an internal focus is warranted; in other cases, such as the IBM story depicts, it is inefficient and may ironically be an outcome of attributes that makes the organization otherwise successful. In managerial research, we are discerning a set of best practices about how to keep organizations more dynamic. These ideas need to be customized to each company and situation, and not all apply to every firm, but corporations should be learning from others as they discern how to best foster new business opportunities in their companies to provide growth for tomorrow.

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COMPARING AMERICAN AND EUROPEAN INNOVATION CULTURES

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Innovation – the improvement of existing or the creation of entirely new products, processes, services, and business or organizational models – drives long-term economic growth and improvements in standards of living and quality of life for peoples throughout the world. In fact, the U.S. Department of Commerce reports that technological innovation can be linked to three-quarters of the United States' economic growth rate since the end of World War II (Rai et al., 2010). Put simply, innovation is nothing less than the creation of new value for the world. Yet this is a lesson now understood by virtually all countries, giving rise to an intense competition for global innovation leadership, as Robert Atkinson and Stephen Ezell of the Information Technology and Innovation Foundation (ITIF) write in *Innovation Economics: The Race for Global Advantage* (Atkinson/Ezell, 2012). That has led many countries to design sophisticated national innovation ecosystems that bring together disparate policies toward finance, scientific research, technology commercialization, education and skills development, tax, trade, intellectual property (IP), government procurement, and labor and regulatory policies in an integrated fashion that seeks to drive economic growth by fostering innovation.

But while smart policies can contribute greatly to bolstering a nation's innovation capacity, underlying those factors lays a country's (or region's) fundamental *innovation culture*, which informs and provides the social-political framework through which innovation occurs in a country. Indeed, innovation involves a complex set of processes that strongly relates to contextual factors (Vieria et al., 2010). 'Innovation culture' has relevance at a number of levels – for example, individual, societal, organizational, national – and differs greatly between Europe, the United States, and Asia and in fact

even differs within the same countries and regions over periods of time. This chapter explores the innovation cultures of Europe with the one of the United States and examines how those disparate innovation cultures have informed these regions' innovation policies and affected their output of entrepreneurial and innovative activities over time. To be sure, a nation's innovation culture is neither monolithic nor immutable, but it can hold key characteristics that significantly impact a nation's ability to innovate.

INNOVATION CULTURE

Before assessing what role, if any, innovation culture plays in how ready a nation or organization is to innovate, we must ask: what is an innovation culture? The anthropologist Edward B. Taylor defined culture as 'that complex whole which includes knowledge, belief, art, morals, law, custom, and any other capabilities and habits acquired by man as a member of society' (Taylor, 1889). The Dutch social psychologist Geert Hofstede's pioneering work in cultural dimensions theory led him to develop a model of national culture that contains five dimensions: power distance (the extent to which the less powerful members of organizations and institutions accept and expect that power is distributed unequally), individualism, masculinity, uncertainty avoidance, and long-term orientation (added later) (Didero et al., 2008). Building from this framework of national culture, Hofstede wrote that '[i]nnovation culture is to be understood in terms of attitudes towards innovation, technology, exchange of knowledge, entrepreneurial activities, business, uncertainty and related behavior and historical trajectories' (Hofstede, 2001).

Innovation is inherently and inextricably linked to change – that is, to the disruption of the status quo and the existing method of doing things, whether with regard to the technologies or processes deployed to create value for customers or constituents. Indeed, as Joseph Schumpeter, the Austrian patron saint of innovation economics famously wrote, 'It is the process of industrial mutation – if I may use that biological

term – that incessantly revolutionizes the economic structure *from within*, incessantly destroying the old one, incessantly creating a new one. This process of Creative Destruction is the essential fact about capitalism' (Schumpeter, 1975). With those words, Schumpeter effectively anticipated the 'political economy of innovation,' highlighting the reality that this creative destruction – that is, innovation – forces individuals, organizations, and even whole regions and nations to adapt or to suffer the consequences of not doing so. For innovation can turn industries (and occupations) into vestigial 'buggy whip industries' with little purpose, just as the automobile replaced the carriage a century ago and as the driverless car (or autonomous vehicle) is poised to replace the person-driven car today (Ezell, 2014). But while most gain handsomely from innovations, for those invested in the old – old products, services, industries, occupations, institutions, forms of work organization, and production processes – innovation is risky and often met with trepidation at best (Atkinson/Ezell, 2012). And all too frequently those invested in the old fight, often vigorously and effectively, protect their interests against particular innovations. As such, a key component of an organization or nation's innovation culture is not only how creative it is to imagine, develop, and commercialize new technologies, products, or services, but also how it reacts and adapts to change and manifests a willingness to take risks as well as how its citizens view the likely impacts of scientific or technological change.

Thus, not having a culture that supports innovation stands #1 among the 'Big Ten Innovation Killers.' As innovation evangelist Joyce Wycoff writes, 'Culture is the playing field of innovation. Unless the culture honors ideas and supports risk-taking, innovation will be stifled before it begins [...] Culture can change but it is a slow process' (Wycoff, 2004). Wycoff describes culture as a concept to describe how innovation is influenced by various human factors: 'Culture is the reflection of leadership, people and values: the outward and observable expression of how they work and behave together. An environment that is flexible, empowering, welcomes ideas, tolerates

risk, celebrates success, fosters respect, and encourages fun is crucial to innovation' (Wycoff, 2004). In other words, an effective innovation culture is vital to innovation success at the organizational level.

Dan Mote of the U.S. National Academy of Engineering argues that effective cultures of innovation at the organizational level exhibit seven key characteristics, they:

- 1) have strong leadership committed to innovation;
- 2) deploy minimal hierarchy in decision making;
- 3) are committed to deliverables and implementations;
- 4) value disparate talents and entrepreneurship;
- 5) value ideas, the creative and the unconventional;
- 6) move quickly but adapt readily; and
- 7) are willing to accept failures (Mote, 2013).

Writing about organizational innovation culture in *Wired* magazine, John Carter offers similar hallmarks. As he writes, innovation cultures:

- 1) invest in their people;
- 2) tolerate risk and failure;
- 3) support inquiry and the scientific method;
- 4) value trust;
- 5) encourage opposing points of view;
- 6) ban politics; and
- 7) embrace the individual.

Certainly many such lists abound, but the key point is that all organizations should conscientiously construct an effective innovation culture and commit to its central tenets.

Yet innovation culture is no less important at the national level. In their article 'How does culture contribute to innovation,' the Estonian researchers Kaasa and Vadi

measure patenting intensity at the national level as an innovation measurement and find 'significant support for the argument that the capability of a country or region to initiate innovation is related to its culture' (Kaasa/Vadi, 2008). Specifically, the authors find a 'reliable link between cultural dimensions and patenting intensity' (ibid). They also find evidence that cultures that excessively value the family tend to be more conservative and less open to new and creative ideas, while cultures focusing more on relationships with persons outside families are more open, in part because relationships with persons with different backgrounds enable a broader world view as a powerful source of new ideas (ibid).

Likewise, the Portuguese researchers Vieira, Neira, and Ferreira find in their study 'Culture impact on innovation: Econometric analysis of European countries,' that 'the cultural environment is of utmost importance for countries to be innovative' (Vieira et al., 2010). The authors examine Hofstede's four original components of his cultural dimensions theory – power distance, individualism, masculinity, and uncertainty avoidance – and find that (in Europe at least), 'three out of four cultural dimensions produce an impact on innovation' with the corresponding implication that 'some countries present more innovation potential than others and, consequently, are in a more suitable position to be competitive and develop entrepreneurial activities [...] with the differences among European nations being quite pronounced' (ibid). Interestingly, the authors find that innovation (as measured by R&D expenditure) is more significant in societies where individualism is higher, which the authors interpret to mean that the innovation process finds a more positive cultural environment in societies that value and reward freedom, autonomy, and initiative (ibid). (In contrast, ITIF finds that nations that effectively balance the tension between individualism – emphasis on individual rights and freedom – and communitarianism – emphasis on the collective good – are in better positions to win the global innovation race [Atkinson/Ezell, 2012].) The Portuguese authors also find the effects of excessive masculinity and of power distance

on innovation to be negative. Uncertainty avoidance, on the other hand, was found to have no impact on innovation (Vieira et al., 2010). But while certainly the specifics of these findings can be debated, their research clearly establishes a connection between a nation's cultural attributes and its innovation propensity.

At the national level, a culture of innovation provides an environment that supports creative thinking and advances efforts to extract economic and social value from knowledge, and, in doing so, generates new or improved products, services or processes. A healthy innovation culture provides a shared set of values and mutually reinforcing beliefs about the importance of innovation as well as an integrated pattern of behavior that supports research and innovation. Finally, a thriving national innovation culture leverages the existing strengths of a country's research and innovation ecosystem.

EUROPE'S INNOVATION CULTURE

The following section examines Europe's innovation culture, past and present.

THE EVOLUTION OF EUROPE'S INNOVATION CULTURE

Europe has a profound history of innovation achievement stretching back centuries: aqueducts, the printing press, the telescope, the steam engine, the mechanical loom, the television, the automobile, and, some argue, the first aeroplane, to name just a few. Indeed, Europe was the birthplace of the Renaissance and the scientific revolution, a period that prized scientific and intellectual curiosity and the innovations they engendered. Europe's scientific revolution gave rise not only to the industrial revolution of the late eighteenth and nineteenth century but also to the great flourishing of intellectual and creative fervor that characterized European capitals such as Berlin, London, Paris, and Vienna in the late nineteenth and early twentieth centuries.

Austria's Innovation Culture circa 1900

Austria – and Vienna in particular – embodied the vibrant intellectual moment at the turn of the twentieth century. Openness to people with different cultural backgrounds became one of the reasons why Vienna stood among the world's most innovative cities at the turn from the nineteenth to the twentieth century, as creative minds from all over Europe moved to the capital city of the Habsburg Empire, considered a cultural melting pot at the time. As Eric Kandel writes in *The Age of Insight* about Vienna circa 1900: 'One of the characteristic features of Viennese life at that time was the continual, easy interaction of artists, writers, and thinkers with scientists' (Kandel, 2012). Indeed, 'Vienna benefitted from an influx of talented individuals from different religious, social, cultural, ethnic, and educational backgrounds.' In fact, this influx contributed to the emergence of the University of Vienna as one of the world's great research universities. As Kandel continues:

'Viennese life at the turn of the century provided opportunities in salons and coffeehouses for scientists, writers, and artists to come together in an atmosphere that was at once inspiring, optimistic, and politically engaged. The advances in biology, medicine, physics, chemistry, and the related fields of logic and economics brought with them the realization that science was no longer the narrow and restricted province of scientists but had become an integral part of Viennese culture.' (Kandel, 2012)

In that era, scientists and inventors in the Habsburg Empire such as Josef Ressel (designing one of the first ship propellers), Ferdinand Mannlicher (inventing the rotary magazine), Carl Auer von Welsbach (inventing the incandescent gas mantle), Sigmund Freud (founding psychoanalysis), and Viktor Kaplan (making the first turbine) changed the way the world works with groundbreaking discoveries.

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And in the field of medicine, the Austrian capital – with the Vienna School of Medicine developed at the Vienna General Hospital – boasted a world-leading institution that attracted talent from across the globe. ‘American students in particular were drawn to the medical school because of its growing reputation for excellence [...] in contrast to the poor quality of nineteenth-century instruction and practice in the United States.’ In fact, the intellectual historians Allan Janik and Stephen Toulmin argue that the United States owes its current preeminence in the medical sciences in part to the thousands of medical students who traveled to Vienna at a time when the standards of American medicine were low (Kandel, 2012).

The turn of the twentieth century also sparked tremendous growth in entrepreneurial and commercial innovation throughout Europe. Indeed, as *The Economist* notes, ‘the vast majority of Europe’s big companies were born around the turn of the last century. So was much of the German *Mittelstand*, and clusters of manufacturers from Lombardy to the Scottish lowlands’ (The Economist, 2012). Leading European firms, to this day, created at that time include Denmark’s Maersk (1904), Germany’s Thyssen-Krupp (1891) and Daimler-Motoren-Gesellschaft (1901), France’s L’Oréal (1909), Switzerland’s Roche (1896), the precursors of Sweden’s modern ABB (ASEA in 1883 and the Swiss firm Brown, Boveri and Cie in 1891), and the United Kingdom’s Rolls Royce (1906) (Economist, 2012, and author research).

But as David Landis wrote in *The Unbound Prometheus: Technological Change and Industrial Development in Western Europe from 1750 to the Present*, ‘technological change is never automatic. It means the displacement of established methods, damage of vested interests, and often serious human dislocations’ (Landis, 2003). And so the tumultuous period of the industrial revolution gave rise to an anti-progress-

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oriented Luddite movement – inspired by Englishman Ned Ludd, who led a movement to destroy mechanized textile looms – that sought to resist the impact technological innovation makes on society and the economy. And though the Luddite movement sprouted in Europe, and in many ways remains strong there today, it has become a global phenomenon, as ITIF writes in *The 2014 Luddite Awards* (Atkinson, 2015).

This development was significantly compounded by the two world wars Europe endured in the twentieth century. As *The Economist* notes, the devastation of the two World Wars ‘made Europeans more risk-averse than they had previously been’ (The Economist, 2012). As Leslie Hannah, a business historian at the London School of Economics, observes, ‘markets that had been closely linked before 1914 fell back into fragments’ which limited European firms’ ability to achieve scale and grow large – particularly in the decades before the European Union’s single market was formed (The Economist, 2012). In fact, according to Nicolas Véron of the Brussels-based think-tank Bruegel, from 1950 to 2007 Europe gave rise to just twelve new large companies – at a time when the United States produced fifty-two. Worse, only three large new European firms were listed between 1975 and 2007 (Véron, 2008). In contrast, as Véron notes, ‘[s]ince the Industrial Revolution, the United States has never ceased to produce new champions [e.g., entrepreneurial start-ups that become listed corporations]. Specifically, 33% of its champions, representing 27.4% of its aggregate market capitalization (as of 2007) were born after 1945; of these, 25 companies (14% of U.S. champions, representing 13% of aggregate market capitalization) were born in the last quarter of the 20th century’ (Véron, 2008).¹

¹ Those companies being Apple, Genentech, Unitedhealth, Oracle, Home Depot, Boston Scientific, EMC, Amgen, Time Warner Cable, DirecTV, Adobe Systems, Costco Wholesale, Cisco Systems, Dell, Qualcomm, XTO Energy, Celgene, Weatherford International, Gilead Sciences, Capital One Financial, Garmin, Amazon.com, Yahoo!, eBay, and Google.

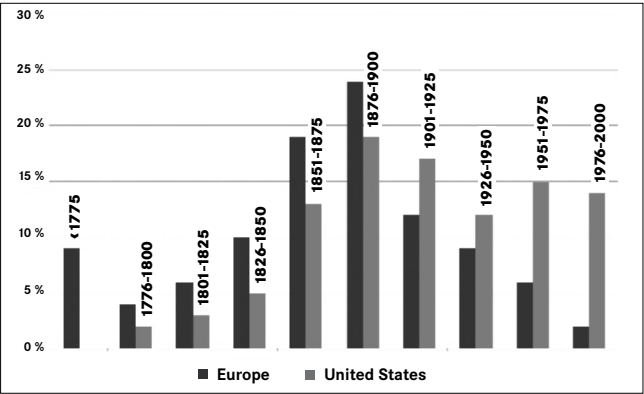


FIGURE 1

Age structure of European and U.S. enterprises in the FT Global 500 (as of September 2007); taken from Véron (2008)

Figure 1 depicts the startling disparity in age structure of the leading American and European enterprises in the *FT Global 500* as of September 30, 2007.

EUROPE’S INNOVATION CULTURE TODAY

Europe’s modern innovation culture is complex and certainly not homogenous; it exhibits a wide diversity across the European continent. European nations, in general, field some of the world’s most sophisticated science, innovation, and technology support agencies. These agencies foster the innovation competencies and skills of their countries’ private sector firms while also promoting innovation within government agencies themselves. European nations have also led in the formulation of national innovation strategies which seek to explicitly link science, technology, and innovation with economic and employment growth, effectively creating a game plan for how their countries can compete and win in innovation-based economic activity.

There’s also evidence that European firms are fairly active innovators. In fact, the European Union’s (EU’s) *Sixth Community Innovation Survey* (CIS) found that 52% of EU-27 enterprises reported innovation activity between 2006 and 2008 (Dahl, 2010).

By comparison, the U.S. National Science Foundation’s 2008 Business R&D and Innovation Survey (BRDIS), which covered the same period and asked the exact same questions as the CIS, found that just 9% of surveyed U.S. firms were active innovators from 2006 to 2008 (although 22% of U.S. manufacturing companies reported innovation activity) (Boroush, 2010).² So, at least by this indicator, European firms are, on average, more innovative than American ones.

In other words, Europe is hungry for innovation from its enterprises, governments, and institutions. But Europe’s innovation challenge is that it still has not realized to the full extent that it cannot achieve an innovation economy without embracing at least a modest amount of Schumpeterian creative destruction while maintaining an expansive, if expensive, social welfare state. The Nordic countries try to manage this tension through an innovative ‘flexicurity’ approach that promises citizens not job security but ‘skills security’ (Atkinson/Ezell, 2012). For, as much as European leaders embrace innovation, they have a decidedly ambivalent view of it. When they refer to innovation, they rather seem to mean science- and technology-based funding, not innovation in Schumpeterian terms. For innovation is the constant transformation of an economy and its institutions. And some countries in Europe seem to be reluctant to accept constant transformation, especially if it has the potential to upset the delicate balance of carefully calibrated social democratic societies. Put simply, even though Schumpeter was a European, most Europeans are not Schumpeterians. Europe wants the benefits of a knowledge-based technology economy without the creative destruction that not only accompanies it, but is required to achieve it. To be sure, some in Europe get this,

² What accounts for this difference in reported innovation activity between U.S. and European firms is unclear. Since the survey instruments are similar, the differences either reflect a different industrial composition in the U.S., U.S. firms’ inexperience in responding to the survey, or the less sanguine possibility that European firms as a whole may in fact be more innovative than American ones. So important is the question that in February 2011 the U.S. National Academies of Science commissioned a new study that will seek to ascertain the reasons for the different reported rates of innovation between U.S. and EU enterprises.

as Paul Giacobbi, a member of the French Assembly, observed: 'The idea that nothing will change, that no factory will ever close, and restructuring will not be a permanent feature is contrary to everything that the direction of the world tells us every day' (Giacobbi, 2010). Unless Europe embraces the idea that innovation entails plant closures and job losses, new technologies with uncertain social or environmental impacts, and new kinds of business models and organizations, it will be challenging for Europe to keep up in the race for global innovation advantage (Atkinson/Ezell, 2012).

Sclerotic regulatory policies – particularly with regard to labor, competition, and bankruptcy policy – in addition to inadequate access to risk capital are probably the two largest inhibitors to Europe's innovation economy. For instance, a 2004 report prepared for the OECD by Eric Bartelsman found that the 'rates of innovation' (e.g., launches of innovative new products or services) between U.S. and EU enterprises were actually the same (Bartelsman et al., 2005). However, Bartelsman found that the United States did a much better job than Europe of more quickly allocating capital and labor to the most promising innovative concepts and start-up businesses, so the U.S. was spawning more 'winners,' even though the underlying rates of innovation were analogous. As an archetypal case, Bartelsman points to the Dutch bank ING Group's efforts to launch an online banking service in Europe. ING Group was the first bank in the world to introduce online banking, but Dutch regulators – fearing the impact online banking would have on employment (i.e., tellers) – introduced laws that slowed the introduction of online banking and compelled ING to launch its service first in the United States, not Europe (McDowell, 2005).

Similar reactions to innovative, information and communications technology (ICT)-based business models and innovations persist across Europe today. For example, France's Culture Minister has attempted to categorize Amazon.com's free shipping of online orders away from what it is – a business model innovation – and classify it as 'a strategy of dumping' (Collier, 2013). Or think of the legal battles the ride-sharing

car service Uber is facing in Belgium and Germany (Euractiv, 2014). The irony is that while Europe wants to foster its own world-class internet companies, its regulators – often lobbied by companies with vested interests – fear the competition these firms would bring to incumbent interests. With such hurdles, it's no surprise when *The Economist* argues that 'Europe's culture is deeply inhospitable to entrepreneurs' and that 'Europe [has exhibited a] chronic failure to encourage ambitious entrepreneurs'. One problem, as *The Economist* points out, is that 'European executives are extremely risk-averse [...] young firms quickly find that established European companies don't like working with small ones' (The Economist, 2012).

Meanwhile, an existential challenge for European entrepreneurs remains securing adequate access to risk capital. As *The Economist* notes, '[f]or the €1.5 to €4 million that firms need to work an idea up into a real business model, money is in desperately short supply' in Europe. Figure 2 shows the vast disparity in levels of venture capital activity between the United States and Europe from 1995 through 2010. In fact, over those years, the United States invested US\$321 billion more in venture capital investment into young, innovative entrepreneurial companies than European Union nations did, with the United States investing US\$478.4 billion to the European Union's US\$157.2 billion in venture capital over that time frame (OECD, 2013).

However, European policymakers are aware of this gap and are taking measures to address it, such as through the creation of the European Investment Fund (EIF), a body financed by the European Union, which invested €600 million (US\$800 million) into venture capital funds in 2013 out of a Europe-wide total of €4 billion (US\$4.5 billion) (The Economist, 2014). In the same line, in 2013 the Austrian government created the 'Gründerfonds' (~ start-up fund), an investment vehicle of €65 million to support young companies with high growth potential in their initial growth phase; the investment volume per deal is in the range of €100 thousand to €3 million. Moreover, the total fundraising for European private equity activity of €53.6 billion (US\$61.2 billion)

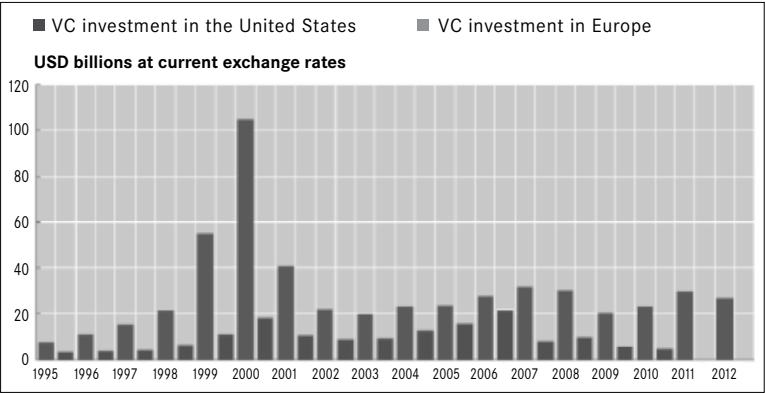


FIGURE 2

VC investment in the United States and Europe, 1995–2012 (OECD, 2013)

in 2013 more than doubled the volume of 2012 (EVCA, 2013). Still, Europe’s young entrepreneurs remain significantly underfinanced. One reason posited for the scarcity of venture capital in Europe relative to the United States, as Peter Thiel notes, is that venture returns in Europe have underperformed those in America (NESTA, 2013). In part, that’s because of deeper capital markets in the United States that more readily enable firm exits, through initial public offerings or M&A activity, allowing venture capitalists to better monetize their investments. On this issue, one other challenge for European entrepreneurs is that it’s more difficult for them to use equity as part of incentive compensation structures. For example, Denmark explicitly discourages entrepreneurs from giving shares to employers, as their tax laws impose an additional 25% tax on any shareholder in possession of less than 10% of the company. In case of an exit, a stock-owning employee would owe 67% of gains to the Danish government. Hurdles such as these have meant that all too many European innovators have left continental Europe for the United States (or even the United Kingdom). For instance, it’s estimated that 50,000 French nationals now live in Silicon Valley alone.

At the other end of the spectrum for Europe’s entrepreneurs lies another challenge, one pertaining to firm dissolution and bankruptcy. As *The Economist* describes a 2010 European Commission study that examined insolvency regimes across European countries, it found that, ‘[s]ome countries keep failed entrepreneurs in limbo for years’ and that ‘many [European] countries treat honest insolvent entrepreneurs more or less like fraudsters, though only a tiny fraction of bankruptcies involve any fraud at all’ (The Economist, 2012). In France, the maximum typical time from the end of the liquidation process until a bankruptee is free from debts is nine years, as Figure 3 shows.

And as *The New York Times* writes in the article ‘Au revoir, Entrepreneurs’ about France, ‘Defeat is seen as so ignominious that France’s central bank alerts lenders to entrepreneurs who have filed for bankruptcy, effectively preventing them from obtaining money for new projects.’ In Germany, it takes six years to get a fresh start, but ‘bankrupts can face a lifetime ban on senior executive positions at big companies.’ In contrast, in Silicon Valley, the attitude some venture capitalists take toward young entrepreneurs is, ‘don’t talk to me until you’re on your third start-up [with two

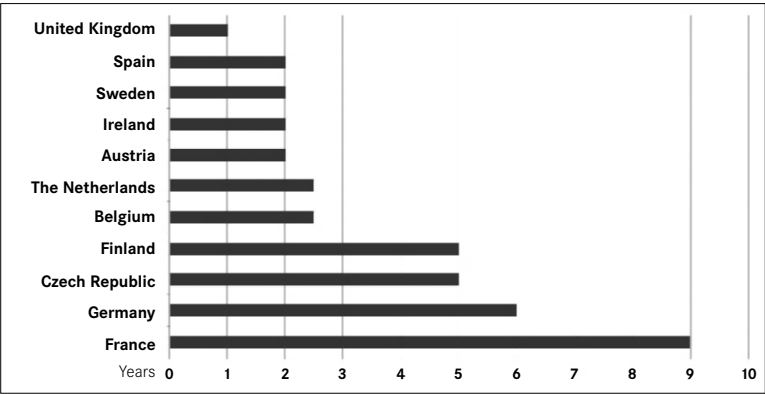


FIGURE 3

Maximum time from end of liquidation process until a bankruptee is clear of debts (European Commission, 2011).

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failures already behind you] because you haven't learned anything useful.' This viewpoint is not prevalent enough in Europe.

However, there are entrepreneurs in Europe who defy logic and culture, think big, don't let failure stop them, and single-handedly create new industries 'in the Silicon Valley way.' Among them is the Austrian Dietrich Mateschitz, one of the most successful entrepreneurs of our time. Despite initial failure and losing his entire life savings, Mateschitz has created Red Bull, the dominant energy drink in the world, thus revolutionizing the beverage industry by adding a new category. Like other newcomers such as Uber, Red Bull faced struggles and was initially banned in France, Denmark and Norway, but the drink was eventually legalized in all three countries. Of course, Mateschitz is not the only example of a successful, industry-changing modern European entrepreneur. A collaboration of Estonian and Scandinavian innovators led by Priit Kasesalu and Jaan Tallinn created the breakthrough voice over internet service Skype, later acquired by eBay for US\$2.6 billion. The Swedes Daniel Ek and Martin Lorentzon launched the innovative music streaming service Spotify in 2006, leveraging a novel digital rights management approach. And of course the flamboyant Brit Sir Richard Branson, in the Mateschitz mold, has built his Virgin empire based on an irreverent, iconoclastic brand strategy that has enabled Branson to sell customers everything from cell phone subscriptions and music to air travel and space flight under the Virgin banner.

Yet despite such role models, there's still a perception – at least in the United States – that even Europe's most ambitious entrepreneurs may not be ambitious enough. A leading Silicon Valley-based U.S. venture capitalist in the renewable energy sector noted that his firm was less inclined to support European entrepreneurs. He stated that entrepreneurs from the United States, Asia, and Europe tended to be roughly at parity with regard to the core science and technological inventions behind their

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start-up's innovative product, but the real difference was that the American and Asian entrepreneurs had developed far more aggressive business models that sought to build billion-dollar companies and disrupt entire industries. This venture capitalist felt that the European entrepreneurs tended to write business plans that would lead to successful companies that would find a certain market niche and work within the existing system. But as he noted, venture capitalists look for 'irrationally ambitious' individuals who wish to fundamentally disrupt established markets, industries, and business models, and he felt that, in general, European entrepreneurs' business plans failed to reflect those aspirations. A similar sense emerges from some Nordic countries, where there's actually a sense of entrepreneurs who are too successful being socially shunned. That is, if they disrupt the finely tuned social justice system too much – whether by making too much money or by launching companies so disruptive that it contributes to unemployment – they are socially frowned upon.

EUROPE'S HIDDEN CHAMPIONS

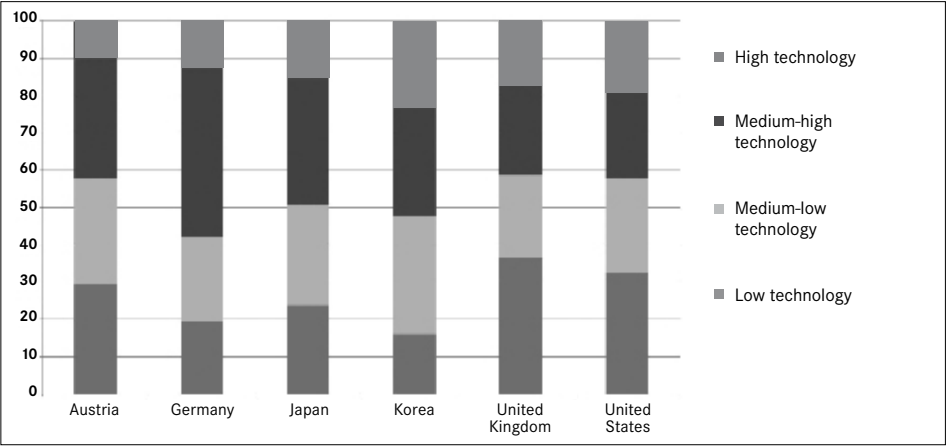
Although European entrepreneurs seem to take a more modest approach when building a company – at least from a U.S. perspective – there are a good number of extremely successful, yet unknown, companies that aim to be among the top three in their global markets, have less than US\$5 billion in revenue, and are little known to the general public. Coined by the German Business Consultant Herman Simon as 'hidden champions,' he describes these mid-level companies as 'simmering under the surface of the global economy while dominating their markets.' These businesses are not only some of the most intriguing companies on the planet, but they are also raking in cash to little or no fanfare. In fact, two-thirds of them are family owned with only 8% of these 'hidden champions' having required private equity investment (Simon, 2008). Austria, Germany, and Switzerland are home to more than 55% of all so-called 'hidden champions' worldwide. Although this area has a population less than 100 million

[1.5% of the world population], there are more small and medium-sized world market leaders located there than in the rest of the world. Research has shown that the success of these hidden champions is derived from distinctive factors such as a strong focus on production, outstanding in-house innovation and research, a highly skilled labor force – in Austria’s case, the dual system of apprenticeship and vocational education – strong exports, and a high vertical integration of manufacturing [21st Austria, 2015].

For Germany, Simon observes that there are clusters of unknown world market leaders across the country. In fact, ninety percent of Germany’s *Mittelstand* operate in business-to-business markets and seventy percent are found in Germany’s countryside, but such is their dominance that eighty percent of the world’s medium-sized market leaders are based in Germany, Austria, or Scandinavia [The Economist, November 2010]. Germany’s *Mittelstand* employ over one million workers and export more than eighty percent of their production [The Economist, March 2010]. The reason for this, according to Simon, is that entrepreneurship is infectious and contagious. The social network that binds people together in these regions provides the inspiration for them to emulate their neighbors’ successes and build a market leader in their own field. Hence, for Simon, Germany is more entrepreneurial than many think, but these entrepreneurs remain hidden – in contrast to places such as the highly visible Silicon Valley [Simon].

The strength of Austria and Germany’s hidden champions can clearly be seen in Figure 4, which examines the ‘technological intensity’ of various countries’ manufacturing sectors as either ‘low-technology,’ ‘medium-low technology,’ ‘medium-high technology,’ or ‘high-technology.’ [The OECD classifies a sector as ‘high-technology’ if global R&D expenditure is greater than 5% of sales; ‘medium-high technology’ if global R&D expenditure is 3–5% of sales; ‘medium-low technology’ if global R&D expenditure is 1–3% of sales; and ‘low technology’ if global R&D expenditure is less than 1% of

FIGURE 4 Composition of manufacturing sector by technological intensity, 2007 (OECD, STAN)³



sales.) Indeed, 45.1% of Germany’s and 32.4% of Austria’s manufacturing enterprises are located in the medium-to-high technology range, reflecting the strong influence of their hidden champions. However, if there is a weakness for Germany and Austria in this picture, it is that they underperform the United States in their share of the most innovative, R&D-intensive manufacturing sectors (for example, sectors such as aerospace, information and communications technology, medical devices, and pharmaceuticals manufacturing) [Ezell/Atkinson, 2011].

The United States has much to learn from Austria and Germany’s approach to the innovation ecosystem that supports these hidden champions, in particular the emphasis on collaborative education and skills development. In fact, a number of European companies that have recently made foreign direct investments in the United

³ Data displayed is 2007, or most recent year available.

States to launch new manufacturing facilities – including Siemens, Volkswagen, and Voestalpine – have also imported their apprenticeship training models. For instance, when Siemens opened a new gas turbine manufacturing facility in Charlotte, North Carolina, in 2011, Siemens partnered with Central Piedmont Community College to launch an apprenticeship program in which students studied half-time at the college, worked half-time at Siemens, and were prepared with the requisite skills to work full-time at Siemens’ plant upon graduation. The Austrian company Blum and the Swiss firm Daetwyler had actually started this *Apprenticeship 2000* program already in 1995 (Apprenticeship 2000).

This enlightened approach to workforce development – particularly in Europe’s Nordic and German-speaking nations – was never more fully on display than during the height of the Great Recession. As the Great Recession sharply constricted global demand, instead of releasing idling workers (as was too often the case in the United States), the German government conceived a ‘Kurzarbeit’ program in collaboration with and co-funded by German industry, unions, and state governments, through which workers in manufacturing facilities not needing to make full production would work half time and be reskilled or up-skilled half-time (The Economist, 2010b). Accordingly, when global demand recovered in the wake of the Great Recession, German firms were fully staffed, and with a workforce reskilled to leverage the technologies and manufacturing processes of the future (Nager, 2014). While the way many American corporations (laudably) give back to their communities is through donations or sponsorships to community service programs, often the way Austrian and German companies do so is through these types of enlightened investments in their workforce. Another hallmark of the European system is its intensely collaborative nature. As Figure 5 shows, almost seventy percent of European firms surveyed report that they collaborate with other enterprises in innovative activities, a rate more than double that of enterprises in the United States, in China and India, or in other OECD nations. The

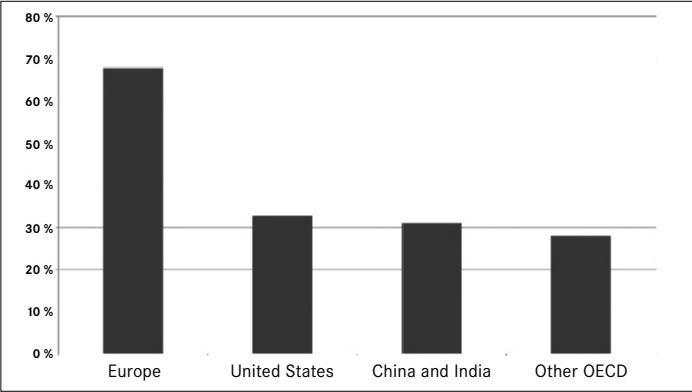


FIGURE 5

Percentage of nations’ firms that cooperate in innovative activities (Chaminade et al., 2010)

collaborative nature of European innovation fits well with the modern concept of ‘open innovation,’ which emphasizes the importance of looking for innovative ideas outside the company and of partnering with customers, suppliers, universities, research institutes, and partner enterprises in the innovation process. However, there is evidence that the innovation process in the United States is also becoming more collaborative. As Matthew Block and Fred Keller write in *Where Do Innovations Come From? Transformations in the U.S. National Innovation System, 1970–2006*, whereas in the 1970s, approximately eighty percent of award-winning U.S. innovations came from large firms acting on their own, today, approximately two-thirds of award-winning U.S. innovations involve some kind of inter-organizational collaboration (Block / Keller, 2008). Indeed, cultural attitudes toward science, technology, and innovation are important. The 2014 World Values Survey revealed significant disparity among European nations as to whether citizens believed that the ‘world is better off, or worse off’ because of technology. Twenty-one percent of respondents in Sweden and 20.4% in Germany believe science and technology will make the world much better off, while just 6.7% believed so in the Netherlands and 11.9% in Spain. Attitudes in Germany and Sweden

were closer to those in the United States and China, however, as 19.6% and 18.3% of Americans and Chinese respectively, felt that science and technology will leave the world in a better place (World Values Survey). In Europe, the World Values Survey found similar values hold for the statement that 'Science and technology are making our lives healthier, easier, and more comfortable.' 25.4% of Swedish and 19.6% of Germans believed that, considerably more than the 14.9% of Spaniards and 13.2% of Dutch who felt that way. Interestingly, Europeans were slightly more inclined to believe that science and technology are making our lives healthier, easier, and more comfortable than Americans, although Chinese believed significantly stronger than Europeans or Americans that this is the case. These attitudes appear to matter as there is a strong positive correlation (0.44) between the extent to which a nation's citizens think that more emphasis on technology is good and their overall per capita GDP growth rate over the last decade (Atkinson/Ezell, 2012).

In conclusion, it's important to reaffirm that Europe remains a vibrant and robust center of global innovation. For instance, European research teams recently achieved the first landing of a space probe on a comet, which has already shed important light on the formation of the Earth, and led the discovery of a new fundamental particle, the Higgs Boson, which has provided critical information on the origin of the universe (MIT, 2015). Europe has also surpassed the United States in developing a medical device innovation ecosystem and its researchers and innovative start-ups are at parity or even ahead of American ones in a vast array of advanced-technology fields including pharmaceuticals, robotics, quantum computing, 3-D printing (additive manufacturing), nano-manufacturing, and other fields. But Europe's challenge will be to ensure that these technologies get developed not only by its leading industrialists, such as ABB, Siemens, or Philips, but also by young, innovative entrepreneurial firms that can be dynamic new economic and employment growth drivers for the European economy.

THE UNITED STATES' INNOVATION CULTURE

As in Europe, America's innovation culture is not monolithic. It has undergone significant change over time and continues to vary markedly within regions. Moreover, American's attitudes toward science and technology have changed significantly over the generations. This section examines the past and present of America's innovation culture.

THE EVOLUTION OF THE UNITED STATES' INNOVATION CULTURE

America's free-wheeling, entrepreneurial, creative innovation culture owes much both to its original Judeo-Christian heritage and to the pioneering frontier mentality that marked America's earliest settlers (coming from Europe), who as they moved westward relied on a self-sufficient, problem-solving spirit.

Indeed, Americans have long embraced both innovation and the inevitability of social and economic progress. For example, the stirring musical pageant 'Our Country 'Tis of Thee,' written by Walter Ehret in the 1950s, is filled with such optimistic statements as 'There was no stopping a nation of tinkers and whittlers, long accustomed to making, repairing, improving and changing,' and 'So when you're spellin' the word America, do not forget the 'I' for the inventors,' and 'Progress! That was the word that made the century turn.' This optimistic sense was reflected not just in story and song, but in the writings of intellectuals who saw technology as a powerful force for liberation and enlightenment. Economist Benjamin Anderson wrote in the 1930s, 'On no account must we retard or interfere with the most rapid utilization of new inventions' (Bix, 2000). America came to lead the world in innovation in part because it was willing to accept and embrace risk and change and then not over-react if there was a problem. As Robert Friedel, a technology historian at the University of Maryland, summarizes this mindset in *A Culture of Improvement: Technology and the Western Millennium*, '[b]y the middle decades of the twentieth century, the improvement of

technologies of all kinds appeared to be an imperative – political, social, economic, cultural – throughout the West, but particularly in the United States [...] Few agendas seemed clearer both to politicians and the public at large than the pursuit of technological promise’ (Friedel, 2010).

THE ROLE OF THE U.S. GOVERNMENT

But while America has cultivated the mythology of the ‘lone innovator making a breakthrough innovation in his garage,’ the reality is that the federal government has played a catalytic role in powering the U.S. innovation ecosystem, including as a funder of research and development (R&D), early procurer of innovative technologies, and source of innovations emerging from national laboratories. In fact, as ITIF writes in *Federally Supported Innovations: 22 Examples of Major Technology Advances That Stem From Federal Research Support*, the origins of many foundational technologies – such as wireless phones, supercomputers, search engines, artificial intelligence, gene sequencing, medical diagnostic and seismic imaging, and hydraulic fracturing – can be traced to at least an initial investment of U.S. federal R&D support and funds (Singer, 2014). Clearly, federal funding of research has helped drive American innovation and played a key role in enabling U.S. leadership in a host of advanced technology industries, from computer hardware, software, and aviation, to biotechnology, as ITIF writes in *Understanding the U.S. National Innovation System* (Atkinson, 2014).

To be sure, U.S. federal government support for innovation dates back to the beginning of the U.S. republic, when in the 1800s the U.S. Armories became the most advanced manufacturers in the country, producing gun parts to a level of standardization that made them interchangeable. Throughout the 1800s and into the early 1900s, the U.S. government played a pivotal role in supporting platform innovations such as the U.S. canal, transcontinental railroad, and telegraph systems and establishing the agricultural extension services supporting agricultural innovation. But it was the Se-

cond World War and the ensuing Cold War and Space Race that institutionalized the foundational federal role in U.S. R&D, resulting in remarkable advances in fields as diverse as electronics, information technology, jet aircraft, radar, atomic power, and life sciences.

After the Second World War, a more science-based system of innovation emerged in the United States, inspired in part by Vannevar Bush, director of the U.S. Office of Scientific Research and Development during the Second World War, whose seminal report ‘Science, the Endless Frontier’ laid out a vision of government funding of basic research in partnership with universities and industry (Isaacson, 2014a). As Bush wrote, the Second World War had made it ‘clear beyond all doubt’ that basic science – such as discovering the fundamental principles behind nuclear and particle physics, computer sciences, biologic sciences, etc. – ‘is absolutely essential to national security’ (Isaacson, 2014a, 219). As Bush wrote in ‘Science, the Endless Frontier’:

‘New products and new processes do not appear full-grown. They are founded on new principles and conceptions, which in turn are painstakingly developed in the purest realms of science. A nation which depends upon others for its basic scientific knowledge will be slow in its industrial progress and weak in its competitive position in world trade.’ (Bush, 1945)

As Walter Isaacson observes in *The Innovators*, Bush had outlined the so-called ‘linear model of innovation’ and his vision catalyzed ‘the creation of a triangular relationship among government, industry, and academia [that] was, in its own way, one of the significant innovations that helped produce the technological revolution of the late twentieth century’ (Isaacson, 2014). Bush played a key role in persuading Congress to establish America’s National Science Foundation, which became a key

funder of basic scientific research. Thus, the U.S. national innovation system post the Second World War became characterized by large, centralized corporate R&D laboratories (often receiving significant federal funding and performing significant amounts of basic scientific research) such as Bell Labs (which invented the integrated circuit) or Xerox's PARC lab, significantly increased federal funding for research universities, and substantial funding of a system of national laboratories. Military laboratories and research institutions such as RAND and DARPA (the Defense Advanced Research Projects Agency) also became key sources of military and civilian innovation (see box). Moreover, the U.S. government as the dominant purchaser of early generations of semiconductors, computing, and networking equipment supporting military priorities such as air defense systems and missile technology (both for nuclear defense and the space race) played a central role in driving price points for emerging computing technologies low enough that commercial business markets for computing technologies became feasible, catalyzing the global information technology revolution. Indeed, it was a succession of innovative integrated circuit manufacturers from Shockley Semiconductor to Fairchild Semiconductor to Intel (along with contributions from the Stanford Research Park and firms including Hewlett-Packard) that would transform the apricot and almond fields south of San Francisco into the world-famous Silicon Valley.

The Evolution of the U.S. Defense Advanced Research Projects Agency

The U.S. Defense Advanced Research Projects Agency (DARPA) was created by President Eisenhower in 1958 in the wake of the Soviet launch of the Sputnik satellite with the initial mission of 'preventing technological surprise' and later 'causing technological surprise' to America's enemies. DARPA's charter originally called for it to develop advanced technologies with both defense and commercial applica-

tion (although after 9/11, DARPA's focus has shifted to supporting the warfighter). DARPA played a catalytic role in developing the Internet, its ARPANET system being one of the world's first distributed computing networks. But as Erica Fuchs writes in 'Rethinking the Role of the State in Technology Development: DARPA and The Case for Embedded Network Governance,' in addition to its own research on advanced technologies, one of DARPA's greatest contributions to the U.S. national innovation system has been as a connector and amplifier of the disparate research activities occurring throughout America's research laboratories. As Fuchs writes, 'DARPA orchestrates the involvement of established companies with start-ups and academic experts, supports knowledge sharing between industry competitors through invitation-only workshops, provides third-party validation of new technology directions, and supports technology platform development.' Explaining how DARPA has played a key role in extending next-generation semiconductor development, Fuchs notes: 'As a central node to which information from the U.S. research community flowed, DARPA's program manager was able to recognize the potential of Si-Ge [silicon-germanium] technology, provide funding, coordinate research activities, and thus help launch a research effort that led to fundamental semiconductor breakthroughs, thus extending Moore's Law' (Fuchs, 2010).

America's strong academic-industry-government/military complex powered the United States to a world-leading economic and innovation position in the post-war era. But public attitudes toward the promise of science, technology, and innovation in the United States (as in Europe) began to sour in the latter half of the twentieth century. Particularly in the 1960s and 1970s, America's culture became less supportive of technology and innovation. Ironically, one only need visit the Smithsonian Museum

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in Washington, D.C., to see the trend on display. The Smithsonian was once known as the National Museum of History and Technology, but when Roger Kennedy became director in 1979, in a period when technology was equated with nuclear war and Three Mile Island, he dropped 'technology' from its name. While a symbolic deletion, it reflected the new attitude toward technology. Rather than celebrate it, the Smithsonian began to focus on 'the social impact of machines and technology' – code for technology's purported negative and disruptive effects (Atkinson/Ezell, 2012). After reviewing a 1994 'Science in American Life' exhibit, one commentator stated, '[t]here is not much on pure science or the thrill of scientific discovery, and there is a great deal on science's unintended consequences' (Thompson, 2001). New York University's Neil Postman summed up this view when he wrote, 'I think the single most important lesson we should have learned in the past twenty years is that technological progress is not the same as human progress. Technology always comes at a price' (Kompf, 2004).

AMERICA'S INNOVATION CULTURE TODAY

However, with those caveats aside, there's little doubt that America maintains the world's most vibrant (and well-financed) innovation culture. And there's no question that the San Francisco-Silicon Valley region – which covers approximately 2,000 square miles, contains three million people, and would be the world's nineteenth-largest economy if a country – comprises the world's most fertile innovation hub. That's why the *2012 Global Startup Ecosystem Report* ranked Silicon Valley the world's number one innovation ecosystem (Herrmann et al., 2012).⁴ Compared to start-ups in other ecosystems the report studied, Silicon Valley has 35% more serial entrepreneurs and

⁴ Tel Aviv, Los Angeles, Seattle, Boston, and New York rank second through sixth; and four European cities – London, Paris, Moscow, and Berlin rate in the top twenty.

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20% more mentors, while Silicon Valley start-ups raise 32% more capital than their peers across all phases of development and are 30% less likely to go after 'niche' markets (Herrmann et al., 2012). Rather, Silicon Valley start-ups tend to be 'born global,' in contrast to many European start-ups, which initially seek to service local, rather than global, markets.

Indeed, Silicon Valley boasts one of the most unique, difficult-to-replicate regional innovation ecosystems in the world. Silicon Valley is: 1) replete with five world-class research universities, five U.S. national research laboratories, and dozens of world-class corporate and private research institutions; 2) a half-century of intense federal R&D investment, with Santa Clara county in the heart of Silicon Valley receiving more federal R&D investment than any other U.S. county from 1950 to 2005; 3) forty percent of U.S. venture capital invested and seven of America's top ten VC investors; 4) six of the world's top ten ICT companies located within a ten-square-mile radius; and 5) a concentration of both advanced-degree holders and foreign-born start-up founders more than twice the national average (Ezell, 2014). In short, Silicon Valley has built a virtuous, self-reinforcing innovation system that attracts world-class, high-skill talent, reveres entrepreneurship, fosters a nurturing and mentoring community, and boasts successful companies that throw off entrepreneurs and capital that seed future generations of innovators.

But the take-away message for companies throughout the world not located in Silicon Valley – whether in America, Europe, Asia, or Africa – is simple: 'You don't have to be in Silicon Valley, but Silicon Valley has to be in you.' In other words, entrepreneurs and enterprises need to embody the spirit and values that guide the Valley. (There is, however, a trend that major companies from various sectors set up an 'innovation center' in Silicon Valley, in order to be closer to where the world of tomorrow is invented – and where their business model might be the next to be challenged, or worse, made obsolete.)

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It starts with the conviction that the role of the innovator is to stand in the future and imagine a vision of a world transformed. As Steve Jobs famously said, 'Only the people who are crazy enough to think they can change the world are the ones who actually do' (Apple, 1998). That was a take-off on Alan Kay's observation that the best way to predict the future is to invent it. But the key insight is that successful entrepreneurs, as so well embodied by the innovation culture of Silicon Valley, set radically ambitious goals. That's why Google declared that its animating mission is to organize all of the world's information and make it accessible and why Elon Musk, founder of SpaceX, has proclaimed his organization's mission as making human life interplanetary. Clearly, these are extraordinarily ambitious, risky goals. But as Larry Keeley, the Founder and President of the innovation consultancy Doblin observes, innovation is risky – but what is really risky is not innovating. And that's where the Valley's attitude toward failure comes in: recognizing that failure has value as long as it results in useful learning. As Drew Houston, the Co-founder of Dropbox notes, there is no need to worry about failure: One only has to be right once. As Luigi Caputo's article 'Fail Often and Fast: The Secret of Silicon Valley Success' notes, 'A positive view of failure is pervasive throughout Silicon Valley' (Caputo, 2014). As the article notes, 'Many entrepreneurs who have changed the world started from failure,' including Henry Ford, Richard Branson, Steve Jobs, Bill Gates, and Google's Sergei Brin and Larry Page (the latter of whom, after proposing a merger of the fledgling Google with Yahoo in 1998, were told 'to continue work on their scholastic project'). (Caputo, 2014). But the 'fail fast to succeed sooner' mantra is more than just a 'ra-ra chant' to embolden young entrepreneurs. Rather, as Peter Sims writes in his book *Little Bets: How Breakthrough Ideas Emerge from Small Discoveries*, a key insight of 'lean entrepreneurship' is rapid learning – placing early 'beta' versions of a product into a market, garnering customer feedback, and rapidly iterating design of the product, service, and software on a collaborative, co-creation basis with customers. This allows

companies to rapidly improve their product or service, while engaging 'venturesome consumers' who are likely to lead adoption of the product and service.

Another hallmark of the Silicon Valley innovation culture is 'design thinking'. In particular, this refers to the use of advanced social research tools such as ethnography, anthropology, and psychography to identify unmet or unarticulated customer wants and needs and to try to respond to them with innovative services. In other words, it's not enough to merely ask customers what they want; the best innovators invest time to discover underlying human needs that customers can't always articulate for themselves. Or, as Henry Ford said, 'If I'd simply asked my customers what they wanted, they would have said a faster horse.' In the late 1990s, when AT&T asked McKinsey to estimate the size of the global market for mobile phones, McKinsey estimated a global market of perhaps 1 million devices. Today, there are almost as many cell-phone subscriptions, 6.8 billion, as there are people on this earth, seven billion. To be fair, McKinsey's estimate was based on the technology and price point of the mobile device that existed at the time, but it missed the underlying human need for connection. (McKinsey's *faux pas* calls to mind the famous prediction offered by Thomas Watson, then-President of IBM, in 1943 that, 'there is a world market for maybe five computers,' again missing how fundamentally computers would change the global economy.) It was a similar kind of customer-needs based insight – that people want to control how we listen to our own music – that led Texas Instruments' co-founder Pat Haggerty to apply transistors to radios, Sony's Akio Morita to develop the Walkman, and Steve Jobs to invent the iPod. The point is that many of the best innovations spring from discovery-oriented, design-based, customer-focused explorations, and this is what Silicon Valley's innovation culture excels at discovering.

But innovative technologies and compelling products are not enough – they must be connected to an effective business model. Or as John Seeley Brown, the famed

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director of Xerox's Palo Alto Research Center (PARC) noted, successful entrepreneurial businesses must effectively simultaneously answer three questions: 1) Is it technically feasible? 2) Is it customer desirable? 3) Is it financially profitable for the firm? Or, as Walter Isaacson writes in *The Innovators*, 'Innovation requires having at least three things: a great idea, the engineering talent to execute it, and the business savvy (plus deal-making moxie) to turn it into a successful product.' As Isaacson quotes Nolan Bushnell, founder of Atari, the world's first computer-based arcade video game manufacturer, 'I am proud of the way we were able to engineer Pong, but I'm even more proud of the way I figured out and financially engineered the business. Engineering the game was easy. Growing the company without money was hard' (Isaacson, 2014).

Another essential element of both the Silicon Valley innovation ecosystem and historically the U.S. national innovation ecosystem has been its openness to welcoming high-skill, foreign-born talent (although admittedly this has abated in recent years as America has made it more difficult for foreign-born students to remain in America upon graduation). Nevertheless, the United States still maintains the allure to attract talent from all over the world that Vienna possessed a century ago. In fact, more than fifty percent of all Silicon Valley start-up companies have at least one foreign-born founder. There's actually another parallel between the Vienna of 1900 and Silicon Valley today, namely its interdisciplinary position at the intersection of art and science. Similar to Eric Kandel's observations about Vienna circa 1900, Piero Scaruffi argues that the success of Silicon Valley is not merely based on the factors usually attributed to it (e.g., defense R&D and procurement, funding from DARPA, Fred Terman's influence at Stanford, the creation of the Stanford Research Park, the discovery of the integrated circuit at Shockley Semiconductor, Xerox's PARC, or Apple's success with personal music and computing). Rather, Scaruffi argues that cultural factors play an equally important role. In particular, he notes the influence of eccentric artists and writers

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who came to the Bay Area in the 1950s and before, the mindset of the student protests, and the hippie culture that spawned the Summer of Love, the first 'Earth Day' (1970) and Gay Pride Parade (1970), the Survival Research Labs (1978), and Burning Man (1986).

Specifically, Scaruffi argues that the first major wave of immigration of young educated people from all over the world to Silicon Valley took place during the hippie era, and that the first major wave of technology was driven by the independents, amateurs, and hobbyists, for whom an anti-corporate and even anti-government sentiment existed. (This was the theme of Steven Levy's book *Hackers: Heroes of the Computer Revolution*, which noted that many of the later-exalted innovators of the Valley, including Steve Jobs and Steve Wozniak at Apple, started off as curious technology hackers [Levy, 2010].) In Silicon Valley, that mindset empowered young, educated people to seek to change the world with disruptive products. Scaruffi also points out that the famous culture of failure, the reward of success, and the casual work environment in Silicon Valley stem from the artist's way of life (Scaruffi, 2014). In a like manner, as Walter Isaacson, author of the books *Steve Jobs* and *The Innovators*, emphasized at a 2014 lecture for the National Endowment for the Humanities, the best innovators are the ones who stand at the intersection of sciences and the humanities and 'can connect the arts to the sciences and have a rebellious sense of wonder that opens them to the beauty of both' (Isaacson, 2014).

It would be a mistake to instantly equate the innovation culture that exists in Silicon Valley to all of America. Indeed, America would be a far more innovative country if the Valley's mantras were embraced in all corners of the United States, in not just its emerging technology industries but also in its traditional manufacturing sectors such as automobiles and in the government agencies and departments that account for an increasing share of America's GDP. Nevertheless, there is something unsailably distinct about America's innovation culture. As John Randt, a Senior Fellow

at the America Council summarizes, ‘American innovation is the product of two indispensable ingredients: The indomitability of the American spirit to solve problems – a quality necessary to overcome the repeated failure upon which all great discovery and creativity is based – together with our system’s exquisite interplay of free market competition and collaboration’ (U.S. Chamber of Commerce, 2013). Or, as Bret Swanson, the President of Entropy Economics frames it, ‘[t]he essence of American innovation is creative entrepreneurship. Innovations come from garages, corporate labs, and even government research centers. Our open system, built on a foundation of a few basic rules, allows and encourages individuals to create the future’ (ibid.).

HOW INNOVATION CULTURES TRANSLATE INTO INNOVATION RESULTS

Economies are successful when their businesses thrive, and when their entrepreneurs turn ideas into businesses. So how do American, and European – but also Asian – companies fare in this regard? To be sure, Europe fields some of the world’s most competitive economies. According to the World Economic Forum Global Competitiveness Index 2014, the United States (3), along with several central and northern European states – Switzerland (1), Finland (4), Germany (5), Netherlands (8), UK (9), Sweden (10) – and three Asian nations – Singapore (2), Japan (6), Hong Kong (7) – were the ten most competitive economies in the world (Schwab, 2015).

However, Europe fares less well at seeding high-potential, fast-growing technology start-up companies. For instance, on *Fast Company*’s list of the sixty ‘World’s Most Innovative Companies in 2014,’ forty-two are American, eight hail from Asia, and only two, Shazam and Philips, are European (Safian, 2014). But this may reflect the American bias of the publisher. European innovators fare much better on *Forbes*’ 2014 list of ‘The World’s Most Innovative Companies.’ While American-based enter-

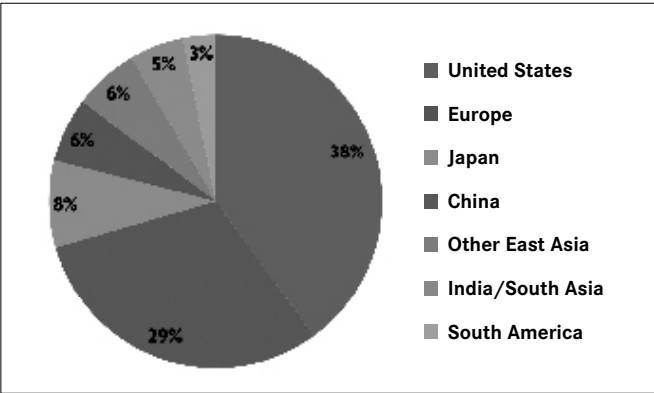


FIGURE 6

Location of *Forbes*’ The World’s Most Innovation Companies, 2014 (*Forbes*, 2014)

prises claim thirty-eight percent of the Top 100 innovators in 2014 on *Forbes*’ list, European innovators claim twenty-nine percent, with Pacific Rim nations accounting for twenty percent (six percent of which are Chinese), as Figure 6 shows (*Forbes*, 2014).

The U.S. also leads the Bloomberg Businessweek Tech 100, which ranks the world’s leading technology companies, accounting for forty-four percent of the world’s top technology companies (Bloomberg Tech 100). Asia follows with thirty-four percent of the leaders, including eleven from Japan, eight from China, eight from Taiwan, six from India, and three from Singapore. Only seven of the global top 100 high-tech companies are headquartered in Europe (three in the UK, three in Germany, and one in Belgium), while South America fields six (five in Brazil and one in Argentina). These statistics should be concerning for European policymakers. As the consulting firm AT Kearny concurs in its report, *Rebooting Europe’s High-Tech Sector*, ‘our research over the past few years has demonstrated, Europe’s high-tech sector is declining,’ which is troublesome because ‘Europe’s global competitiveness depends on a vibrant high-tech sector’ (AT Kearny, 2014).

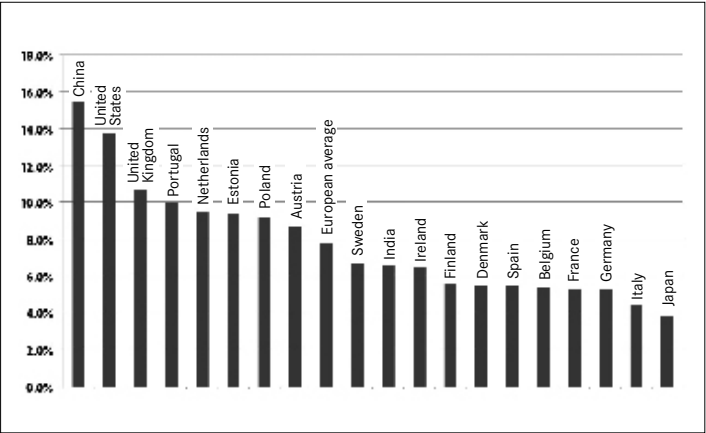


FIGURE 7

Early-stage entrepreneurial activity (% population aged 18-64) (Singer, 2015)

Unfortunately, the data shows that Europe still has a problem creating new businesses destined for growth (The Economist, 2012). According to the 2014 Global Entrepreneurship Monitor, the Total Early-Stage Entrepreneurship Activity rate (which measures the percentage of individuals aged 18-64 in an economy who are in the process of starting a business or are already running a new business, not older than forty-two months) shows both China and the United States leading Europe in entrepreneurial activity (Singer et al., 2015). Both China's early-stage entrepreneurial activity rate, at 15.5%, and the United States' at 13.8%, significantly outstrip the European average at 7.8%, and even Europe's most industrious entrepreneur, the United Kingdom, at 10.7%, as Figure 7 shows.

Encouraging the formation of more young, innovative, entrepreneurial high-tech start-up companies must be a central component of European policymakers going forward.

CONCLUSION

This article has demonstrated that cultural aspects have a significant impact on innovation and inform how entrepreneurial countries, organizations, and people can be. The United States maintains the world's most vibrant innovation culture, where risk and failure are broadly tolerated, inquiry and discussion are encouraged, and the government's role in business plays a less prominent role ('The U.S. is not a country, it's a business', Dominik, 2012) and science and technology – though perhaps not all their consequences – are broadly embraced. American culture rewards success. These ingredients have contributed to the rise of fifty-two new large companies in the United States over the past sixty years, compared to Europe's twelve, as well as America's being the home of many of the world's most innovative entrepreneurial companies today.

The picture is more nuanced in Europe. There certainly is no innovation pinnacle such as Silicon Valley, which attracts the world's best and most ambitious entrepreneurs to start disruptive companies, where they find seemingly abundant risk capital from serial entrepreneurs to finance their potentially market-disrupting (or sometimes just crazy) ideas. But there is excellent science, there are ambitious entrepreneurs who start businesses (though perhaps not enough), and there are global industry leaders, particularly in the automotive, energy, chemical, life sciences, robotics, and machine tool and equipment industries. However, there are elements in the European innovation culture that need improvement: a simpler regulatory environment, a broader availability of risk capital, and more tolerance of risk and change being critically important.

Europe is clearly lagging the United States in risk capital, which has allowed the United States to quickly grow some of its young firms into global leaders. Also, if start-ups are financed through risk capital, bankruptcy aspects are less prevalent, because they don't have to take out loans from inherently risk-averse banks, which will lend

you money if you can prove that you don't need it (Bob Hope) or if you bet your house, which if you lose when the companies fails, stigmatizes the entrepreneur further. According to the Global Entrepreneurship Monitor (GEM), the 'usual suspects' of social norms in Austria that inhibit founding activities are: the lack of risk tolerance, the lack of entrepreneurial thinking, and the fear of failure. However, between 2007 and 2012 the GEM observed a marked improvement in Austria's innovation culture (Dömötör/Fandl, 2014). If formerly closely linked markets became fragmented after 1918 and World War II, thus making Europe more risk averse, then the reopening of borders after 1989 offers an opportunity for a renaissance of (Central) Europe to position itself as one of the world's preeminent innovation hubs – as was the case at the turn from the 19th to the 20th century. Vienna and Berlin are regaining their traditional position as hubs between Eastern and Western Europe and magnets for talent from Europe and beyond. In fact, thirty-seven percent of entrepreneurs in Vienna are foreign-born (Dömötör/Fandl, 2014), underscoring the entrepreneurial spirit that immigration stimulates. Entrepreneurship is infectious and contagious – not only in the U.S., but also in Europe.

Finally, it's important to note that policymakers on both sides of the Atlantic can play an important role in stimulating an innovation culture in their nations. They can do so first by implementing a policy environment – including financial market, education, tax, competition, regulatory, and labor policy – that supports innovation. They can do so by ensuring that government agencies themselves adopt and embody innovation methods and principles and become early adopters and procurers of innovative technologies. And they can do so by designing a trade agreement in the Trans-Atlantic Trade and Investment Partnership (T-TIP) that creates the conditions by which innovative industries can flourish on both sides of the Atlantic (Wein/Ezell, 2013).

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STARTUP CULTURES. A COMPARISON OF THE GROWING IMPORTANCE OF HIGH-TECH STARTUPS IN AUSTRIA, ISRAEL AND KOREA

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INTRODUCTION

The startup boom has reached a new high. According to *The Economist*, the global importance of startups for the economy and for society has grown continuously over the last few years (The Economist, 2014b), while the World Startup Report states that in 2013 well over 140,000 startup companies were founded worldwide.

In recent years, Austria has been relatively successful at founding innovative startups, but by international standards it still lags behind, as is made clear by every available study and analysis (Binder, 2015; AustrianStartups, 2014; SpeedInvest, 2013). Thanks to a series of initiatives, Vienna in particular can be considered a European startup hub (PGM, 2014), but in an international context the situation is rather more complex. The US has a long-established startup culture, particularly in Silicon Valley, so it is hardly surprising that in absolute terms more startups are located in the US than in any other country (The Economist, 2014c). For this reason, this article will focus, not on the US, but on two global innovation leaders whose startup economies have been much talked about in recent years, namely Israel and Korea.

Relative to its population and size, more startup companies are founded in Israel than in any other country (Senor/Singer, 2012). According to *The Economist*, Israel has 375 startup companies per million inhabitants, compared with 190 in the US (The Economist, 2014b), a consequence of the uncertain geopolitical situation, which leads to a greater willingness to take risks, and of the large numbers of technologically skilled immigrants who are given government support to start their own businesses.

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Korea is also characterized by a very dynamic startup culture and is considered one of Asia's main startup hubs (Millard, 2014). According to the *Süddeutsche Zeitung* of 9 January 2015, it has more startups per capita than any other country, a function of its technophile culture and of public and private support resources, funding and investments.

Since Israel and Korea rank among the global innovation leaders (Austrian Council for Research and Technology Development, 2014), the Austrian Council for Research and Technology Development visited both countries to gain a broader knowledge of their RTI systems and startup cultures. A delegation travelled to Korea in November 2013 and to Israel in June 2014. The insights gleaned from these visits form the basis of this article.

For the purpose of this article, startups are defined as young companies that are not yet well-established, founded with low startup capital and the aim of implementing an innovative business idea (often in the area of e-business, communications technology or life sciences). They are generally dependent at a very early stage either on receiving venture capital or seed capital (possibly from business angels) or on floating on the stock market in order to expand their business and strengthen their capital base (Gabler Wirtschaftslexikon, 2015).

We shall first sketch out the situation in Austria and then describe the startup cultures in Israel and Korea, attempting to provide a brief account of the most outstanding characteristics of each system. The final section of the article will describe the main conclusions to be drawn from these case studies and outline the potential implications for Austrian RTI policy.

AUSTRIA

CHARACTERISTICS OF THE RTI SYSTEM

Measured by macroeconomic performance variables, Austria does very well against the global competition. Compared with other countries, Austria has a high employment rate and rising prosperity. In the category of per capita income, Austria ranks third in the EU and eleventh worldwide (IMF, 2014). At 1.5% since 2000, Austrian economic growth has been well above the Eurozone average and almost equal to that of the US.¹ This growth is accompanied by relatively low income inequality by international standards (as measured by the Gini coefficient), high environmental standards, and high life expectancy (as measured by the OECD Better Life Index). There are several factors behind these positive developments. Undoubtedly, the two most important ones are the internationally competitive manufacturing and tourist industries, which support numerous innovative small and medium-sized enterprises, and Austria's return to the dynamic centre of Europe after the fall of the Iron Curtain (Aiginger, 2013; Keuschnigg et al., 2014). In addition, it should also not be forgotten that Austria's performance in science and technology has been improving steadily since the 1980s. A variety of analyses credit the Austrian RTI system with a constantly improving performance (Austrian Council for Research and Technology Development, 2015). However, this success should not distract from the fact that, for all the headway it has made, Austria is still in the group of innovation followers; there is a performance gap between it and the group of innovation leaders (European Commission, 2015).

¹ This positive development was mainly due to exports, which have risen by 3.5% since 2000. Since imports rose rapidly, the budget deficit from 2000 to 2013 could be transformed into a surplus of € 10.5 billion. This was above all due to the rise in exports to Central and Eastern European countries as well as to the US and Asia (Aiginger, 2013, 22–38).

With the declared aim of becoming a member of the group of innovation leaders, the Austrian government has adopted a Strategy for Research, Technology and Innovation (2011), but despite this clear objective, the country is treading water or even falling behind compared with its European competitors, as a number of international rankings make clear (Austrian Economic Chamber/WKO, 2014). In-depth analysis of the Austrian RTI system by the Council for Research and Technology (2015) clearly reveals the reasons for this gap. The education system performs well below its potential, hampered by high social selectivity and sub-optimal quality. Although scientific output is of above-average quality, the resources for competitive funding of basic research are far below the levels of leading countries like Switzerland, Sweden or Germany, something which is likely to have a negative impact on research performance in the longer term. From the perspective of this article, the problems that hamper the Austrian RTI system mostly have to do with the conditions under which business startups operate; compared to other countries, the number of startups in science and technology-intensive areas is far below Austria's evident potential. The blame lies partly with certain specific regulations, which evidently impede startups, and partly with a lack of venture capital and private investment in research and development. To address the second issue, RTI policy has recently initiated a package of measures to improve the legal and economic framework for philanthropic grants, donations, trusts and funds, and private risk financing. However, the implementation of this package has not yet taken effect and its actual impact remains to be seen.

SPECIFICS OF THE STARTUP CULTURE

The percentage of self-employed individuals in Austria (WKÖ 2013) is well below the EU average (8.8% as compared to 12.5% for EU28, not including agriculture), and the number of startups has stagnated since 2009 and is still well below its previous

level. From 2009 onwards, roughly as many businesses have folded as were founded (Statistics Austria). Self-employment is therefore not a particularly attractive prospect for Austrians, even though there have been considerable improvements in the startup environment in recent years. A number of private initiatives – in part with public funding – exist to help businesses survive the tricky startup and market development phase. The Pioneers Festival is a supra-regional event for presenting startups. Business angels, business incubators, co-working spaces, startup events such as Start-Up Live or Startupweekend, training and workshops all contribute to a lively startup scene. Ventures Almanach Austria provides a good overview of the various investments, investors, training, incubators and co-working spaces (Inventures, 2015).

There are also evident efforts to communicate the interests of this group more clearly to politicians and to set up something like a professional association, e.g. austriantstartups.org (see Binder, 2015, 87f.). A key issue is the perception of startups in the media, including TV programmes illustrating investment in startups, but also in publications and companies specializing in this sector.

Regardless of the strengths or weaknesses of the startup ecosystem in Austria, the country quickly becomes too small for startups to thrive, or even actively impedes them. The lack of venture capital, inadequate understanding of the problems startups face, and lack of demand soon force companies to internationalize or even relocate. Wutscher and Witzani (2014) report on over 200 startups that have moved abroad as a result of these factors. Naturally this represents a loss for the companies' original location, but it also indicates the willingness of entrepreneurs to take any steps necessary to ensure the survival and growth of their businesses.

For years, startups have been a subject of increasing importance in the political sphere. As always when a new field opens up, the resulting mood of optimism leads to a rather uncoordinated occupation of this 'new' territory by government-related

institutions and funding bodies, all searching for the 'funding gap', which means that new programmes can be introduced or old ones extended, thereby consolidating or increasing the influence of the ministries and related institutions. However, this approach rarely leads to structural change but rather to the depletion of existing possibilities. A relatively broad spectrum of funding programmes for new young companies has sprung up, ranging from incubation and the promotion of new talent to market launches.

At the federal level, funding is dominated by the the Austrian Research Promotion Agency (FFG) and the Austria Wirtschaftsservice GmbH (AWS). The FFG focuses mainly on funding innovation projects, while the AWS concentrates more on companies' financing needs and growth. A whole series of other institutions also concern themselves with the needs of startups.

The evident deficits in the Austrian startup ecosystem are often reduced to the lack of venture capital. The funding system attempts to address this acute shortage of venture capital, above all via the AWS Start-up Fund and the AWS Business Angel Fund:

- The Start-up Fund was established in 2013 (with a thirteen-year lifespan) and has resources of € 68.5 million. It provides startups with venture capital and invests in both the startup and initial growth phase of companies located in Austria. The sums invested are between € 100,000 and € 3 million. Returns on investment are ploughed back into other startups.
- The AWS Business Angel Fund implements the idea behind the European Angels Fund in Austria, together with the European Investment Fund (EIF). The fund doubles the investment of selected business angels; the financing achieved can add up to € 45 million (standard amount: € 22.5 million).

In spite of this government support, the actual amount invested has declined considerably in recent years. According to AVCO, the Austrian Private Equity and Venture

Capital Organisation (2014b), investment totalled € 154.6 million in 2012, but in 2013 it sank to € 88 million. These sums financed 130 companies in 2012 and 121 in 2013.² Although there is only a modest amount of venture capital available in Austria, one category of investment is showing encouraging signs. When it comes to early-stage investment, Austria does manage to equal the European average. This is primarily due to the public investment funds mentioned above, but also to the willingness of investors to finance this segment.

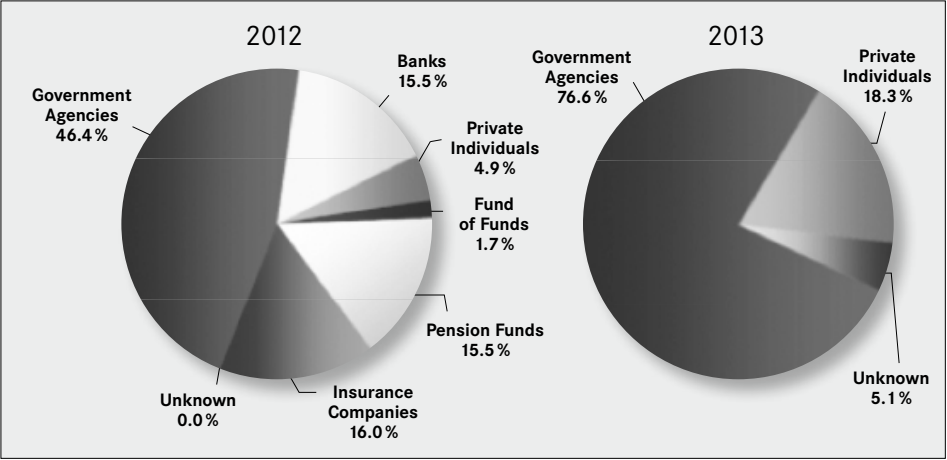
Austria has suffered a dramatic setback in funding, however, which declined from € 172.8 million in 2012 to € 19.8 million in 2013. The decline was caused by the fact that banks, pension funds and insurance companies put a complete stop to their investment activities (see Diagram 1). However, there was also significantly less funding available from public bodies, approximately € 80 million in 2012 dropping to a mere € 15 million in 2013. This means that government-related institutions accounted for more than three-quarters of the funds raised.

This development runs counter to international trends. Globally, venture capital reached a record high in 2014 (EY, 2015). The dramatic decline in funding in Austria is the result of new regulations (for example, Basel III), the absence of a private equity law, restrictive implementation of European regulatory guidelines, and the absence of a legal structure for venture capital funds (see Improveo et al., 2012).

The lack of venture capital makes the new possibilities opened up by crowdfunding seem like a lifeline. A new crowdfunding law passed in April 2015 has created a much more modern and liberal framework for crowdfunding. A capital market prospectus is only necessary with a total investment of € 5 million or more. For lesser sums,

² Ernst and Young announced an investment sum of merely € 7 million for 2014. As a result, in 2014 there were only seventeen investments in eleven financing rounds. Whether the decline from 2013 to 2014 is real or the result of differences in survey construction between EY and AVCO is an open question.

DIAGRAM 1 Venture capital funding sources in Austria in 2012 (left) and 2013



Source: AVCO, 2014a.

the company or project that is seeking investors only has an obligation to provide information. The maximum commitment per investor was also raised, depending on income. Despite the previously highly restrictive environment in Austria, there are a number of crowdfunding platforms that cover the various investment models (Gumpelmaier, 2015).

Along with activities at the federal level, cities and regions are starting to play a role in the funding of startups. The efforts of the City of Vienna are noteworthy here. Via the medium of the Vienna Business Agency, they are attempting to improve the ecosystem for startups in Vienna. Tyrol is also in the process of creating an interesting ecosystem. Current deficits are being actively addressed, private initiatives strengthened, and interaction within the system encouraged. Inventures (2015) provides an overview of these regional structures.

ISRAEL

INTRODUCTORY DESCRIPTION AND CHARACTERISTICS OF THE RTI SYSTEM

Israel is one of the wealthiest and most innovative countries in the world. With an average per capita income of around US\$ 37,000, it ranks twenty-fifth on the International Monetary Fund's Economic Outlook Database (2014). By comparison, Austria ranks eleventh with US\$ 48,957. In the years before the global economic and financial crisis, Israel's economic growth was consistently above 5%, and since the crisis it has hovered between 3% and 4% (World Bank, 2015). Of the 187 United Nations member states on the Human Development Index, Israel has held sixteenth place since 2011 (UNO, 2014) and is thus one of the forty-seven members of the group of 'very highly developed states'. Austria comes eighteenth on the Human Development Index. Israel's innovation performance is particularly impressive. According to the Innovation Union Scoreboard (2014), it is one of the group of 'innovation leaders', outperformed only by Switzerland, Sweden and Finland (Erawatch, 2014, 2). With a civilian R&D rate of almost 4%, Israel occupies a leading position globally (OECD, 2015; World Bank, 2015). Nowadays this is largely due to the innovative and dynamic private sector, which covers around 80% of all R&D costs. Public funding provides about 10%, with the remainder coming from foreign investors.

The government's current strategic focus on funding RTI activities foresees a significant increase in the proportion of public sector funding, leading to a relative decline in private sector funding. Even so, the corporate sector's contribution to the R&D rate will still be higher than in comparable countries for the foreseeable future. With well-qualified personnel and excellent research performance, some of the leading scientific research institutions worldwide, such as the Weizmann Institute of Science, provide the foundation for an increasingly knowledge-based economy (Erawatch, 2014, 17f.).

The medium and high-tech sector is now responsible for nearly half of all exports (The Economist, 2010), even though the main focus of the Israeli economy was on agricultural production until well into the 1960s (Wolffsohn, 2007, 420 ff.). Oranges and other citrus fruits played a particularly important role; at times, their share of exports constituted up to 60% of the GNP. Even today, citrus fruits are still Israel's main agricultural export, but they constitute slightly less than 3% of the GNP. Thanks primarily to targeted government initiatives and an innovative corporate sector, large-scale structural change has taken place since the early 1990s. What used to be an agriculture-based developing country has transformed itself into a 'high-tech nation' (The Economist, 2010; Die Presse, 2014). The Israeli RTI system is still very new. Crucial governance structures and institutions were only established after the founding of the state of Israel in 1948. Nevertheless, despite its relative youth, Israel's RTI system is very competitive and high-performing (European Commission, 2013). Numerous innovation rankings place Israel among the top nations, or at the very least in a respectable mid-table position. Israel is ranked twenty-fourth (and Austria twenty-second) in the World Competitiveness Yearbook of the International Institute for Management Development (2014), and fourteenth on the INSEAD Global Innovation Index (2014), whereas Austria ranks twenty-second.

SPECIFIC CHARACTERISTICS OF ISRAELI STARTUP CULTURE

The Israeli business sector is very dynamic and innovative (European Commission, 2013). Not only does it provide the bulk of R&D spending – over 80% – but it is also an increasingly important employer. Although only around 10% of employees work in high-tech industries, the proportion of researchers, technicians and engineers is one of the highest in the world at 18 per 1000 employees (Erawatch, 2014, 17f., OECD, 2015). In the US it is 8.5, the EU average is 4.6, and the Austrian figure is around 10. The business sector also produces a higher-than-average number of patents:

with 2.5 triadic patents per researcher, Israel leads the international patent statistics ahead of Japan and Germany (Erawatch 2014, 17).

Israel's outstanding feature is the high level of startup activity (Senor/Singer, 2012). Israel has more high-tech startups founded and a higher per capita venture capital intensity than any other country in the world (The Economist, 2014b). Tel Aviv, its surrounding regions and the so-called Silicon Wadi constitute the second-most attractive technology and startup region in the world, second only to Silicon Valley (Die Presse, 2014; Forbes, 2013; Wirtschaftswoche, 2012). It is therefore not surprising that, with over 200 businesses, Israel has more companies listed on the US technology stock market NASDAQ than any other country, more than Europe, Japan, China and India taken together (Die Presse, 2014). Relative to its population size, two-and-a-half times as much venture capital is invested in Israel as in the United States, thirty times as much as in Europe, eighty times as much as in China and 350 times as much as in India (Erawatch, 2014, 19f.).

Rapid population growth through immigration is often cited as the reason for the startup boom in Israel (Senor/Singer, 2012). In the 1970s, several waves of immigration, in particular from the former Soviet Union, led to a massive influx of scientifically and technologically well-qualified people. In total, Israel took in around a million former Soviet citizens. Immigration on such a massive scale naturally poses great challenges for a small country, given not only the need to provide enough housing but also to resolve the issue of how the labour market can absorb these immigrants. The mentality of the immigrants undoubtedly contributed to the creation of the startup nation (Senor/Singer, 2012). They were often ambitious and aspired to build up a livelihood; and because they generally arrived with little or nothing to lose they were willing to take greater risks. This phenomenon has also been observed in Silicon Valley (Sturgeon, 2000).

Politicians soon recognized the potential that lay in these well-qualified immigrants and began to roll out specific subsidies and support measures. Only then – as most

experts today agree – did the startup nation begin. A crucial factor was a programme set up at the end of the 1980s to help young entrepreneurs finance startups and to provide specific know-how about the process of founding a company. Over the years, this programme was expanded and is known today as the 'Technological Incubators Program'. The incubator programme was explicitly created for the Russian immigrants described above to capitalize on their diverse scientific and technological backgrounds and their specialized know-how. The concept behind it was to enhance the immigrants' latent potential by helping them to start up companies. Right from the start, the programme was administered by the Office of the Chief Scientist (OCS) of the Ministry of Industry, Trade and Labour.³

The main aim of today's Technological Incubators Program is to take innovative technological ideas considered too risky by private investors and to transform them into viable startups. If these startups successfully complete the two-to-three year programme, they are able to raise money from private investors themselves and to face the challenges of the market (Erawatch, 2014, 14.). There are currently 24 incubators scattered throughout the country, including – quite deliberately – the peripheral regions. The Office of the Chief Scientist is responsible for the entire process. It has an annual budget of around € 500 million and fifty employees. Each incubator has a small, on-the-ball team of experts in various fields. The aim is to provide a creative ecosystem for startups.

Companies accepted for participation in the programme receive US\$ 600,000 over a period of approximately three years. 85% of this comes from the government, the remaining 15% must be raised by the company itself. Around 200 to 400 entrepreneurs apply to each incubator every year. A crucial aspect of the programme is that the incubator does not merely provide financial support but also expert advice.

³ See <http://www.incubators.org.il/>

A further explanation for Israel's successful startup culture is the role of the Israeli military (Senor/Singer, 2012). The Israeli army purchases advanced technologies and acts as an important contact network. It also runs its own research and development facilities which recruit from among the best university graduates. Because of compulsory military service, almost every Israeli citizen serves in the army for three years. Informal connections are forged, which later in a business context allow for a much quicker process of establishing cooperation, alliances and startups. However, in Saul Singer's view, the role of the military is not necessarily something other countries should aspire to emulate (futurezone, 2014).

KOREA

INTRODUCTORY DESCRIPTION AND CHARACTERISTICS OF THE RTI SYSTEM

The rise of South Korea has been remarkable. In the 1960s, it was still one of the poorest countries in the world. According to the OECD, Korea is one of the few recent examples of an agricultural society successfully transforming itself into a leading global industrial nation (OECD, 2014, 32). This transformation is, of course, all the more striking given that at the beginning of the 1950s the Korean War destroyed almost all of the country's infrastructure, and the pro capita income was less than US\$ 100. Today, the Republic of Korea is Asia's fourth-largest economy. In terms of gross domestic product, South Korea's economy ranks fifteenth globally, and it is the ninth-largest exporting nation. The balance of trade over the last ten years has always been positive. In 2014, the GDP per capita was approximately US\$ 24,329 (IMF, 2014), putting Korea among the top thirty countries worldwide.

Korea is extremely densely populated, with around 50 million inhabitants in an area not much bigger than Austria. Its geography – 70 % of Korea's territory is mountainous terrain – made it impossible to rely exclusively on agriculture. The country has

hardly any natural resources, so the focus has had to lie on industrialization. Well into the 1990s, the strategic focus of seven consecutive economic five-year plans was on industrial development, including reforms in areas such as education, research, technology, infrastructure, trade, etc. (OECD, 2014, 32).

A central component of this strategy has been the development of an efficient and effective RTI system (OECD, 2014, 35). The strategy has been very successful – up to a point. Korea's RTI system is still relatively young but extremely dynamic. Various global innovation indexes place the country in the top ten (DIW, 2014, IMD 2014; INSEAD, 2014). The research-spending ratio is currently just over 4 % (4.03) and should reach 5 % by 2018. This puts the country in a position that even globally top-ranking innovation countries such as the US and Switzerland have not attained (Erawatch, 2013, 4). Research is mainly conducted by large business conglomerates known as *chaebols* – the Korean term for the vast, multinational, family-owned businesses typical of Korea, which have had a lasting impact on the country, its economic development and its social structure over the last fifty years. Together, the four largest companies (Samsung, LG, Hyundai, SK) account for around 60 % of research spending. The private sector as a whole accounts for well over 70 % (Erawatch, 2013, 17).

With this strategy, Korea has successfully caught up with the leading innovation nations on the global market. However, it is now becoming increasingly clear that the strategy has reached the limits of its usefulness, and a greater orientation towards a front-runner strategy is necessary. In 2013, this challenge was directly addressed by the 'Creative Economy Plan' whose goal is to make even greater economic capital from Korea's creativity and imaginativeness. More than ever, science, research and technology are to be the driving forces behind the economic development of the country, turning Korea into a knowledge and innovation-based economy (OECD, 2014, 193ff.). This naturally includes the creation of favourable conditions for startups (OECD, 2014, 135ff.).

SPECIFIC CHARACTERISTICS OF KOREAN STARTUP CULTURE

'If you could digitalize beer, the Koreans would be the first to produce and market it,' an international observer recently said of the Korean startup scene, which has developed in a few short years into a centre for innovation and market capitalization.⁴ *Forbes* (*Forbes*, 2014), for instance, predicts that Korea will be the next global high-tech startup hub. Relative to its population size, Korea already has the largest number of high-tech startups in the world (*Süddeutsche Zeitung*, 2015).

The Korean startup boom is primarily the result of a new political policy. The government has long sought a way to loosen the stranglehold of the *chaebols* (see OECD, 2014, 32ff.). Korea still lacks successful small and medium-sized enterprises of the kind typically found in many Central European countries. This weakness has long been recognized, but it was only possibly to tackle it once governmental policy changed, and in particular once the current president, Park Geun-hye, took office (*The Economist*, 2014a).

Central to this new policy is the political will to make changes and achieve the stated aim of applying to Korea the lessons learned from the success of Silicon Valley in the US. To this end, the Ministry of Trade, Industry and Energy has invested around US\$ 2 billion a year in Korean startups since 2013. In January 2015, it was announced that an additional budget of US\$ 400 million would be made available for developing and marketing new and innovative products and technologies, of which a third is earmarked for industrial growth engines such as drones, autonomous cars and smart wearables. The Ministry's goal is to accelerate the structural changes that have already begun, and to create a broader basis within the economy. A further aim is to increase the export of goods and services – even though Korea's exports recently reached a record high of US\$ 573 billion.

⁴ J.H.N. Zinsmeister, personal communication.

At the same time, the citizens of Korea are being urged to establish startups themselves. In the past, Korean graduates mostly aspired to work for a *chaebol* like Samsung or Hyundai. Nowadays a realistic and attractive alternative start to a successful professional career is working for a startup company or becoming a successful entrepreneur oneself.

This trend is most advanced in the capital, Seoul, which, as one of the most technologically networked cities in the world, has an excellent chance of becoming an international startup hub. Gangnam, probably Seoul's most famous district, has become a particularly fashionable centre and contact point for startups (*Financial Times*, 2012). Google plans to open its first Asian campus in this chic district, and it is here that the Korean internet giant Naver's first startup incubator will open in 2015. Gangnam is said to combine the best of New York City with the best of Silicon Valley (Lee, 2014). Moreover, the Korean government plans to turn Gumi, a city south of Seoul, into another rival of Silicon Valley. Here the startup scene is at its liveliest, with a startling growth rate (*Süddeutsche Zeitung*, 2015).

As discussed above, state support for startups in their early stages has been essential to the success of the Korean boom. This support includes startup-friendly market regulations, fiscal resources specifically earmarked for SMEs and startups, advisory services, and an incubator network (OECD, 2014, 141ff.) Over the next three years, the Korean government will invest over US\$ 3 billion in the startup market. Special mention should go to the 'Tech Incubator Program for Startups' (TIPS) which offers startups a complete package of support from finance to mentoring in their first two to three years.⁵ TIPS is explicitly modelled on the Israeli incubator programme (*The Wall Street Journal*, 2014). It increases fivefold any sum privately invested up to a maximum of US\$ 500,000. An array of government and private platforms and angel

⁵ Siehe <http://www.jointips.or.kr>

funds are also available, run with minimal bureaucracy and hence easily accessible even for inexperienced entrepreneurs. Korea's Small & Medium Business Association (SMBA) plays a key role here. SMBA certifies startups for venture companies, which in turn can take advantage of tax breaks and loan guarantees by the government.

The SMBA recently expanded its activities to Denmark, where it established five startups with the support of the Danish embassy. Denmark is seen as a gateway to Europe because of its transparent economic structure and openness to innovation. The SMBA has selected two Danish accelerators: Startupbootcamp and Scion DTU. Government support in the form of loan guarantees has led to increased investment from the US. Yellow, for example, was able to secure a \$100 million investment from the Silicon Valley-based venture capital company Formation 8. Internationally known accelerators include SparkLabs, Kstartup and FT Accelerator, while other investors in this development are Kcube, Bon Angels and SoftbankKorea. Foreign investors are increasingly recognizing the chances offered by the Korean startup market and setting up their own funds, like Altos Ventures and BlueRun Ventures.

These public and private funding measures in support of startups were not the only factor behind the startup boom. Particular social conditions also had to prevail. In this respect, hardly any other country offers such advantageous conditions for startups and young entrepreneurs as Korea. Of the 25 million inhabitants, approximately half live in Greater Seoul, where well over 80 % of the population have a smartphone. Internet connection speed throughout the country is 50 MB per second. The Koreans' delight in convenience in every sense is also a major factor: their ideal would be 100 % self-organization by smartphone. The result is that there is hardly a nation quicker to accept new technology than the South Koreans (Süddeutsche Zeitung, 2015).

CONCLUDING REMARKS

As mentioned in the opening section of this article, the US – and Silicon Valley in particular – is generally regarded as a role model for the creation of a flourishing startup culture. Its key advantages are a willingness to take risks and the fact that many more young people there aspire to be entrepreneurs. The US also has the necessary finances to invest in startups, and, of course, the military plays a key role as a consumer in the early stages (for example DARPA, see Block-Keller, 2011). It funds exploratory technological developments that are not restricted to civilian applications.

Where such conditions have not arisen naturally over the years, the state has to step in. In her book *The Entrepreneurial State* (2013), the economist Mariana Mazzucato argues that the role of the state is vital in establishing a functioning entrepreneurial culture. The legal and taxation framework is just as important as the education system, research funding programmes and intervention mechanisms. Without appropriate government funding structures, startups cannot establish themselves. It is not creative startups and risk-taking venture capitalists who are the motor behind the development of technological innovations leading to economic upswing and prosperity, but rather state action, which is and always has been crucial – in financing public education, building and expanding infrastructure, funding basic research and introducing measures to support entry into the market place.

Examples range from electrification to the internet, whose creation and expansion would hardly have been possible without state support. Apple's success, for instance, was built on technology that had been developed almost exclusively with public funding. Similar arguments are brought by the MIT economist Daron Acemoglu and the Harvard political scientist James Robinson, who describe the role of the state in the introduction to the German edition of their bestseller *Why Nations Fail* so succinctly that we summarize it here: it is the rules – or institutions – states opt for, which determine whether or not they will succeed economically. Economic growth is driven by innovations

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and by technological and organizational changes based on the ideas, talents, creativity and energy of individuals. But this requires appropriate incentives. Moreover, skills and ideas are distributed all over society, which is why any state that neglects large parts of its population can hardly expect to exploit the existing innovation potential and to profit from economic development. All this leads to the simple conclusion that the key to sustainable economic success lies in the development of an array of economic institutions which render the talents and ideas of a state's citizens useable by offering appropriate incentives and opportunities, secure property and contract rights, a functioning legal system and free competition so that the majority of the population can participate productively in the economic system (Acemoğlu/Robinson, 2013).

As discussed in this article, in both Israel and Korea the state was heavily involved in creating the startup culture that functions so well today. In Israel, the need to cope with mass immigration, above all from the former USSR, made state intervention the order of the day. By offering the huge influx of scientifically and technologically well-qualified immigrants government support to establish their own businesses, Israel was able to take in around a million ex-Soviet citizens and integrate them into the labour market. Today, a broad consensus prevails that this constituted Israel's beginnings as a startup nation. A crucial factor was the exemplary 'Technological Incubators Program', which helps young entrepreneurs with finance in the early stages of startups. Another key factor is the military-industrial complex, which not only has a high demand for technological innovations but also invests directly in research and development.

The starting point for the startup boom in Korea was a clear government commitment to breaking the dominance of the global multinationals and to diversifying the economy by expanding the number of medium-sized businesses. An independent startup culture has only been able to develop in recent years after the adoption of this strategic objective, flanked by appropriate funding structures and targeted intervention resources as well as government investment. As in the case of Israel, government

measures to support startups in their early stages are seen as a crucial factor in Korea's success. Korea's 'Tech Incubator Program for Startups' (TIPS) was explicitly based on the Israeli model.

When it comes to developing startup ecosystems, there is in principle broad scope for action by government institutions. However, it is essential that they act in a coordinated fashion, oriented towards the real needs of entrepreneurs and not merely serving the political ambitions of ministries and politicians. Austria, it has to be said, has not been immune to 'land-grabbing' by various interested parties. The resulting pattern is sadly familiar from other areas of politics. Adaptation to the new conditions has primarily been attempted via the funding system, i.e. existing programmes have been expanded to include startups, or new programmes have been created. The structures which have emerged have more to do with empire-building on the part of government agencies and ministries than with the needs of startups. There are too many funding programmes, and the medley of support measures is largely arbitrary. Structural changes, by contrast, have been largely ignored – in this case the legal framework for venture capital, crowdfunding, startups, etc. Overall, one has the impression that, while all sorts of individual measures have been implemented, there has been no systematic perspective, no strategy-driven approach, and no coordination.

To put it simply, there are two major problems Austria must tackle. Firstly, entrepreneurs are given barely any support in developing, testing and scaling their business ideas, or else are supported by measures that are inappropriate for the early stages of development. The number of interesting startups is thus much lower than it could potentially be. Secondly, there is a danger that venture capital will dry up still further and startups will be forced to try their luck abroad.

Recent developments in Austria suggest that there may soon be a change in outlook. The Ministry of Science, Research and Economy's Action Plan for a Competitive Research Area (2015) is based on the goal of encouraging startups that was laid

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down in the federal government's Strategy for Research, Technology and Innovation (2011). The package of measures in this action plan includes launching an incubator programme modelled very closely on the international examples discussed above (BMFWF, 2015, 22). Equally positive mention should go to initiatives agreed by the government for increasing the proportion of private funding for research and innovation activities, in particular the Ministry of Science, Research and Economy's crowd-funding initiative and the public benefit package that will enable the creation of up-to-date structures in this area for the first time.

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GREECE AT A CROSSROADS: TO INNOVATE OR NOT TO INNOVATE?

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INTRODUCTION

The reforms and austerity measures which the Troika suggested to the Greek government lead to substantial reductions of the nominal unit labor costs, of the current account deficit, and of the public deficit (Eurostat, 2013). Beyond these initial reform successes, the current economic situation in Greece is devastating: GDP shrank by almost 30% in the past six years, the unemployment rate remains above 25%; and youth unemployment can be called only dramatic (Eurostat, 2013). And although Greece showed in 2014 initial signs of recovering from its 2008 crash following the reforms imposed by the troika, its economy continues to suffer.

A raft of policy recommendations were identified and debated, all seeking to help the Greek economy find its way out of the crisis. Institutional reforms, in particular the liberalization of closed professions, further wage reductions, and the privatization of public industries, are meant to help improve the competitiveness of the Greek economy. All recommendations at the same time are implicitly expecting that 'the market' will solve the remaining problems. However, six years of recession have made clear that enforcing austerity measures and pushing through desperately needed reforms to the regulatory environment is not enough to create new growth in Greece and transform it into an innovation-driven economy similar to other countries in the Eurozone. At the same time we observe a considerable number of scientists who are able to conduct cutting edge research in Greece along with a tiny number of high-tech industries. Although embroiled in the current difficulties of administrative provisions, these firms create highly valuable products in Greece. We also observe that the Greek diaspora includes a significantly larger number of scientists working at leading research institutions and entrepreneurs working or running high tech companies in the

US and across Europe. Moreover, the country holds a unique asset when it comes to winning the international race for talent: the attractiveness of its quality of life. Greece is at a crossroads: Greek society can either choose to transform the country into an innovation-based economy producing technological breakthroughs that create added value in high-tech and knowledge-intensive industries. To achieve this goal, Greece needs to develop an innovation system by implementing a specific set of policy measures. Or, if decision-makers continue not to change anything, the country will have a steady, tourism-based economy, supplemented by a food manufacturing base. However, these components will not yield substantial prosperity increases for Greek society.

The rest of the paper is organized as follows: Section two presents a short review of the current economic situation in Greece, making clear why austerity measures and institutional reforms are necessary but not sufficient. Section three describes why focusing on innovation is a key ingredient for getting Greece on a path toward long-term economic growth. Section four presents a specific policy plan to make Greece more innovative. Section five concludes.

CURRENT SITUATION IN GREECE

An overview of the pre-crisis Greek economic structure (see Table 1) clarifies, why Greece is in such deep trouble. Most employees, even in the manufacturing sector, work for firms with less than ten employees, unable to take advantage of increasing economies of scale. Greece is specialized in agriculture and tourism, with both shares above the EU average, and the production of food, beverages and tobacco products is the largest single piece of the already small manufacturing sector in Greece – thus in segments with low value added (McKinsey, 2012). Therefore, Greece has only a low share of tradable goods and services in GDP terms, resulting in a low average export to GDP ratio of about 25% (see Table 3, p. 228). Greece managed to maintain a closed

TABLE 1 Share of selected economic activities of gross value added in% and distribution of labor force in the manufacturing industry depending on firm size in%

	Agriculture, forestry and fishing	Manufacturing	Catering and hotel industry	Share of employees in the manufacturing industry in firms with less than 10 employees	Share of employees in the manufacturing industry in firms with more than 50 employees
	2010			2009	
Greece	3.1	10.0	6.8	46	41
Germany	0.8	20.9	1.6	7	78
Finland	3.0	18.0	1.7	9	75

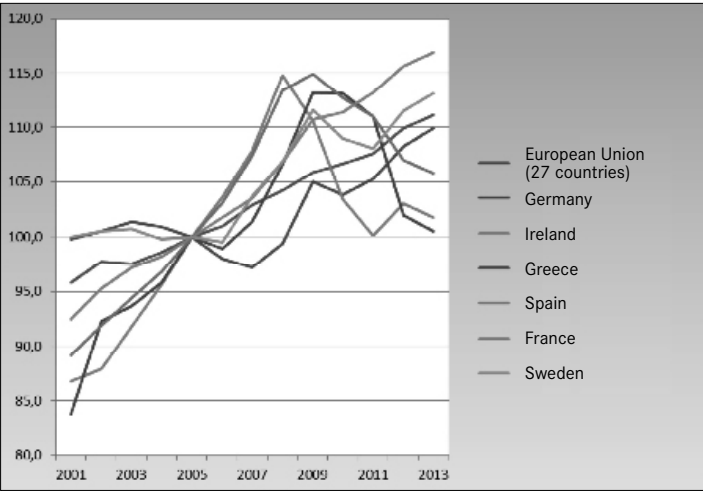
Source: Eurostat (2013).

economy, despite having joined the European Union in 1981, revealing its structural problems. An economy of its size, fully integrated in the EU, should have produced much larger export shares – of say about fifty percent – over time.

On the positive side, there are also, albeit few, IT businesses in Greece, getting 40% of all R&D investments (Grant et al., 2011) that, along with similarly small-scale high-tech companies in other areas (McKinsey, 2012), might be the nucleus for economic expansion, but are currently too small to develop sufficiently if institutional reforms alone are continued. Moreover, several austerity measure targets have been achieved, and initial successes reported. The labor cost structure of the Greek economy (see the nominal unit labor costs in Figure 1), which in 2001 were relatively low in Greece, peaked at the beginning of 2010 and dropped significantly in 2013, with reforms having reduced wages compared to previous years (Buti/Turrini, 2012).

At the same time, so far little has been done to actively support the Greek economy. Moreover, the *private* sector still suffers under the highly inefficient and corrupt public

administration. The OECD (2010, 2014) provides composite indicators, for instance of product market regulations (see Table 2). Despite some improvements over the last five years, the indicator reflects the numerous regulations, bureaucratic hurdles and restrictions that Greek entrepreneurs and SMEs still face. Greece is one of the most regulated economies in the EU (OECD, 2014), and each decision to enter the market bears a substantial risk of failure because bureaucratic hurdles can be insurmountable for entrepreneurs.¹ In this vein, estimates show that bureaucracy costs about 6.8% of GDP in Greece, while the EU average is 3.5% (Drymiotis, 1012). Similarly the World Bank indicator on the ‘Ease of Doing Business’ reports for 2010 that Greece has an overregulated legal framework that puts substantial burdens and lengthy procedures on its entrepreneurs and business owners regarding entry regu-



Source: Eurostat (2013).

FIGURE 1

Nominal unit labor costs: Greece currently with the lowest labor costs

¹ For a real life example see the start-up story, see Thomas (2011).

	2008	2013
Greece	2,3	1,8
Netherlands	0,9	0,9
Germany	1,3	1,3
Finland	1,1	1,2
Portugal	1,4	1,3

Source: OECD (2010) und OECD (2014).

TABLE 2

Information on product market regulations represented by composite indicators

lations, property registration and obtaining or extending licenses or permits, as well as reporting duties. Greece ranked 109th out of 183 countries, far below any other Eurozone economy. Despite reports of incremental improvements in the business climate – Greece’s indicator rose to 72nd in 2014 (see Figure 2) – it is obvious that the reforms have not been sufficient so far. For instance, foreign direct investment as one critical indicator for the openness and innovative environment of a country still shies away from Greece; this money is allocated to countries with more attractive investment conditions (Evans-Pritchard, 2012). This leads to the last crucial issue: corruption, the other side of the coin of over-regulation, is part of everyday life, like the bribery of bureaucrats, tax collectors, and judges. Greece is considered to be the most corrupt Eurozone country (Figure 3). Corruption is not just detrimental to the economy in general, but specifically to innovation and entrepreneurship. Corruption is one reason why researchers and innovators stay away or leave. Recent investigations cannot find evidence of changes in the level of corruption.²

² See the recent report of Transparency International (2013), which ranked Greece as 80th in the world and found no evidence of improvement. For further information see the Corruption Perception Index: <http://www.transparency.org/cpi2013/results>.

	Final consumption (% of GDP) 2001–2010 average	Exports (% of GDP) 2001–2010 average
Greece	89.38	22.33
Netherlands	73.04	70.06
Germany	76.79	41.63
Finland	74.32	41.81
Portugal	85.1	29.38

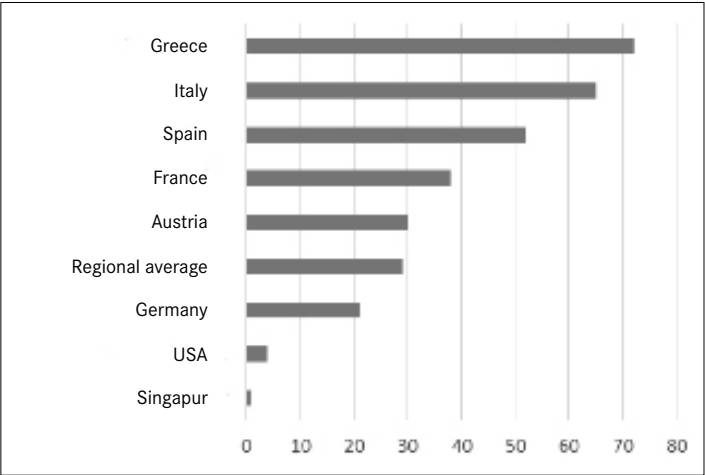
Source: Eurostat (2012).

The picture of the Greek economy is completed by information on expenditures in consumption (Table 3) related to GDP. In Greece, final consumption represents 90% of GDP, far above average (Eurozone average is 77%), with excessive public consumption making clear that the investment level in Greece, in particular for R&D, is far below most other Eurozone economies.

Still, many experts expect that the Greek economy will start recovering only by enforcing further institutional reforms, thus unleashing competitive forces, and by doing ‘more of the same’ in terms of economic outcomes. However, the analysis makes it clear that Greece does not have a cost problem but fundamental institutional and structural problems. Cutting costs will make Greece more competitive, but at a wage level below European standards. If only the doubtless necessary institutional reforms are made, Greece will follow a path of limited growth in sectors of low added value. Tourism, agriculture and trade are not enough to create sustainable, growing wealth for the whole country. If Greece is to make growth progress *within* the group of Eurozone countries, it must move beyond institutional reforms. As we argue, it needs to focus on policy measures that support an innovation-driven economy in combination with the necessary institutional reforms. As we will show, there exists a basis for such a model.

TABLE 3

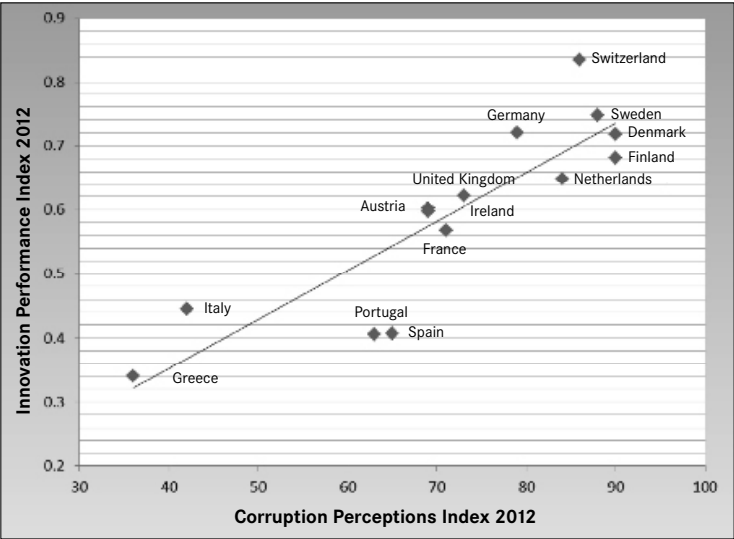
Information on final consumption-to-export ratios



Source: World Bank (2014), <http://www.doingbusiness.org/rankings>.

FIGURE 2

Ease of Doing Business 2013



Source: Innovation Union Scoreboard (2013), Transparency International (2013)

FIGURE 3

Innovation Performance and Corruption

Note: A higher Corruption Perceptions Index corresponds to a lower level of corruption in a given country.

ELEMENTS OF THE GREEK INNOVATION SYSTEM

Tourism and agricultural products will remain an important part of Greece's economy, but in these sectors currently products and services of mostly low value-added are produced. It is certainly possible to make the existing products (food and beverages) more innovative, and it is also possible to increase the quality of offers as regards tourism. The McKinsey (2012) report has shown several ways how this could happen. But tourism and agriculture will not be enough to create sustainable, growing wealth for the whole country. Greece has to tackle the central problem of moving up on the value-added scale.

Ample research demonstrates why it is worth developing an innovation-friendly environment with support for innovative firms. Aghion and Howitt (1992), for instance, focus on such firms and, using an endogenous growth approach with the Schumpeterian theory of 'creative destruction,' find that innovative firms are at the center of sustainable economic growth. As Baumol and Schilling put it, 'innovative entrepreneurs do make a substantial difference to a nation's growth rate, having introduced many breakthrough innovations' (Baumol/Schilling. 2008, 1).

From the analysis of innovation chains, we know that an economy needs an upstream innovation system (Nelson, 1993) in order to be able to initiate entrepreneurial activities on a broader basis with innovative and productive firms. Essentially, an innovation chain starts with excellent basic research, with flowing transitions to publicly financed applied research. The research and development activities of private companies yield stepwise spillovers from ideas to innovative products, which need proof of concept, market demonstrations and commercialization (Gilbert et al., 2008). Moreover, just building publicly and privately financed research institutions is not sufficient. On the one hand, the development of new ideas and innovative activities requires, as Nelson and Wright (1992) emphasize, the exchange and interaction of all players in such an innovation chain beyond those acting in firms. On the other hand, spillovers

of new ideas to innovative products with business ventures need a regulatory environment that protects ideas and allows an easy entry of new firms into the market. If these ingredients for innovative actions are mixed in the right way, the long-term commitment to research and innovation will pay off with growth, higher incomes and prosperity (Cho/Pucik, 2005, Wong et al., 2005).

Thus, the key to such transformation is developing an innovation-oriented industry structure and a well-functioning innovation system. We should not forget that Greece is one of a group of countries driven by innovation, including Finland, the Netherlands, Germany, and France, but also Belgium and Austria. These Eurozone economies invest around 3% of their GDP into R&D, and hence into their innovation systems.

What seems even more important: many other Eurozone countries have agreed on a political consensus that these investments are of crucial importance no matter which party is in control. The budget is set and scientists are given wide latitude to do their work. As a result, their economies are driven by innovation and continual refinement, with new products and technologies regularly being introduced. They are successful in the global markets because of their new technologies and not because of their low unit wage cost.

The Greek economy is not. Its investments into R&D amount to 0.67% of GDP, less than any other Eurozone economy and far below the EU average. In addition, private R&D investments make up less than 0.2% of GDP. Sweden, at the other end of the scale, allocates 3% of its GDP to private R&D.³ Research networks barely exist in Greece, and collaboration with industry is poor. Also, when it comes to ability to handle launches of new products, Greece again finds itself at the bottom of rankings

³ Innovation Union Scoreboard (2014): <http://ec.europa.eu/enterprise/policies/innovation/facts-figures-analysis/innovation-scoreboard/>.

on management practice scores (Grant et al., 2011). No wonder that in the 'innovation performance index' prepared by the European Commission, Greece ranks far below any other Eurozone country (see Figure 3, p. 229).

Putting together the puzzle, it is crucial for any economy aiming to create a business climate conducive to entrepreneurship to adjust its institutional system. This means it must reduce regulatory burdens, ensuring the right conditions prevail for an environment open to innovation, and invest in the development of its innovation system as described here. If these steps are taken correctly, entrepreneurs are able to transfer new ideas into marketable products *in* their home country and not abroad. The problem remains that all systemic and institutional factors need to be in place in order to allow innovations to evolve efficiently. If any single factor is missing, innovation will occur more slowly than is possible. This dilemma mirrors literature on 'innovation systems,' referring to the factors limiting the effects of an innovation-driven economy.

Looking at the Greece of today, this picture does not seem encouraging for the vision of an innovation-driven Greek economy. However, one has to acknowledge initial improvements over the past year, and many of the assets of Greece have been substantially underappreciated in the analysis of Greece's economic prospects. The first asset is the small number of mostly basic research institutes that produce considerable research output (Grant et al., 2011).

A second asset is that there exist a huge number of top Greek scientists. The share of top Greek researchers among all researchers in the world is above 3%, while the Greek population among the world population is only 0.2%.¹⁶ However, Greece is 'exporting' 85% of these top scientists, more than any other Eurozone country, to research institutions outside Greece, to other European member states and even more to the US. Similarly, when focusing on ERC grants (the most competitive research grant of the European Research Council), another indicator for research excellence,

and when averaging Greek researchers (in Greece and in Europe) over the Greek population, we observe that the ratio of grants to the population is comparable to innovation economies like Finland, Germany, or Great Britain, and better than the ratio for Spanish, French or Italian researchers (see Table 4).⁴ This holds even without taking account of the majority of Greek diaspora scientists working at institutions outside the EU. If this 'brain power' could be unleashed within Greece, the country could turn more quickly into an innovation-driven economy.

Third, Greece also has a few innovative companies – a large share of them in the IT business – that have remained in Greece, many of them in Athens. These firms do sporadically work with the existing research institutes, but are not clustered and co-located in the same area, despite the obvious potential for mutually beneficial cooperation. Some of them have developed new ideas that are on the cusp of being turned into marketable products (Tsiros, 2013). These firms have remained in Greece despite the adverse innovation environment.

This brings us to the fourth 'asset' of Greece: its attractiveness in terms of climate and quality of life. In an increasingly global race for the best talents, life quality outside labs turns into a crucial success factor. Labs, researchers, patent lawyers and venture capital can move easily, while climate, landscape and historical heritage cannot. Some outstanding research universities in northern Europe and the northern US have already experienced the problem of competing against universities in places with higher quality of life, like California, Australia and Israel. Europe so far does not possess a 'global attractor', where world-class academic research is matched by locations with attractive climate and quality of life. In this respect, Greece has a unique comparative advantage to most EU members and could make a significant

⁴ Also among ERC grants 45% of the approvals have been allocated to Greeks in Greece and 55% to Greeks in other EU member states, see Herrmann and Kritikos (2013).

TABLE 4 Distribution of ERC Grants, home and abroad, and related to population

	Population in millions (2011)	ERC grants home (2007–2011)	ERC grants abroad (2007–2011)	Total ERC grants (2007–2011)	Share over population
Greece	10.5	24	28	52	5.0
Germany	81.8	250	150	400	4.9
Finland	5.4	35	6	41	7.6
Spain	46.1	100	30	130	2.8
France	65.0	240	50	290	4.5
Italy	60.6	145	100	245	4.0
United Kingdom	62.5	310	40	350	5.6

Source: ERC (2012), Eurostat (2013), Calculations of DIW Berlin.

contribution to Europe’s collective problem of lacking the combination of places with internationally competitive employment conditions and attractive life quality. If quality of life is matched with excellent research and public administration, Greece could become an attractor not only for tourists but also for talents (see Herrmann/Kritikos, 2013).

Thus, drawing these arguments together, there is a well-established understanding of what is required at the beginning of the innovation chain. However, given the high regulatory burden and the unfriendly environment towards innovative companies in Greece, there are only a scattered number of high-tech start-ups and no knowledge-transferring institutions or applied research connecting the existing basic research institutes with the potential of later exploitation of their fundamental findings. And instead of spin-offs from universities and networks between researchers, institutes work rather in an isolated way with the majority of their top researchers leaving the country, while there is still a mild taboo in Greek society against turning research results into business ideas.

AN AGENDA FOR INNOVATION IN GREECE

Several factors are required to design the transformation to an innovation-driven economy. To attract, train and retain talented people and to give researchers, entrepreneurs and managers a fitting structure enabling them to make their specific contributions within an innovation chain, economies need appropriately developed innovation systems. These consist of high quality schools, universities and *independent* research institutes, as well as professional education systems and excellent research within the public sector. It further needs a functioning financial sector, informal and formal institutions, as well as non-exploitative networks, and locally and thematically organized clusters. Last but not least, it also needs a suitable regulatory environment that facilitates internal markets open to new products and international competition. In the center of these approaches is thus the exchange and knowledge-transfer between the world of research and the world of business, making new products out of research ideas.

A good starting point is that Greece does not have to build an innovation system from scratch. When political decision-makers start developing a strategy for the extension of the Greek innovation system to provide Greek talents with the necessary support and to attract talents from other parts of the world to Greece, they can rely on existing research institutes and entrepreneurs willing to found innovative businesses. The first and foremost need in such a strategy is to close the gap in Greece’s innovation chain, between basic research institutes and innovative businesses, by making substantial investments into publicly financed research and into the capacity-building of new research institutes, and by clustering them around the existing ones. Further, institutions which create networks and clusters, protect (intellectual) property rights and streamline bureaucracy, will allow Greek entrepreneurs to introduce new marketable products or processes in Greece instead of in other countries. Related to the systemic and institutional factors of an innovation

system and the status quo of these factors in Greece, the following steps are recommended⁵:

Establish and develop new research institutes:

Given the specialization of the existing research institutes and universities on the one hand, and the traditional (agriculture and tourism) and modern (IT, pharmacology, energy, nanotechnology) sectors on the other hand, research capacities need to be substantially extended, with a strong focus on creating spatially-bounded knowledge spillover. More specifically: a substantial number of *new* research institutes with a strong focus on applied research need to be created, developed and clustered in such a way that they close the gap in the innovation chain. Given that such a strategy needs a strong increase in public investments, and given the current state of the Greek national budget, the European Commission provides in the Research Framework Programme Horizon 2020, and with structural funds and the smart specialization strategy, several new tools that will help Greece to finance these investments. Ideally, these investments are accompanied by a restructuring of the public research system.

Create incentives for researchers to stay in or come to Greece:

The most important resources for generating an innovation economy are the researchers working for it. Well-educated researchers are the driving force behind cutting-edge research, new developments and innovation. In order to be able to compete with research institutions elsewhere in the world, Greek stakeholders must remove the barriers that discourage Greek researchers from staying home and other researchers from coming to Greece. Thus, working and research conditions have to be designed appropriately to turn the brain drain into brain circulation. Attractive conditions contain three aspects: (a) independent research with the only target of top

⁵ For a further discussion of policy measures, see Herrmann and Kritikos (2013).

quality research output; (b) salaries that compete with similar institutions in Europe; and (c) a low regulatory burden for starting research in Greece.

Expand research clusters based on existing specialization:

When founding new research institutes, it will be of crucial importance to focus their new research in areas Greece is specialized in. Clusters will be particularly successful in terms of knowledge spillovers when research institutes, universities and innovative companies are geographically concentrated (siehe Ellison/Glaeser, 1999). In this context, the Greek government has to rethink the geographical reallocation of its scattered research institutes and to allow private businesses to establish their firms next to research centers. Furthermore, the technology park infrastructure, built in the past with the help of structural funds from the European Union, should be reactivated. The main aim of such clusters is the linking of science with business, and the composition of knowledge spillovers from research institutes to firms and businesses. Therefore, there is a central need for applied research institutes (such as the German Fraunhofer Institutes). In particular, these institutes are able to provide knowledge-based solutions to the special needs of technology-oriented start-ups aiming to place innovative products on the market. At the same time, spin-offs are often established around applied research institutes when their researchers aim to transform their own research ideas into products.

Risk capital for innovative entrepreneurs:

Once knowledge spillovers are turned into new products, it is necessary to close the equity gap of high-tech start-ups. Access to venture capital will then be one major requirement for a vibrant entrepreneurial culture in Greece. Where necessary, standards and regulations for the provision of seed and equity capital should be adjusted so that venture capital is attracted to Greece on the one hand (see Bygrave/Timmons, 1992), while seed capital needs to be provided from public sources on the other. Most importantly, venture capital will be attracted if research centers

of excellence are established, research clusters are developed, and top researchers are attracted.

Independence of research institutes:

The Greek research landscape is strongly determined by political interventions. Investments in research institutes and universities will, however, only work in the sense of being attractive to top researchers if universities and research institutes become independent of political influence. Ministers and MPs need to step back, only providing an overall budget and then leaving, for instance, the selection process of new researchers to internationally recognized scientists. This process can be supported by an independent research organization providing research grants only on the basis of research quality.

Strengthening efforts to cut red tape:

Despite incremental improvements in the business climate, as shown in the World Bank 2014 report, regulations are still very high for firms in Greece, hindering or imposing substantial cost to both innovators and researchers who are seeking to commercialize their invention through new business ventures. And innovative companies are the first to leave if institutional reforms are not continued. Administrative efforts for entrepreneurial activities need to be substantially reduced. This should include not only reducing the number of days needed to register new businesses, but also the number of bureaucratic steps involved in this process, as well as the number of regulations, fees and reporting duties while running a business. Last but not least, there are similar barriers to closing a business which also need a major reform. Instead of slowing down its improvements, Greece needs to become one of the World Bank's top twenty when it comes to 'ease of doing business,' as a couple of EU countries recently succeeded in doing. Moreover, all reforms approved by legislation and those reforms that still need to be passed by parliament will only become effective once implemented and enforced by the courts. To support the necessary adjustment processes, administrative officials need to be appropriately trained.

Codification and simplification of legislation:

In a similar vein, conflicting legislation also creates uncertainty and additional costs for businesses. Codification means bringing all amendments to a given law, adopted at different times, into one law. A swift and comprehensive codification of Greek legislation will eliminate contradictions and simplify administrative legislation. This should include the reduction and unification of the number of administrative procedures relating to any single activity (for details see the EU efforts on 'better regulation', EU-Commission, 2009).

Incentives for regional and local authorities to attract new firms:

Greek municipal leaders are excluded from business revenues produced in their municipality, thereby reducing their interest in caring for the local business climate. For successful innovation economies, municipal leaders committed to creating an excellent local business climate (efficient, fast administration, excellent primary and secondary education and good health services) are essential, as they create 'hands on' the right environment for innovative entrepreneurs. In most successful innovation economies, municipalities are therefore entitled to a share of the locally produced tax income, rewarding their efforts to create an attractive business environment. The central authorities in Athens therefore need to give away control over certain taxes which could be raised by municipalities (see Herrmann/Kritikos, 2013).

Diaspora policy:

All measures discussed so far aiming to close the gaps in the innovation chain can be supported by a target-oriented diaspora policy. Currently, the Greek diaspora, although very strong, is not treated as an asset. Beyond the goal of creating a specific labor market policy for recruiting talented individuals abroad, the diaspora policy should open interaction and cooperation between those who go abroad and those at home. This could include options for creating exchange programs for top researchers, turning the brain drain into a brain circulation in order to increase knowledge

transfers, finance R&D, attract venture capital, increase management capacities, or even for export promotion of innovative products produced in the homeland to the diaspora. Thus, the goals of Greek innovation policy can be substantially accelerated if accompanied by a target-oriented diaspora policy (Plaza, 2013).

Given the vested interests at all levels, it will not be easy to implement such a policy. Further, it needs Greeks to change how they view themselves, developing from the pre-crisis self-image of an economy based on trade and tourism, and transfer to the vision of an innovative country. However, if Greek authorities commit themselves to the long-term goal of turning Greece into a European Silicon Valley, while communicating to the citizens its long-term benefits, reforms will find political support.

CONCLUSION

Greece's Eurozone membership may have given the false impression that the Greek economy may be driven by innovation – it is not. It faces not only institutional but also severe structural deficits with a small industrial basis, low export ratio, small businesses and many closed professions. If decreasing labor costs and further institutional reforms were to be the only active policy, then Greece's future would be a low wage economy with an extended workbench of other innovative economies. Greece can only become prosperous if it also uses its comparative advantages beyond tourism, trade and agriculture.

Greece has a foundation of high quality research institutes at the beginning of the innovation chain, a handful of innovative companies who remained in Greece despite the high regulatory burden, as well as an impressive diaspora in research, finance and business. As outlined in this article, the Greek authorities need to make substantial investments into the innovation system, accompanied by further institutional reforms and an appropriate diaspora approach in order to create an innovation policy which closes the gaps in the innovation chain. By doing so, the number of innovative companies would

substantially increase, thus allowing Greece to find a path towards sustainable growth. However, if Greek authorities rest on their laurels of having slightly improved the institutional surroundings, researchers, businesses and capital will continue to stay away. To this end, an innovation agenda is proposed, designed to turn Greece into an innovation-based economy. However, Greek decision makers must make clear that embarking on an innovation centered policy will not result in an instant improvement in the Greek economy – indeed it will take one decade at minimum. However, the time to start is now, as the earlier these reforms are put into practice, the sooner the country will enter a sustainable economic growth path.

Of course, whether or not Greece actually becomes an innovation hub depends not just on investments into R&D and research centers, but also on establishing a partnership between the worlds of research, business and entrepreneurship, where ideas can be freely exchanged. Greek Ministers and MPs, regardless of party, must commit to investing time and money, formulating a vision that inspires young Greek entrepreneurs, scientists, and citizens. They must also take concrete actions that signal a serious commitment to innovation. Combined, these efforts may become key to creating trust in the Greek political system. If the Troika – now called 'the institutions' – should decide to actively support this process, she would be enabled to successfully accomplish the still necessary reforms. To that end the future discussion between the creditors and Greece needs to be refocused on the Greek capabilities.

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FROM MOZART TO SCHUMPETER: A TRIPLE HELIX SYSTEM APPROACH FOR ENHANCING INNOVATION IN THE SALZBURG REGION OF AUSTRIA

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LUDOVIT GARZIK Austrian Council for Research & Technology Development, AT

1 INTRODUCTION

The Austrian region of Salzburg, especially the homonymous city, which is the country's fourth-largest city and the capital of the federal state of Salzburg, are known for their long cultural traditions in classical music and history that broadly influence all regional institutions. The city emerged as a centre of culture and arts during the *Gründerzeit* (also referred to as 'promoterism'), a period of economic upswing in 19th century Germany and Austria that was fuelled by large capital inflows coming from fast-paced industrialisation and post-war financial reparations. Much of the city's fame comes from being the native place of 18th-century composer Wolfgang Amadeus Mozart. This fame has been strongly preserved, thanks to an impressive tourism industry and many cultural events highly visible nationally and internationally. Many think that Mozart's omnipresent figure on a chocolate ball is more famous abroad than all Austrian technology could ever be. In recent years, regional strategies started to give more importance to an innovation-based, sustainable development for the future. The *Science and Research Vision for the State of Salzburg* (Ohler et al., 2011), adopted by the Government of Salzburg in June 2001, acknowledges that the future must be much more invested in science, research and development in Salzburg (Ohler et al., 2011, 1) and identifies several fields for regional research: culture, tourism and leisure, health and well-being, food, environment, the wood industry, information and communication. Salzburg's economic policy strategy *Salzburg. Business Location Future. Economic programme 2020*¹ includes science, research, innovation and sustainability among its main objectives.

¹ <http://www.salzburg.gv.at/ssz-wipro2020.pdf>

Realising these objectives requires a consolidation of Salzburg's research and innovation policies, framework conditions and infrastructure, as regional R&D statistics indicate an important lag relative to other Austrian regions. For example, the research base is relatively weak, being concentrated mainly in the academic sector and a few R&D-intensive companies with limited absorption capacity of research investments. Government intramural R&D expenditure (GERD) in Salzburg in 2011 amounted to 1.45% of GDP, placing the region second to last among the Austrian regions in this respect. This is less than half of the 2.7% of GDP national average and is far behind the 4.64% and 3.42% of GDP shares of Styria and Vienna, the leading regions in this respect (Source: Eurostat). Salzburg also ranks second-to-last in terms of R&D expenditure per economic unit active in R&D, with nearly €950,000 per unit in 2011. By research sector (basic research, applied research, and experimental development), Salzburg had one of the highest shares of R&D expenditure per economic unit in basic research among all regions during 1998-2011 (26% in 2011), next to Tyrol, Styria and Vienna, but ranked average in applied research (35% in 2011) and low in experimental development funding (40% in 2011) (Source: Statistics Austria). This reflects a slower development of the region's R&D institutional capacity than the relatively fast-growing public R&D investment, causing budget congestion and reducing investment efficiency.

The innovation base of the region also has several weaknesses: low innovative behaviour of firms, no major industrial concentrations and clusters, small horizontal and vertical business networks, and significantly lower start-up intensity relative to the other regions, although the number of start-ups has risen steadily in recent years. Although new innovation infrastructure support services have been created, e.g., Innovation Service Salzburg, and a network of technology business incubators (Techno-Z), their effectiveness is rather limited, partly by the region's small area and partly by the local economic structure. Salzburg's economic setup is dominated by the service

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sector (47.6% employees in Salzburg, higher than the 41.5% share for Austria) and a comparatively smaller manufacturing sector (Salzburg: 24.5%, Austria: 28%). The manufacturing sector is less represented compared to other states, and also to the Austrian average. There are few leading companies, most operating in wood, plastic and mechanical engineering. Industry structure is largely traditional, with a low share of employment in human capital-intensive and research-intensive industries, and low levels of R&D. The service sector is represented by tourism (which is the crucial economic factor²), transport, banking and business services, as well as culture, health and social services, ICT, media, trade (wholesale) distribution, logistics transportation. The service sector is strongly export-oriented, with companies that focus more on regional and international markets than on the local supply. This is a source of brain drain of young, often highly qualified employees, residents and businesses (Salletmaier et al., 2007).

This paper provides a fine-grained analysis of the Salzburg region's innovation system from a Triple Helix Systems perspective, with the aim of identifying the main challenges to regional innovation and offer suitable policy recommendations. The research has been guided by two questions: (i) *What are the main features of the Salzburg region as a Triple Helix System of regional innovation?* (ii) *What policy measures can be adopted, from a Triple Helix System perspective, to enhance regional innovation in an essentially cultural and touristic region like Salzburg?*

The article is structured as follows: section two describes the theoretical framework of the article, which is placed at the intersection of regional innovation and Triple Helix literature. Section three focuses on the research method and design, while section four describes the main findings of the analysis. Section five offers a detailed

² For example, the percentage of overnight stays in Salzburg is 19.3%, second only to the region of Tyrol (33.8%), for a share of residential population of only 6.3%, and is at large distance ahead of other Austrian regions (Source: Statistics Austria).

discussion of the findings, structured around each of the two research questions that guided the study, and section six concludes with the limitations of the research and directions for further research.

2 THEORETICAL FRAMEWORK

The theoretical framework of this study is based on the regional innovation and Triple Helix literature. First, a review of key issues of regional innovation models is provided (e.g. origins, types, differences among them and criticism concerning several weaknesses); then the use of the Triple Helix model in regional innovation research is discussed, in light of the new perspectives it introduced, especially the recent Triple Helix Systems approach.

Regional innovation models entered the innovation policy debate in the early 1990s in the context of a shift from the shortcomings of the 'traditional', national state-led regional policy of the 1980s towards a regional endogenous capacity-building policy based on local factors like human capital, business culture and production capacity, education and learning (Moulaert/Sekia, 2003). Increasing internationalisation of business and technology that blurred national borders and enhanced global competition, and the emergence of regional economic clusters also contributed to the process (Enright, 2001). Localised learning, knowledge creation and transfer started to be seen as key to improving the innovation capabilities and performance of local firms, thus building competitive advantage for regions (Asheim/Isaksen, 1997; Maskell and Malmberg, 1999; Asheim/Gertler, 2004; Asheim et al., 2005). Regional innovation and cluster-building became policy objectives for many governments in the advanced economies in view of enhancing regional and national competitiveness (e.g. the BioRegio project in Germany in 1995 for the establishment of regional biotechnology clusters, or the UK government's cluster-driven industrial policy for regional development since 1998) (Cooke/Memedovic, 2003). A similar policy focus on

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technological modernisation and regional innovation was also present in the European Commission's plan to narrow development gaps within Europe and accelerate catching-up processes by means of the 1993 pilot project called Regional Technology Plan (RTP) and its successors Regional Innovation Strategies (RIS), Regional Innovation and Technology Transfer Infrastructures and Strategies (RITTS) and Regional Technology Transfer Projects (RTT). Insights drawn from these initiatives documented the regional innovation dimension of the EC's *Green Paper on Innovation* (Route of action 12) (European Commission 1995, 45)

A variety of regional innovation models emerged in the academic literature of the 1980s and 1990s, from the 'territorial innovation models' family – e.g. 'milieu innovateur' (Aydalot, 1986), industrial districts (Bagnasco, 1977; Becattini, 1987; Brusco, 1986), localised production systems (Bouchrara, 1987) and new industrial spaces (Saxenian, 1994; Storper/Scott, 1988) – to clusters of innovation (Enright 1984), regional innovation systems (Edquist, 1997; Lagendijk, 1998) and learning region (Cooke, 1998). In spite of apparent semantic coherence, various ambiguities and even divergence appeared when these models were analysed in terms of (i) innovation dynamics; (ii) role of institutions and organisations; (iii) view of regional development (evolution learning, role of culture); (iv) view of culture; and (v) type of relations among agents and with the environment (Moulaert/Sekia, 2003). For example, while innovation is often seen as a way of generating and implementing technology at firm level, there is an ambiguity on the meaning of innovation and culture, and a lack of a functional link between culture and market performance, or between culture and non-market aspects (ibid.).

The variety of regional innovation models and their conceptual ambiguities have often been a source of confusion in the definition and validation of empirical representations of regional innovation systems (Doloreux/Parto, 2004). While some argue that, due to the more descriptive than explanatory conceptualisation of regional innova-

tion systems, all regions have some kind of regional innovation, albeit very different in their effectiveness (Bunnell/Coe, 2001), others identify features in the absence of which a region cannot be considered to be an innovation system, e.g. a collective identity generated from local competencies (Cooke et al., 1997) or a mechanism for knowledge integration (Vilanova/Leydesdorff, 2001). The lack of conceptual clarity was attributed to the strong emphasis on process and inter-firm relations, in line with the Schumpeterian perspective and the main tenets of evolutionary economic theory (Cooke et al., 1997). This emphasis on process, rather than on structure, agency and performance, or in other words, no clear attribution of power, responsibility or possible responses from the actors concerned, is seen as a cause for the proliferation of many 'fuzzy concepts' in the regional innovation literature (Markusen, 1999). Also, the continuous redefinition of regional innovation models through empirical investigation, e.g. at the level of main institutional actors and of the innovative profile and competitiveness of the region, have added to the 'fuzziness' (Doloreux/Parto, 2004). However, the lack of conceptual clarity is not necessarily a reason to reject the regional innovation system theory but rather to increase awareness on their variety and difficulty to replicate them (Cooke, 2001; Iammarino, 2005).

Improved conceptualisations of regional innovation systems have been facilitated by further clarifications in: the definition of a region and the role of institutions, the distinctions between different scales of innovation (Bunnell/Coe, 2001; Cooke, 2001; 2005; Cooke/Schienstock, 2000; Cooke et al., 1997; Doloreux/Parto, 2004; Parto, 2003), and other definitory elements, such as: the knowledge base, industry and technology specialisation, institutional arrangements and governance structures, corporate organisation of firms, etc. (Howells, 1999), financing for strategic investments in innovation infrastructures, institutionalised learning and productive culture conditioned by trust, reliability, exchange and cooperative interaction (Cooke et al., 1997), and cultural factors (Cooke, 2005). Three of these key elements are discussed

in more detail below, in light of their relevance to our study: the regional knowledge base, industrial specialisation, and cultural factors.

- A region's knowledge base is seen by Autio (1998) as a set of two separate subsystems: a knowledge generation and diffusion subsystem, consisting of local public research institutions, universities, technology-mediating organisations, etc., and a knowledge application and exploitation subsystem, consisting of industrial companies, with their customers and horizontal and vertical networks. The interplay between tacit and codified knowledge in firms is a critical element for a region's knowledge base. Two types of knowledge have a critical role in determining the innovative capabilities of regional industries: an analytical one (in science-based industries) and a synthetic one (in engineering-based industries). They have different mixes of tacit and codified knowledge, different sectoral and policy support implications, and different relations to geographical proximity (more important for industries relying on a synthetic knowledge base and less so for industries drawing on an analytical knowledge base) (Asheim/Coenen, 2005; Martin/Moodysson, 2013). Knowledge-intensive sectors in production and services are important not only at the regional level, but also for national and international innovation systems, due to complementary interactions that each region must build in response to the knowledge-based global economy. Such external interactions outweigh internal innovative competences and construct a 'knowledge monopoly' to stand out in the global landscape (Malecki, 2010; Ronde/Hussler, 2005; Tödtling et al., 2006). Therefore, policy interventions need to consider both the nature of a region's knowledge base, as well as its institutional setup (Martin/Trippl, 2014).
- A region's industrial specialisation depends on specific local factors, such as economic structures and industrial legacies, and efficiency in generating new knowledge, resulting from the R&D intensity of the local private sector and public research institutions (Martin/Sunley, 2006; Fritsch/Slavtchev, 2010). Regions with

a higher specialisation in high-technology services, or close to such regions, are more innovative, due to a higher capacity to transform knowledge into innovation (Rodriguez, 2014). In contrast, regions with path dependency patterns are slower in the process of building location-specific industrial specialisation and competitive advantages (David, 1985). In old industrial regions, path dependency may lead to lock-ins and slow industrial restructuring that may be difficult to correct through policy interventions (Hassink, 2005; Lambooy/Boschma, 2001). In less favoured regions (peripheral, old industrial and metropolitan), lock-in, fragmentation and organisation 'thinness' can be major barriers to innovation (Tödtling/Trippl, 2005).

- Culture, seen as attitudes towards innovation, technology, exchange of knowledge, entrepreneurial activities, business and uncertainty (Hofstede, 2001) is an integral part of a regional innovation system, through its influence on institutions and individual actors, and the relations among them. The cultural settings of a region are extremely stable due to collective beliefs and values that give a distinct identity to the local people. This stability is further reinforced by the cultural patterns of regional institutions, which themselves emerged as products of the dominant cultural value system (ibid). Two cultural dimensions are important in the process: a *spatial dimension*, given by the attractiveness of specific locations to the creative class, and an organisational dimension, related to how public or private organisations can influence innovation (Gee/Miles, 2008). In changing an innovation culture, much depends on the transmission of attitudes from one generation to another, especially when they share geography and scientific focus (Azoulay et al., 2009). In the regional innovation literature, cultural factors intervene in different ways in different models: as trust and reciprocity in 'innovative milieus' and industrial districts, as networking and social interaction in the new industrial spaces, as part of a local society-culture nexus for development in local production systems, as a source of learning by interacting in the regional innovation systems, and as part of

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the interaction between economic and social life in learning regions (Moulaert/Se-kia, 2003). Later studies highlight cultural factors as a key dimension of high-tech clusters (e.g. James, 2005; Saliba et al., 2012; Salo, 2014; Saxenian, 1994), high-density art, cultural and media clusters (Currid/Connolly, 2008), 'cultural districts' (Le Blanc, 2010), 'cultural technology districts' (Di Pietro et al., 2014) and open innovation environments (Tödtling et al., 2011). 'Regional cultures of innovation' are part of the framework conditions for creating a knowledge economy and inform the organisational culture of incumbent firms in specific regions (Cooke et al., 2004; Cooke/Rehfeld, 2011), and 'productive culture' is one of the key subsystems of a productive region, which is locally embedded and operates through the local companies, networks and social system, determining the type of development in the region (Cooke, 1997). Other cultural aspects involved in a regional innovation system also include: a culture of cooperation, associative culture, and learning culture (ibid.). Newer insights into the complexity of a regional innovation system's culture have been derived by applying the concept of 'cultural framing' at the intersection of five frames (ethnic, landscape, political, labour and business) and four dimensions (attitudes and values, institutional setting, values, and impact) (Cooke/Rehfeld, 2011).

In spite of the remarkable volume and variety developed over the last two decades, the regional innovation systems literature is often criticised for lack of clarity and answers to several theoretical, empirical and policy issues. For example, Doloreux and Parto (2004) highlight the absence of a unified conceptual framework that could guide research and policy, as well as far too much emphasis on 'local' institutional landscape without much detail on the nature of institutions and their interactions. Uyarra (2007) notes the use of concepts based on assumptions that are often overstated and, in some cases, are not sufficiently grounded in empirical evidence. Asheim

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et al. (2011) refer to gaps in explaining the very nature of the regional innovation system itself, the boundaries of industrial districts, clusters and regional innovation systems, the role of cognitive frontiers, knowledge transfer and learning. Sternberg (2007) identifies a lack of focus on the entrepreneurial dimension and a dominance of empirical studies on intraregional networks and linkages between innovative actors. In the last fifteen years or so, an increasing body of regional innovation research has been developed in different parts of the world using the Triple Helix approach of innovation driven by university-industry-government interactions, which highlights the key roles played by universities on the one hand and governments on the other. For example, Casas et al. (2000) document the emergence of regional knowledge spaces in Mexico, built upon institutional interactions between public research centres and firms, and stimulated by government intervention. Defazio and Garcia-Quevedo (2006) highlight the role of the Catalan regional government in shaping the local S&T/R&D systems, and Rolfo and Calabrese (2006) present a similar case for Italy. Portugal cases (e.g. Castro et al., 2008; Natario et al., 2012) sustain a Triple Helix-based model of organising institutional networking in both national and regional systems, especially in developing economies based on traditional and mature sectors, and in less favoured regions. Uneven concentrations of regional innovation capacities have been identified, from a Triple Helix perspective also for Sweden (Coenen, 2007; Coenen/Moodysson, 2009; Dannell/Persson, 2003), Finland (Jauhiainen/Suorsa, 2008), UK (Huggins, 2008; Smith/Bagchi-Sen, 2012). These studies point out the emergence of distinctive patterns of regional innovation and development that are determined by the relative dominance of the three components of the Triple Helix, and have higher intensities in high-growth sectors and lower intensities in small or peripheral regions. In the latter case, governments are called to provide pro-active and fine-tuned policies to construct regional advantage and correct the region's weaknesses, skills and knowledge flow to the big regions, and lower role in high-technology. More

recent studies use the Triple Helix approach also for investigating the relationship between universities and the regional creative economy, with strong implications for regional innovation and development (e.g. Augustinaitis/Reimeris, 2012; Suciu et al., 2013; Comunian et al., 2014).

A new framework for the analysis of Triple Helix interactions at the regional level was introduced by the Triple Helix Systems approach (Ranga/Etzkowitz, 2013), which unifies elements of the Triple Helix model into an 'innovation system' format composed of components, relationships and attributes (functions) according to innovation systems theory (Bergek et al., 2008; Carlsson, 2003; Carlsson et al., 2002; Carlsson/Stankiewicz, 1991; Edquist, 2005). A Triple Helix System conceptualises innovation as a set of actors and activities in the Knowledge, Innovation and Consensus Spaces that need to have strong and effective connections among them. The Triple Helix Systems framework provides a fine-grained view of innovation actors and relationships, and transcends sectoral or technology boundaries by focusing on the interactions between actors from all three spaces. It explains variations in regional innovative performance by the structure of and articulation between the spaces, and can help regional innovation policy-making to be better tailored to the needs of the system's actors. On these grounds, the Triple Helix Systems approach is used in our study for its capacity to counterbalance some of the weaknesses of regional innovation models discussed above, such as unclear conceptual frameworks, too much emphasis on 'local' institutions without much detail on the nature of the institutions and their interactions, lack of focus on entrepreneurial activities.

3 RESEARCH DESIGN

This section starts with a discussion of the research framework chosen for the study, followed by a description of the research method and questions.

3.1 RESEARCH FRAMEWORK

The research framework that guided this study is based on the Triple Helix Spaces mentioned above: the Knowledge, Innovation and Consensus Spaces. Each space has specific components and functions, as follows (according to Ranga/Etzkowitz, 2013):

- **The Knowledge Space** includes components (institutions and individuals) with the capacity to generate, disseminate and use knowledge: in universities, academic research groups and interdisciplinary research centres, as well as individual academics and entrepreneurial scientists; in the business sector, company R&D divisions or departments; in the government sector, public research organisations, mission-oriented research laboratories, etc. The Knowledge Space has the purpose of creating and developing knowledge resources to strengthen the knowledge base, avoiding fragmentation and duplication of research efforts.
- **The Innovation Space** includes, on the one hand, hybrid structures operating at the university-industry interface, like technology transfer offices, science parks, business incubators, start-up accelerators, etc., which facilitate knowledge commercialisation, provide services and support structures, and partner with local city and regional governments to find resources for their objectives. On the other hand, it includes innovative companies in the private sector and individual entrepreneurs, venture capitalists, business angels, etc. Its purpose is to develop local innovation and entrepreneurship potential, both from local resources and resources from elsewhere, and to ensure a competitive advantage for the region and the country.
- **The Consensus (Governance) Space** includes government and non-government actors who come together to generate ideas and negotiate resources for the advancement of a knowledge-based regime, in a broad vision of governance where the cross-fertilisation of diverse perspectives may generate results that are not

likely to be accomplished individually. The Consensus Space has the purpose of defining rules and regulations, promoting research and innovation programmes and policies, and drawing actors from other spheres into a collaborative process. Salzburg's regional innovation capacity is analysed through a detailed examination of institutional actors and relationships in each of the Knowledge, Innovation and Consensus Spaces. Individual actors are not included in the study, as no evidence could be found of individuals with significant influence in the three spaces on a personal, rather than institutional basis.

3.2 RESEARCH METHOD

The research method is qualitative, based on a case study of the Salzburg region, one of the nine Austrian regions in the NUTS 2 classification³. This region was selected on the one hand because it is one of the lowest-performing Austrian regions in research and innovation, and on the other due to its specific cultural traditions that could potentially have a unique influence on the development of its research and innovation base. The analysis uses available regional data at the NUTS2 level, which are relatively scarce. The performance of the Salzburg region is compared to that of other Austrian regions, as appropriate.

3.3 RESEARCH QUESTIONS

The study has been guided by two main research questions:

- a. What are the main features of the Salzburg region as a Triple Helix System of regional innovation?

³ The nine Austrian regions in the NUTS2 classification are AT11 Burgenland, AT12 Lower Austria, AT13 Vienna, AT21 Carinthia, AT22 Styria, AT31 Upper Austria, AT32 Salzburg, AT33 Tyrol, and AT33 Vorarlberg. A small tenth region is also designated (ATZZ Extra region) at NUTS2 level, but was not considered in the analysis because of very low figures.

- b. What policy measures can be adopted to enhance regional innovation in Salzburg from a Triple Helix System perspective?

4 RESULTS

This section describes institutional actors and relationships in each of the Knowledge, Innovation and Consensus Spaces of the Salzburg region.

4.1 THE KNOWLEDGE SPACE

The Knowledge Space is examined in terms of main institutional actors (universities, university-based centres for cooperation with industry, non-university research institutions, and R&D-intensive companies), publication record and R&D personnel, as measures of knowledge production in this space.

Universities

Universities are the core element of Salzburg's Knowledge Space. The Austrian higher education system includes three types of universities: *federal universities* (Universitäten), *private universities* (Privatuniversitäten) and *universities of applied sciences* (Fachhochschulen), which are regulated by different laws. All three types are represented in the Salzburg region, which hosts five universities: two federal (public) and two private, and one university of applied sciences (Table 1, see below). The five Salzburg universities have different origins and general profiles (Box 1).

Box 1 – Salzburg universities' origins and general profile

The University of Salzburg (Paris-Lodron University) is the oldest and by far the largest institution in terms of student enrolment numbers. It was founded in 1622 by Prince Archbishop Paris-Lodron and was supported by a confederation of

Table 1 Universities in the Salzburg region

University	Type (public/private)	Inception year	No. students/of which foreign students* AY2013/2014	Department structure
University of Salzburg (Paris-Lodron-University)	federal, public	1622 (1964)	16,718/5,749	Theology – Law – Humanities, Cultural and Social Sciences – Natural Sciences
Mozarteum University of Salzburg	federal, public	1841	1,695/976	Music – Theatre – Visual Arts
University of Applied Sciences Salzburg	public	1995	2,525/668	Engineering – Business and Social Sciences – Design, Media and Arts – Health
Paracelsus Medical University	private	2003	908/203	University Clinics – Medical Institutes
Private University Schloss Seeburg	private	2007	328/65	Economics and Management Sciences

*Source: University websites, Unidata, BMWFW

33 Benedictine abbeys of Southern Germany, Austria, Switzerland and Salzburg. The university was closed down in 1810 after Salzburg’s annexation to Bavaria and was re-opened in 1962 as a public university. It started with a Faculty of Catholic Theology and Philosophy, and a Faculty of Law was added in 1965. The Faculty of Natural Sciences was added in 1975, within a university reform that also included a plan to build a Faculty of Medicine, but that plan was never realised. Instead, the private Paracelsus Medical University was founded in 2003. *Mozarteum University of Salzburg* was established around the mid-19th century to provide specialised education in music and the arts. This focus did not change over time and the university became one of the leading European music schools. Mozarteum students, lecturers and alumni have an active pre-

sence in Salzburg’s cultural life and contribute to the region’s image as a culture and classical music hub. The Mozarteum has a great contribution to the region’s cultural prestige as it attracts top musical talents from all over the world and has a high percentage of foreign students (57%). *The University of Applied Sciences Salzburg (FHS)* was established in 1995, shortly after the law allowing the creation of universities of this type in Austria was passed in 1994. It operates as a private company with limited liability, having as shareholders the Arbeiterkammer (.chamber of labour’) Salzburg and the Wirtschaftskammer (.chamber of commerce’) Salzburg, and is located on two campuses, Urstein and Kuchl. Although the law defines both education and research as the mission of universities of applied sciences, the focus on education is dominant. *Paracelsus Medical University (PMU)* is the largest private university in Salzburg and is focused on education and research in human medicine and other health sciences. It was founded in 2003 with the aim to create a regional source of well-educated people and a hub for health research cooperation. The university is managed by a homonymous private foundation and a board of trustees. It has strong institutional and personnel links with the Salzburg County Hospitals in order to base the research on real-time experience and data, and with several universities nationally and abroad. *The Private University Schloss Seeburg*, the youngest among Salzburg universities (est. 2007), takes pride in the quality of life and the enjoyable surroundings of the Salzburg countryside to attract students to management and economic studies. The university defines its mission as an action competence centre aiming to connect science and business.

The education and research performance of two universities – the Mozarteum (Arts & Humanities) and the University of Salzburg – are internationally recognised in Quacquarelli Symonds and Times Higher Education international rankings (Table 2), but none of the five universities appears in the Top 500 Academic Ranking World Universities (ARWU, also known as the Shanghai ranking).

➤ **Educational performance**

In Austria, the capacity of universities to provide well-educated human capital is particularly important in the context of a low mobility of people, which makes it important for every region to educate and retain its own human capital. The percentage of the population aged 25–64 having completed tertiary education in Salzburg has nearly tripled over the last twenty years, from 5.1% in 1991 to 14.4% in 2011 (Source: Statistics Austria), denoting a success of government measures to involve more people in tertiary education. The Salzburg universities produce a large number of graduates relative to other Austrian regions (3.1 university graduates per 1,000 citizens in Salz-

Table 2 International rankings for Salzburg universities
relative to other Austrian universities, AY 2013/14

University	Quacquarelli Symonds rank	Times Higher Education rank
University of Vienna	156	182
Vienna University of Technology	246	226–250
University of Innsbruck	288	201–225
University of Graz	411–420	351–400
Mozarteum (Arts & Humanities)	399	401+
University of Linz	551–600	401+
University of Salzburg	701+	401+
University of Klagenfurt	701+	401+

burg), which ranks Salzburg third in the country after Vienna and Carinthia, and above the national average of 3.0 (Source: Unidata 2012).

The University of Salzburg has a strong educational focus on humanities, social, cultural and natural sciences, and provides the whole range of degrees in these areas, according to the Bologna system (Bachelor, Master’s and PhD). Courses taught in English account for less than 10% of the programme (e.g., 245 courses in the winter term 2014/15, compared to 2,898 courses taught in German). The Mozarteum is focused on music and arts, and provides the whole range of academic degrees in these disciplines (Bachelor, Master’s, and PhD). The University of Applied Sciences (FHS) has a broad spectrum of disciplines (Engineering, Business and Social Sciences, Design, Media and Arts, Health Studies) and grants only Bachelor and Master’s degrees, no PhDs. Similarly to other universities of applied sciences, the FHS aims to build strong links to the regional economy, and its graduates are in high demand in the region. Paracelsus Medical University (PMU) trains students as MDs and grants PhDs in Molecular Medicine. The Private University Schloss Seeburg provides practice-oriented studies in Business, Economics, Economic Psychology, Sports and Event Management, and grants Bachelor, Master’s and MBA degrees but not PhD degrees. Educational activities follow a largely traditional structure. Entrepreneurial education for students is not explicitly addressed in the five universities’ curricula, except for one degree programme in SME Management & Entrepreneurship that was started in 2014 at the University of Applied Sciences. The University of Salzburg offers no specific entrepreneurship programme and has two management programmes, i.e. an Executive MBA and a degree programme in ‘General Management’. Moreover, entrepreneurial education is not present in primary and secondary education either, although it could be useful in initiatives like the ‘Commercial Academies’, which are very popular in Austria. Most Salzburg universities (except for the Mozarteum) share the concern of a relatively low share of foreign students, which varies from nearly 20% at the Private Uni-

versity Seeburg to 57% at the Mozarteum [Source: Unidata, AY 2013/14]. This is largely caused by the low supply of courses taught in English, which is a barrier to international students, but also by the modest marketing efforts for attracting international students, e.g. via the English versions of the university websites⁴. The majority of foreign students are from Germany, which is very close [the University of Salzburg is only 6 km from the border]. The share of foreign graduate students is expected to increase rapidly in the coming years, which is a positive development for the region in terms of international exchanges and cultural mix but can also be a significant drawback as most foreign students return to their home countries after graduation, leaving the region with a deficit of skilled graduates to contribute to local development. The employability of Salzburg university graduates is relatively high, and most of them are employed in the public sector, as revealed by a recent survey conducted in the spring of 2014 by the University of Salzburg⁵. The average time until first employment was identified at 4.2 months, and the highest employability of alumni (about 70%) was in the Humanities, Social and Cultural Studies. The majority of alumni (62.3%) were employed by public institutions while the second largest group (21%) were students involved in PhD or other studies, taking up employment while still in education. The third group (13%) consisted of other types of alumni (trainees, people on leave on sabbaticals or maternity leave, etc.⁶), and the fourth group (4%) were self-employed. Less than half (47.6%) of the employed respondents were working in private businesses while the majority (52.4%) were working in non-private businesses, as a mix of public

⁴ For example, the Private University Schloss Seeburg's website is in German only.

⁵ The survey was conducted among University of Salzburg alumni with a Bachelor, Master's or a PhD degree in order to better understand their employment situation. The observation period was July 2005–March 2014 and the number of respondents amounted to 4,830. The response rate was 22% (1,063 interviewees returned the completed forms between 11 April 2014 and 5 May 2014). The average age of the respondents was 30.8 years.

⁶ Some alumni in this group could also be unemployed, considering that a common practice in Austria is to offer training for unemployed people so that they do not show up in unemployment statistics.

services (36.2%) and non-profit organisations (16.2%). The share of self-employed alumni identified in this survey (4%) is much lower than the rate of self-employed across all branches and educational levels for the Salzburg region (10.5%) [Source: Wirtschaftskammer Salzburg, 2012 data]. This could be due to the high employability rate of University of Salzburg graduates, which does not leave much room for self-employment.

➤ **Research performance**

Only three of the five Salzburg universities perform research activities: the University of Salzburg, the University of Applied Sciences and Paracelsus Medical University. In light of the available data, the research performance of these universities is discussed from the perspective of the public and private research funds received and the different types of public funding available [Table 3]:

Public funding for the Salzburg universities is allocated through the national and regional funding system according to the University Act of 2002, and can be institutional and competitive:

- a. *Institutional funding* is allocated top-down from the federal level through the *General University Fund (GUF)*. It accounts for the largest share (about 90%) of university funding and has two components: a block funding based on a three-year performance contract that considers the criteria 'need', 'demand', 'performance', and 'societal objectives', and a performance-oriented, formula-bound budget share of up to 20%, which is based on indicators for teaching, R&D and societal activities. Every university is eligible for a GUF quota, e.g. the University of Salzburg has a quota of 4.55% and the Mozarteum 1.94%. This quota is not predetermined but has varied very little among the twenty public universities of the country over the last twenty years, subject to changes in the number of students or in the volume of

Table 3 Universities in Salzburg, Funding Structure 2013 (in Euro)

University	Overall budget	Institutional funding (national/regional)	Competitive funding from public authorities	Competitive funding from private sources (companies)
University of Salzburg (Paris Lodron University)	143,700,000	127,700,000	14,000,000	2,059,342
Mozarteum Uni- versity of Salzburg	49,300,000	48,400,000	200,000	700,000
University of Applied Sciences Salzburg*	26,200,000	22,400,000 (14,200,000 national, 8,200,000 regional)	900,000	600,000
Paracelsus Medi- cal University**	not available	1,700,000 (only regional)	6,700,000	770,000
Private University Schloss Seeburg**	not available	not available	not available	33,000

Source: BMWFW, University Budgets, Austrian Science Fund, all 2013, PMU 2012.
* The University of Applied Sciences is funded by national and regional funds according to the respective law and contracts.
** Private universities are not eligible for national funding. They rely on public regional funding and private funds.

research projects. Universities can increase their share of national funding through competitive (project-based) funding.

- b. *Competitive (project-based) funding* has a much lower share (about 10%) and is open to thematic bottom-up approaches.
- Most of the competitive funding for basic research comes from the *Austrian Science Fund (FWF)* for projects submitted by individuals or teams in all science fields. The percentage of FWF grants applied for and grants approved for the Salzburg region relative to the national level has been relatively stable in 1997–2008 at around 6–8% for grants applied for, and 4–6% for grants approved, but a downwards trend started in 2009 and has continued ever since, signalling a loss of competitiveness relative to the other Austrian regions. Also, the ratio between the number of applications and the respective budgets remained relatively stable between 2005

and 2008, but budgets have started to go down since 2009 more steeply than the number of applications, which suggests shrinking project sizes (Source: Austrian Science Fund).

- Most of the competitive funding for applied R&D comes from the *Austrian Research Promotion Agency (FFG)*. The share of approved funds for Salzburg in the period 2004–2014 is low relative to other regions that host at least one public university, like Tyrol, Carinthia and Upper Austria, varying from less than €10 million in 2004 to €14 million in 2014 (Source: Austrian Research Promotion Agency). Another source of competitive funding is the *European Research Council* grants, but they are absent for the Salzburg region (Source: Austrian Research Promotion Agency). The much lower share of competitive funding relative to institutional funding brings about low levels of competition and international peer review. Consequently, there is little evidence on the research quality at the universities.

Private funding (e.g. donations) goes mainly to the private universities, which are prevented by law from receiving public institutional funding for educational purposes from the federal government, and thus their main source for funding remains private donations and competitive funding from regional authorities. For example, PMU gets about two-thirds of its funding from private donations, while the rest comes from regional agencies (e.g., the province and city of Salzburg, Salzburg Regional Authorities Association), tuition fees, research contracts and own income (e.g., further education courses).

From a disciplinary research perspective, Life Sciences have a leading position due to the research capacity of PMU. The establishment of PMU in 2003 was expected to be followed by a significant increase in Life Sciences funding for the Salzburg region, but this expectation was not met, neither in the Austrian Research Promotion Agency (FFG) grants, nor in the Austrian Science Fund (FWF) grants. For example, applied R&D projects in Life Sciences in Salzburg received some low levels of FFG funding

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[around €0.5 million] only in the period 2009–2011, in contrast to other regions like Lower Austria or Upper Austria that had a constant stream of projects during 2006–2013 (Source: Austrian Research Promotion Agency). Also, the percentage of FWF grants applied for and grants approved in Life Sciences for the Salzburg region relative to the national level increased in 2004–2008, subsequent to the PMU inception (from 5% to 7% for grants applied for, and from 2% to 9% for grants approved), but the percentage of approved grants has gone down since 2009, even if the percentage of grants applied for has remained relatively stable. This provides no clear evidence that the 2003 establishment of PMU triggered a breakthrough in the competition with other regions in Life Sciences and, even worse, the highest shares of 7% or 8% reached before 2008 have not been reached again after that (Source: Austrian Science Fund). A similar situation is found also at the level of Life Science projects from Salzburg in the Health Programme of FP7 (2007–2013). Here, a low but stable share of projects is recorded, with funding around €1 million from 2009 to 2013, but there is no sign of increasing numbers of projects and budgets that could be attributed to PMU (Source: Austrian Research Promotion Agency).

University-based centres for cooperation with industry:

Christian Doppler Laboratories and Josef Ressel Centres

The Christian Doppler Laboratories and the Josef Ressel Centres are initiatives of the Christian Doppler Research Association, which promotes cooperation between scientists and innovative businesses. Christian Doppler Laboratories have been established since 1989 at universities and pursue application-oriented basic research at universities or non-university research institutions. In 2013 there were 73 active laboratories employing about 700 scientific personnel. The University of Salzburg hosts six of them. Josef Ressel Centres pursue application-oriented research at universities of applied sciences. In 2013, four centres were active, one of them being

located at the University of Applied Sciences in Salzburg. In both cases, research ideas come from the private sector. The research groups are established for a limited period of up to seven years and are embedded in the respective university environment. The groups have a high degree of scientific freedom and are evaluated at an international level. Around 150 company partners cooperate with the research units.

Non-university research institutions

Salzburg has several non-university research institutions that are active, especially in Humanities, Social and Cultural Sciences (Table 4).

Salzburg Research, a research and technology organisation specialised in applied R&D in ICT and new media is the largest research institution in the region in terms of personnel (75 employees). It receives 30% of basic funding from the regional government, which makes it closely connected to the regional authorities. Among the other research institutions, most (approx. 75) are specialised in Humanities, Social and Cultural Sciences. They are small-sized (about nine employees on average) but overall they account for the largest share of employees in Cultural Sciences (26%) across all Austrian regions (relative to total employees in Cultural Sciences in Austria) and also for the highest share of employees in Cultural Sciences (79%) within the region (relative to total employees in the Salzburg region) (Source: GSK in Österreich, 2008). Overall, the activities of the regional research institutions have a very limited economic and technical orientation.

The funding for these research institutions consists of institutional funding from the region and competitive (project-based) funding from regional, national and European funds (no data available on the shares of these funding streams). The number of grants for Salzburg's research institutions allocated by the Austrian Research Promotion Agency (FFG) increased dramatically in the period 2004–2013, from less than 20 in 2004–2007 to 164 in 2010–2013 and amounted to €2.6 million in 2013 (Source:

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Table 4 Research institutions in the Salzburg region

Research institution	Type	Area of activity	Personnel
Salzburg Research	non-profit	Information and Communication Technologies / New Media	75
Bautechnische Versuchs- und Forschungsanstalt Salzburg	non-profit	Construction / Engineering	63
Academy of Sciences – Geographic Information Science	non-profit	Geographic Information Science	63
Research Studios Austria	non-profit	various	11
Research institutes for Humanities, Social and Cultural Sciences	various	various	N/A (estimated at 675 people at about 75 institutes*)

Source: <http://www.salzburg.gv.at/themen/bildungsforschung>
*There are approximately 300 non-university research institutes in Humanities, Social and Cultural Sciences in Austria⁷, of which more than 25% are in Salzburg, i.e. more than 75 institutes. They have an average of 9 employees [Source: GSK in Österreich, 2008]

Austrian Research Promotion Agency). This high growth in the number of grants allocated by the FFG to the Salzburg region demonstrates a political commitment to provide public institutional funding to the non-university research institutions of the region, but it has not been matched by a similarly high growth of research output, such as patents or spin-offs, which demonstrates a mismatch between national research investment and the region’s capacity for translational research. A large part of the competitive institutional funding for the non-university research sector allocated by FFG was channelled through the COMET programme. While regions like Tyrol or Carinthia obtained COMET funding for K1 centres or K projects, Lower Austria successfully launched a K2 tribology centre in 2010, Salzburg did not

⁷ This estimate is based on the survey ‘GSK in Österreich’ (2008), which identified a total of 583 research institutes in Human, Social and Cultural Sciences in Austria, divided into: university institutes (272); Academy of Sciences institutes (36); Ludwig Boltzmann Institutes (17); other non-university institutes (253).

adequately exploit its potential for K centres. This potential is present, but the institutions need to organize themselves inside the region and cross-regionally. The funding for non-university research institutions in the Life Sciences in Salzburg, which was relatively low at around €300,000 during 2006–2009, started to increase constantly from 2010, reaching approx. €1 million in 2013 [Source: Austrian Research Promotion Agency].

R&D-intensive companies

In 2011, 284 R&D-performing units were recorded in Salzburg [Source: Statistics Austria] with an average R&D investment of approx. €1 million per year. This can be considered quite low in comparison to the leading Vienna region (€1.93 million) or the Carinthia region (€2.02 million), which has a similar gross regional product. Also, the evolution over time of these R&D institutions does not show significant improvements: in 2007 Salzburg recorded 227 R&D-performing units with an average R&D investment of €0.925 million per year. The top 30 companies in Salzburg in terms of revenue and employees are specialised in trade (€43 billion in revenue, approx. 125,000 employees), followed at a large distance by industry production (€3 billion revenue, approx. 12,000 employees) and logistics/services (€2 billion revenues, approx. 11,000 employees) [Source: Wirtschaftskammer Salzburg and Austrian Council, 2012]. Among the other companies, only a few are active in medium/high-tech sectors. They are mostly SMEs that typically do not conduct research activities. Some (usually the medium-sized ones) own a department for development where some incremental innovation is performed.

The R&D activities of the business sector are supported by the Austrian Research Promotion Agency (FFG), which doubled the number of grants allocated by FFG to Salzburg from 269 in 2004–2007 to 546 in 2010–2013, but the region still ranks third-lowest relative to other regions in Austria [Source: Austrian Research Promotion

Agency). The low R&D investments of Salzburg companies suggest a limited contribution to the region's Knowledge Space.

R&D personnel

R&D personnel in Salzburg have increased in the last twenty years, reaching 2,560 FTE employees in 2011, but remain one of the lowest relative to other Austrian regions and also relative to the total of 61,170 FTE employees in Austria in 2011 (Source: Statistics Austria). One main cause for the low numbers is the high proportion of students in Humanities, Social and Cultural Sciences, especially at the University of Salzburg, the leading university of the region. Another important cause is migration (brain drain). Salzburg has a high rate of brain drain that has varied at around 14% for people with a university degree and reached a peak of 18.7% in 2011 (Source: Statistics Austria). The Salzburg brain drain rates for people with a university degree are much higher than those at the national level (16.8% in 2011) (Source: Statistics Austria).

Publications⁸

The publication numbers examined here are only those from the three universities that perform research activities as the publication data of research institutions and companies are not available. This lack of data leaves out a part of the knowledge production potential of the Knowledge Space but this part is not considered to be so important as to change significantly the overall picture of knowledge production presented below. For future publication data records, it would be important to collect

⁸ Publication counts differ from one institution to another subject to the publication type counted (e.g. some only count peer-reviewed articles in journals, others also count non-peer-reviewed publications, contributions to conferences or book chapters). Moreover, the Universities of Applied Sciences do not publish their statistics. Therefore there is no simple way to examine publication statistics for Salzburg or compare them to the other regions. Here we apply the federal ministries' counting method which focuses on the public universities first and then does the same for private universities.

information about joint publications by different actors in the Knowledge Space, e.g. universities and companies in an industrial PhD programme.

Public universities in Salzburg (University of Salzburg and University Mozarteum Salzburg) recorded in 2012 a number of 2,581 publications for 1,230 FTE scientific personnel, resulting in an average publication rate per person of 2.1 (Table 5). This is higher than the 1.8 average rate of the University of Vienna, the largest university in the country, which has 7,386 publications for 3,336 FTE scientific personnel. Among the private universities, Paracelsus Medical University's (PMU) publication numbers are the most important, as the Private University Schloss Seeburg is insignificant in this respect. From its 2003 inception until 2013, PMU's publications increased from 238 (of which 209 were peer-reviewed) in 2003 to 4,052 (of which 3,030 were peer-reviewed) in 2013 (Source: Website PMU, November 2014). Two distinct phases can be noted in the evolution of the publication growth rate in the last ten years: a first phase, from the 2003 inception until 2009, which can be considered as a stabilisation period, with relatively low and constant growth rates, and a second phase from 2010 onwards with higher growth rates of publications in the medical and life sciences sector.

4.2 THE INNOVATION SPACE

The Innovation Space is examined in terms of innovative actors (companies, business support organisations, spin-offs and start-ups) and patents as a measure of the innovation output in the economy.

Innovative companies

An official record of innovative companies is not available as the Salzburg Chamber of Commerce that keeps a record of local companies does not classify them based on innovation-related criteria. Therefore there is no formal data on innovative companies either at the Chamber of Commerce or at the Federation of Austrian Industries

Table 5 Publications by public universities 2010*–2012
(Vienna and Salzburg region)

University	2012	2011	2010
VIENNA			
University of Vienna	7,386	7,854	7,825
Medical University of Vienna	2,631	2,530	2,390
Technical University of Vienna	4,892	5,086	5,232
University of Natural Resources and Life Sciences Vienna	1,934	2,042	1,847
Veterinary University of Vienna	1,104	969	911
University of Business Economics Vienna	905	838	862
University of Modern Art Vienna	176	152	150
University of Music Vienna	351	340	217
Academy of Art Vienna	219	235	304
Total	19,598	20,046	19,738
SALZBURG			
University Mozarteum Salzburg	291	223	174
University of Salzburg	2,290	2,099	2,127
Total	2,581	2,322	2,301

Source: Unidata
*In 2010 Unidata started to collect overall publication data in a systematic way.

or at the Commercial Section of the regional ministry. All these institutions stated in autumn 2014 that they were in the process of collecting the respective data. Therefore the innovative capacity of Salzburg companies is estimated indirectly, using as proxy the start-up intensity (ratio of new companies relative to existing ones). This ratio varies a lot between the regions, and for Salzburg it is of 6% – one of the lowest in the country, far behind the 23% and 21% shares in Vienna and Lower Austria, the leading regions in this respect (Source: Statistics Austria). This indicates low renewal dynamics in the business sector.

The promotion of start-ups is part of the political agenda all over Austria. Start-up support and coordination are provided by the regional chambers of commerce. In 2012, the start-up intensity relative to regional chamber's members (% of active members of the Chamber of Commerce) and citizens (start-ups per 1,000 inhabitants) for the Salzburg region was 6.5% and 4.0% respectively. Relative to other regions of the country, these figures were the third lowest, standing below the Austrian average of 7.9%, and 4.2%, respectively (Source: Wirtschaftskammer Salzburg). However, relative to the region itself these values are the highest in the last two decades. The same rank of third lowest is also retrieved when considering the share of Salzburg start-ups relative to all start-ups in Austria and relative to all members of the Chamber of Commerce in Austria in 2012 (6% and 7.3% respectively) (Source: Chamber of Commerce Salzburg).

The low start-up intensity could be attributed to the presence of a core group of trade, logistics and tourism industries that have low innovation levels, but also to the large numbers of graduates in Humanities, Social and Cultural Sciences who are employed in a large majority in the public sector and leave a very small pool of start-up candidates. This low number could possibly grow if a stronger entrepreneurial culture existed in the region. Entrepreneurial culture is characterised in the literature (Gee/Miles, 2008) on the one hand by a 'spatial dimension,' which exists in Salzburg due to the obvious attractiveness of the region to the creative class, especially in music and arts, but this is not matched by the other dimension – the 'organisational dimension.' This is related to the ability of organisations to foster innovation and to the existence of an innovation culture that supports free flow of knowledge within the respective organisations and an entrepreneurial spirit pervading from the top-level management down to the lower levels. There is no evidence in Salzburg that top-level management promotes such culture. In addition, the legal and financial steps to start a company in Austria are not very simple, as demonstrated by Austria's 101 rank in the

World Bank’s 2014 ‘Starting a Business’ ranking (www.doingbusiness.org), just between Tunisia and Antigua. Compared to Finland (Rank 27) and Sweden (Rank 32) as European innovation leaders, this is a high barrier. There are several offers from the Chamber of Commerce and other institutions for legal advice, but that is not sufficient to generate a faster start of businesses.

Business Support Organisations

In Salzburg, business support organisations are represented by five Techno-Centres (Impulszentren/IZ) and two Technoparks (Table 6) that are managed by universities, notably by people who have little work experience in industry, and thus industry demand is not sufficiently considered in the transfer activities of these institutions. Technoparks have a long tradition in the Salzburg region. Their success was always determined by the level of capacity utilisation, so that a key priority of park managers was to fill the space available to the maximum. This leads to a distorted use of the park, from innovation support to real estate development. There are also innovation support services within Salzburg that provide consulting services to all the Innovation Space actors. For example, Innovation Service Salzburg is financed by the regional government and the regional Chamber of Commerce. Additional partners are the Federation of Industries, the University of Salzburg, the University of Applied Sciences Salzburg (FHS), Salzburg Research, the Techno-Z Techno-Centres and the Investment Promotion and Investor Service Agency Salzburg.

Spin-offs

The most important source of academic spin-offs in the Salzburg region is the national (public) incubator Business Creation Center Salzburg (BCCS), which was created as the academic incubator of the Salzburg federal state. It supports university spin-offs founded by graduates and staff that can stimulate regional innovation

Table 6 Business support organisations in the Salzburg region, 2013

Business support organisation	Number	Number of companies/of which newly founded	Workplaces
Techno-Centres (IZ)	5	57/28	377
Technoparks (TP)	2	96/63	646

Source: <http://www.innovationszentren-austria.at>

potential. BCCS receives funding from the federal government (Federal Ministry for Transport, Innovation and Technology) through the AplusB programme for supporting academic spin-offs managed by the Austrian Research Promotion Agency (FFG), and is also co-funded by the federal state of Salzburg. The University of Salzburg and the University of Applied Sciences Salzburg are BCCS shareholders, and they also engage Key Technology Ventures Karlsruhe. BCCS hosted eight start-ups in July 2014 and employed four people for supporting them, while the start-ups employed twenty-two people. The number of incubated companies at the Salzburg BCCS as well as the number of workplaces thus created are average relative to other regions. The number of employees in BCCS is high compared to international business incubators who employ on average one person per seven start-up companies. At the end of 2014, it was announced that the BCCS funding will not be continued and the incubator will stop its activities in 2015. It is not known yet what successor for hosting start-up companies will be created.

Centers of Competence in the COMET programme

The COMET programme was launched by the Ministry of Science, Research and Economy and the Ministry of Transport, Innovation and Technology in 2006 to foster long-term science-industry cooperation for top-level research (Source: Austrian Research Promotion Agency). The programme operates through: K2 centres, which have minimum one scientific partner and five company partners, run for 10 years with

a maximum funding of €5 million per year and a public funding share of 40–55%; K1 centres; and K projects that operate with shorter running time and less funding. Salzburg is at the lower end of the regions participating in the COMET programme during 2006–2013, with one participation in a K1 centre that is, however, not situated within the region of Salzburg, and three K-projects (no K2 projects). It attracted only 1% of the funding available through this programme, one of the lowest amounts compared to other regions (Source: Austrian Research Promotion Agency). The capacity of the Centers of Competence to stimulate university-industry cooperation projects was considered to be the most important element of their mission (Technopolis, 2013, 40), but the low numbers for Salzburg indicate a limited capacity to do so, both within and beyond the local borders.

Patents

In 2012 Salzburg ranked third-lowest relative to other Austrian regions with 16.8 patents per 100,000 inhabitants, a level that is below the 26.9 country average and far behind the leading region of Upper Austria's 45.6. The number of patent applications per million inhabitants for the Salzburg region has been relatively constant at around 100–150 over the period 1998–2013, ranking third lowest relative to other regions, while the number of patents filed in the same period has also been relatively constant at around fifty, with a peak at eighty-five in 2006 (Source: Austria Patent Office). Salzburg patent applications at the European Patent Office in Munich, where most of the globally-acting Austrian companies apply, ranged between 100–230 per million inhabitants in the period 2000–2010, with a decline after 2007 that is also visible in many other regions (Source: Eurostat). The low patenting levels can be explained by the lack of significant high-tech companies and technological infrastructure and the low capacity for applied R&D of the local companies, most of which are active in trade, logistics and services. The stability of the patenting levels

can be attributed to the relatively constant nature of this regional structure, which changes slowly over time.

4.3 THE CONSENSUS SPACE

The Consensus Space is examined in terms of key governance actors at the national and regional level, the mechanisms of the consensus-making process, and the legal framework and relevant programmes for research and innovation.

Key governance actors

Research and innovation governance in Austria is performed at national and regional levels, both of which include three administration levels with specific responsibilities (see Fig.1):

- a policy level: policy-making and trans-regional negotiations
- a civil servants level: strategy based on policy requirements
- an agency level: policy implementation and one-stop-shop for research

The policy level consists of a regional minister, the governor and the Salzburg Research Council:

- The governor of the Salzburg region is not only the head of the regional government, but is also responsible for several topics, one of which is economic policy, applied research and innovation.
- The regional minister is in charge of universities, science and research, as well as a department responsible for the implementation of these issues.
- The Salzburg Council of Science and Research was established by regional law in 2002 and was therefore the first regional advisory body in Austria. It was followed by similar bodies in Upper Austria in 2003, in Styria in 2005 and in Burgenland in 2014. It supports the development of the Salzburg region in all aspects of science,

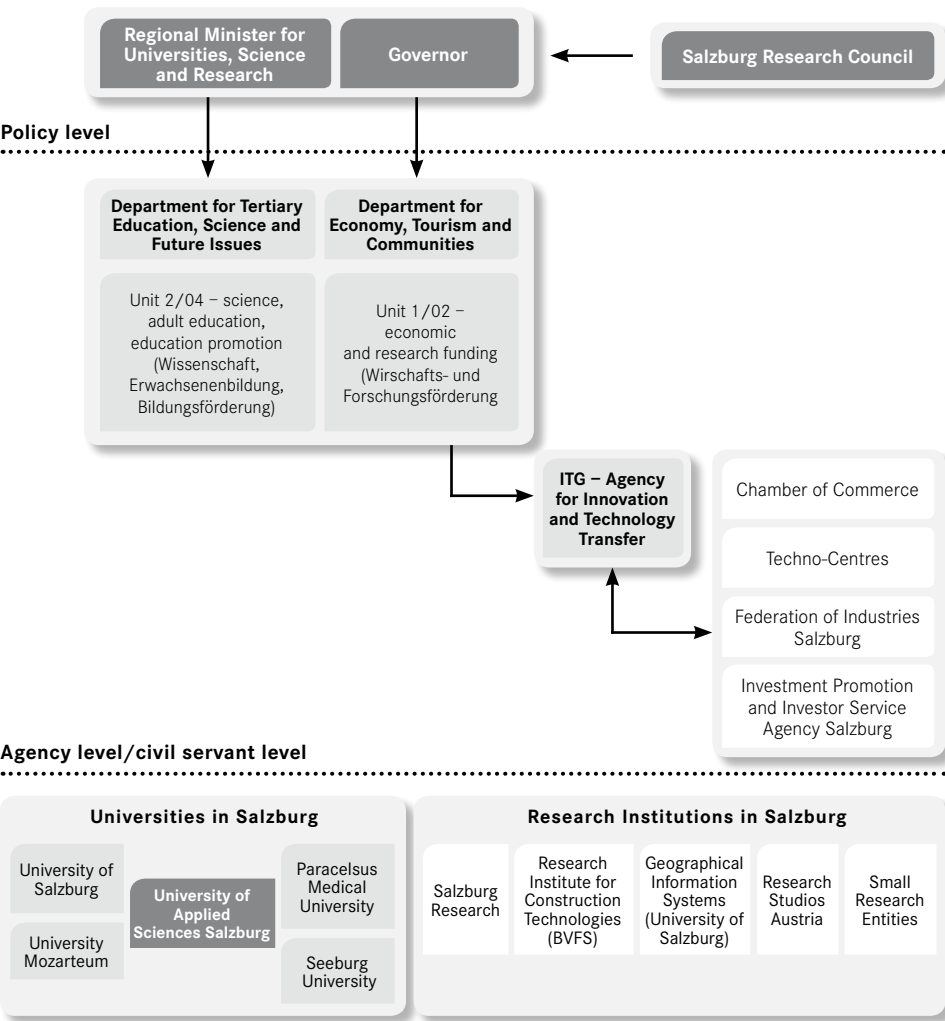
research and economic development. The council consists of 14 members who hold influential positions in relevant R&D institutions in the region, like the University of Salzburg, the University of Applied Sciences or the research institutions. Therefore they can address broad research and innovation aspects and draw conclusions about the strengths and weaknesses of the region. A dilemma they are confronted with, however, is whether to take a critical view of the work of the institutions they represent, which sometimes implies the need for a change of institutional setting, or to represent the interests of these institutions in the Council and maintain the current state of play without changing the setting. One operational aspect that weakens the council's recommendations is that their recommendations are not published and therefore no public discussion takes place of their background and consequences. Until 2013 the Council adopted about 120 recommendations in 36 meetings.

The civil servants and agency levels are mixed in the management of the Agency for Innovation Services, the Department of Tertiary Education, Science and Future Issues, and the Department of Technology and Innovation. On the one hand, this strengthens the collective strategy implementation process, but on the other it reduces the potential freedom of movement of an agency that is not dependent on political limitations in its everyday work. A principle of subsidiarity operates within all these levels.

The consensus-making process

The consensus-making process requires effective communication between institutions and individual actors. In the case of Salzburg, communication has been problematic. After the 2004 elections, political power was shared quite equally between two parties (Socialist Party, SPÖ, and Conservative Party, ÖVP), and trust between individuals had shrunk to a minimum because of strong political competition. The manifest distrust and deep political conflict prevented the political class and their

Figure 1 Key governance actors in the Salzburg region, 2014



Source: Authors' compilation

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downstream civil servants to design and implement measures that would have been necessary to correct the regional innovation deficiencies. Institutional communication lines had dried out because individuals were never sure about the level of details they were allowed to discuss at. This pattern is even more important if we broaden the focus from an intra-regional to an inter-regional view. From outside, the Salzburg system was opaque because of the lack of information and communication. Contact partners could not provide information for cooperation issues and consequently cooperation did not take place, resulting among other things in a weak performance on EU programmes. A similar lack of communication existed also between research-oriented activities and economy-oriented innovation activities at all three administration levels discussed above. This situation generated a real administrative chasm, going down from the top, where there were two regional ministers responsible for research and innovation, one with a basic research orientation (from the Socialist Party) and the other with a more applied research orientation (from the Conservative Party), all the way to the civil servants and the agency levels, where there was a clearly defined representation of one or the other side.

After the May 2013 elections, the situation changed as a result of a change in the structure of the coalition in power, from two quite equal parties before 2013 to three parties, with one leading party and two smaller coalition partners. At the lower levels of the civil servants and agency, the representation remained largely unchanged. The decision-making process also changed in the sense that decisions made at the policy level are now implemented within the whole administrative system and not just within one side of the chasm. The political change was expected to improve the institutional communication but that didn't happen significantly. With a new government after the May 2013 elections, expectations have been high that the communication deficiencies would be overcome, but the old patterns are still visible as the institutions remained very cautious about providing information to outside organisations. For example, in

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April 2014 the President of the Regional Parliament asked the regional government what the recommendations of the Salzburg Council were since it was founded in 2002 and which recommendations have been implemented. On the one hand, the question was as an expression of regular political work, but on the other it confirms the lack of communication and the persistence of the administrative chasm described earlier. Even if organisations like the Salzburg Council described above have performed quite well within their statutes, the effect was not visible in the implementation work of the regional administration.

Institutional communication among Consensus Space actors is uneven. There are many initiatives for information exchange, which are managed to a large extent by the political level, especially by civil servants and special interest groups. The Chamber of Commerce serves its members very well, and so does the Department of Technology and Innovation in the regional government, but a platform for cross-institutional communication is missing (e.g., one where the University of Applied Sciences could learn more about future planning of the University of Salzburg, or where universities could learn more about the needs of industry in order to elaborate a complex application for the COMET programme). In brief, the Consensus is missing. The Future Strategy of the regional administration indicates measures to provide a more efficient governance system for the future⁹.

Legal framework and most relevant policies and instruments for research and innovation

The legal framework situation in Salzburg is in line with all other regions regarding European, national and regional policies and instruments. A region can influence the framework conditions through formal and informal communication between the nati-

⁹ <http://www.salzburg.gv.at/en/standortzukunft-kurzfassung.pdf>.

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onal and regional level, but has much fewer possibilities to change regulations established at the European level such as European competition law, which is regarded as a fixed framework. The negotiations at the national/regional level are influenced by the shares of R&D funding at each of these levels, i.e. about 10% regional and 90% national. Therefore national policies are expected to be decided predominantly at the national level, and will first meet the needs of the regions that have a higher regional R&D funding. For example, programmes like AplusB do not fit equally to all regions, and the centres established in Vienna and Styria with support from this programme are better off than the centres in regions with a smaller amount of R&D funding. Regional policy priorities include: gender, transparency and strengthening of competition¹⁰.

Two laws have an important impact on research and innovation: the public university law and the private university law, which are briefly described below.

➤ **Public University Law**

The University Law has been in a permanent change process since World War Two, but three major moments marked significant changes. The first was in 1975 and aimed to broaden university access to all levels of society, not only to the rich. That change has not produced satisfactory results, as today still a person's education level is largely influenced by the social status of the parents. The second major change was in 1993, when terms like efficiency, management and evaluation were introduced and the main lines of today's governance model were established. The last major change was in 2002, introducing the autonomy in the university organisation and management, as well as their financial independence implemented via three-year performance contracts. Despite these changes in the legal framework, actual changes in the compe-

¹⁰ http://www.salzburg.gv.at/themen/bildungforschung/obtree_allgemein-forschungswissenschaft.htm

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tition among universities did not happen because the percentage of funds allocated to each institution in the university system did not really change. The funding level is already fixed when a new performance contract is negotiated, and policymakers at the federal level do not move large portions of money from one university to another. This confines universities in any region, Salzburg included, to its financial framework and also introduces limitations on a university's motivation to be more competitive. Even the Austrian Science Fund (FWF) cannot solve this challenge, because on the one hand the competitive basic research funding it provides is low compared to the basic institutional funding, and on the other success rates are low and the motivation of university researchers to apply for grants is limited as well. Only 20% of university researchers ever place an application for a Science Fund grant in their career. To put that into an international context, in Denmark the application level is more than 70%.

➤ **Private University Law**

Private universities have a short history in Austria. The respective law was passed in 1999, giving the possibility to any person in Austria to apply for the foundation of a private university. The application is validated by the Accreditation Council. The process is competitive, as reflected by a relatively low success rate of applications, which is only around 15%. Private universities create an opportunity for the regions to establish additional education and R&D capacity without relying on national funding, as private universities cannot get national basic funding for education purposes. Since 2007, they are allowed to get national funding for R&D. This was also the case in Salzburg, which had originally planned to establish a Faculty of Medicine at the public University of Salzburg since its reform in 1975, but eventually managed to do so in the form of the private Paracelsus Medical University (PMU) created in 2003. At the end of 2014, there were twenty-four private universities established all over Austria. Some of them were established in regions that have limited access to public universities and

therefore fill a regional gap in the supply of tertiary education. Most private universities focus on education and have no or just limited capacity of R&D.

There is one major difference between public and private universities – except the funding regime – that needs to be stressed here: private universities can decide upon the admission rules and enrolment fees of their students while public universities cannot. This is a qualitative (selection of the best students) and quantitative (financial autonomy) disadvantage of public universities.

Regional strategies

The local economic development strategy is the main economic strategy in Salzburg. The previous edition of the strategy¹¹ elaborated in 2003 noted Salzburg companies' low demand for public support for technology and innovation (p. 79) and the lack of big companies who could process more than one research project each year. These aspects are in line with our findings in the Innovation Space. The current edition of the strategy¹² elaborated in 2011 also mentions the low production capacity and innovation capacity of the region (p. 31). Nevertheless, the economic situation of the region is seen as very prosperous with a positive outlook, as demonstrated by the thousands of jobs created especially by the car importers registered in Salzburg. While the turnover and profitability of these companies is actually impressive, there is little to no technology and innovation connected with the activities of these companies, which is a disincentive for the creation of start-ups and the development of an entrepreneurial culture, as stated in the Innovation Space.

The strategy on tourism¹³ also contains a section on service innovation. Activities in this area started in 2013 and aim to establish Salzburg as a hub for innovative tourism projects.

¹¹ <http://www.salzburg.gv.at/wirtschaftsleitbild-langfassung.pdf>

¹² <http://www.salzburg.gv.at/ssz-wipro2020.pdf>

¹³ http://www.salzburg.gv.at/strategieplan_2020_-_internetversion.pdf, p. 36

Research and innovation measures

Regional programmes for R&D and innovation are implemented within the legal framework for regional R&D and innovation support. Regional R&D support accounts for about 10% of the overall public investment in R&D in Austria. There are several regional programmes implemented by the regional Ministries for Science and Research. The research-oriented part is provided by the Department of Tertiary Education, Science and Future Issues¹⁴. The programme scope is not defined in detail; institutions and individuals can apply for research projects that are not defined in financial or disciplinary terms, but follow certain formal guidelines. Regional support for the innovation activities of companies is largely provided by the national Research Promotion Agency that has a cooperation contract with the Salzburg region. Nevertheless the region also has its own innovation support measures¹⁵, but the amount of money available for a project is limited to €20,000. In addition, there are several consulting initiatives to promote innovation activities in the region, including a specific coaching programme.

Public support measures for innovation include innovation vouchers of either €5,000 or €10,000, used by the Austrian Research Promotion Agency to help the research and innovation activities of SMEs and stimulate their cooperation with research institutes. Public support is managed by the regional ministry on the basis of the above-mentioned economic strategy for Salzburg 2020.

Private support measures for innovation are weak because of the weak links between the local R&D community and potential private funding institutions or individuals, but also because of the overall situation of the risk capital market in Austria. Austria is

¹⁴ http://www.salzburg.gv.at/foerderung_beratung

¹⁵ <http://www.salzburg.gv.at/themen/wt/forschung-unternehmensbezogen.htm>

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part of the Basel System, which prevents banks to engage into high-risk projects of companies or start-ups. The venture capital market was traditionally weak all over Austria and was further weakened during and after the years of the economic crisis started in 2008. In 2013, the European Venture Capital Association (EVCA) ranked Austria in terms of investment volume in risk capital not only behind the innovation leaders but also behind Eastern European countries like Poland. The argument that Austria is a small country is not valid because countries of comparable size like Sweden, which is about the same numbers in population and GDP, has twenty times higher volume of risk capital than Austria (Source: EVCA, 2013). In terms of the GDP share of investment volume, the picture is even worse, as Austria finds itself at the lower end, in a region of emerging countries like Romania, Hungary, Czech Republic or the Baltic countries (Source: EVCA, 2013). As these countries are also part of the Basel system, an explanation comes from a long record of low investment volume in Austria relative to the neighbouring countries. For example, while Germany recovered from the last crisis and investment numbers went up slowly, investments in Austria shrunk every year (Source: EVCA, 2013). For policy-makers, this should be an alarm signal of losing competitiveness in Austria, but no action has been taken to change a risk-averse society. European private equity and venture funds invested €88 million into Austrian companies in 2013.

Smart Specialisation Strategy

The Smart Specialisation Strategy is part of the regional plan to identify regional focus areas and include them into a strategy for participation at European level. The planning was in progress in autumn 2014 and is scheduled to be finished in 2015.

5 DISCUSSION

This section is structured around the two research questions that guided our study.

a. What are the main features of the Salzburg region as a Triple Helix System of regional innovation?

The regional innovation performance of the Salzburg region as a Triple Helix System is determined by the structure of and interactions between the Knowledge, Innovation and Consensus Spaces. The analysis identified a Knowledge Space that is better developed relative to the Innovation and Consensus Spaces but weak relative to other Austrian regions in terms of education and research performance. The interactions between the spaces are very limited.

The Knowledge Space is concentrated in five universities. Only two of them (Mozarteum and University of Salzburg) are internationally recognised. Salzburg universities produce a large number of graduates relative to other Austrian regions and above the national average. Most of them are trained in Humanities, Social, Cultural and Natural Sciences (University of Salzburg), Music and Arts (Mozarteum) and Medicine (Paracelsus Medical University), and comparatively much fewer students are trained in Engineering, Business and Management Studies (University of Applied Sciences and University Schloss Seeburg). Education is largely traditional, with little emphasis on entrepreneurial education (only one degree programme on SME Management & Entrepreneurship is taught at present at the University of Applied Sciences, started in 2014). Courses taught in English account for less than 10% of the programme and foreign students are in relatively low numbers in most Salzburg universities (except for the Mozarteum). The majority of foreign students are from Germany, which is in close proximity, and leave the region after graduation, which creates a deficit of highly educated human resources for local development. University graduates have a high employability and most of them go to the public sector with only few becoming self-employed. The research performance of the universities is relatively low and has

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developed at a much slower pace than the volume of public R&D investment allocated in recent years. Both the education and the research performance of universities are strongly influenced by the funding flows, which are dominated by institutional funding, with low levels of competitive funding and international peer-review assessment of research quality.

The Knowledge Space also includes several non-university research institutes that are small-sized and are active mainly in Humanities, Social and Cultural Sciences, with very limited economic and technical orientation. They received an increasing amount of public institutional funding from the Austrian Research Promotion Agency (especially through the COMET programme), but that has not been matched by a similarly high growth of research output such as patents or spin-offs. This shows a mismatch between national R&D investment and the region's capacity for translational research. There are also few R&D-intensive companies, with relatively low R&D investments. The top 30 companies in Salzburg in terms of revenue and employees are specialised in trade, industry production, and logistics/services. Among the rest, only a few are active in medium/high-tech sectors. They are mostly SMEs that typically do not conduct research activities and most often have a department for development that performs some incremental innovation (usually the medium-sized ones). The R&D personnel numbers and publication output for the region are also low.

The Innovation Space is generally weak. The innovation performance of local companies is not formally assessed by the local authorities, and one related indicator – the start-up intensity (the ratio of new companies relative to the existing ones) – is one of the lowest in the country (6%), suggesting low renewal dynamics of the business sector. The low start-up intensity could be attributed to a poor entrepreneurial culture, a relatively complicated start-up registration process, a limited pool of start-up candidates among the university graduates, who are trained mostly in

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the Humanities, Social and Cultural Sciences and are employed in a large majority in the public sector, and also to the presence of a core group of trade, logistics, and tourism industries in the region that have low innovation levels. The Innovation Space also includes several business support organisations (five Techno-Centres and two Technoparks) that do not sufficiently consider industry demand in their transfer activities. Technoparks relate their success to the level of capacity utilisation, turning the park more into a real estate development instrument rather than an innovation support one. Academic spin-offs are incubated in the national (public) incubator Business Creation Center Salzburg (BCCS), which is funded by the federal government and co-funded by the federal state of Salzburg, but will be discontinued from 2015. Salzburg had a low participation in the COMET Competence Centers programme during 2006–2013 and attracted only 1% of the funding made available through this programme, which indicates a very limited capacity of the Competence Centres to stimulate university-industry cooperation projects. The patent numbers rank Salzburg third lowest relative to other regions and are related to the lack of significant high-tech companies and technological infrastructure, and low capacity for applied R&D of the local companies.

The Consensus Space is well-represented in terms of institutional actors, legal framework and policy instruments, but its effectiveness is reduced by a lack of communication and trust between them, primarily for political reasons. Although each single institution can be considered successful in implementing its own strategies, the consensus on common goals and the collective energy to bring the region forward is missing. This could be also a consequence of political attention being oriented mainly towards the dominant topic of culture and arts and less towards research and innovation.

b. What policy measures can be adopted, from a Triple Helix System perspective, to enhance regional innovation in an essentially cultural and touristic region like Salzburg?

The policy measures proposed below have as underlying objective a stronger connection between the nature of the region's knowledge base and its institutional setup, in line with literature insights (e.g. Martin/Trippl, 2014).

Strengthening the Knowledge Space:

- *Reduce the institutional funding of universities and research institutions and increase competitive funding.*

As we have seen, the funding flows of universities and research institutions are a major determinant of their education and research performance. At present, the institutional funding allocated through the General University Fund (GUF) is high (about 90%) and relatively fixed, which has proven to be a disincentive for universities to attract more competitive funding and become more visible internationally.

- *Stimulate the enrolment of students in Technical (STEM) and Natural Sciences*

The large number of students enrolled in Humanities, Social and Cultural Sciences in Salzburg is not necessarily related to a determined wish to follow a career in these disciplines but can also be the result of insufficient information about alternative opportunities in technical, engineering and natural science. Therefore, better information about these disciplines should be provided in order to allow broader career options (e.g. a Science Day or other awareness measures supported by the government).

- *Strengthen the human capital for research and innovation*

The analysis of the Knowledge Space revealed a limited availability of R&D personnel in Salzburg, which, in spite of a continuous increase over the last twenty years, is still one of the lowest among Austrian regions. Increasing the number of R&D personnel implies not only an increase in the number of students enrolled in STEM disciplines but also a better retention of graduates in R&D institutions and better measures against the high migration (brain drain) rate of the region, which is especially high for people with a university degree.

- *Strengthen the entrepreneurial education for students*

Entrepreneurial education for students is currently represented only by one dedicated programme in the University of Applied Sciences and two management programmes in the University of Salzburg, with no clear approach to entrepreneurship at the lower education levels. The entrepreneurial education needs to be strengthened, in parallel with a broader redesign of the education system, in order to ignite the entrepreneurial spirit in students. Also, new teaching and learning methods need to be introduced for this purpose, including online learning, gaming, etc.

- *Intensify efforts to retain university graduates to the region*

A large number of university graduates (especially the German students) leave the region after completing their education, creating an important knowledge deficit for the region. The political option for the future in this respect is not to prevent German students' access to Salzburg education institutions but to motivate them stay in the region and use their knowledge for regional benefits. The main incentive for young graduates to stay in the region is to offer them attractive job options. As the employment opportunities in local firms are limited, start-up creation, especially in arts and culture, could be one way to inspire young human capital to stay.

- *Increase universities' international visibility in education and research*

International visibility in education could gain from the introduction of more study programmes taught in English and better international marketing, while the research performance could gain from the introduction of an international peer review system to improve the research quality assessment. Moreover, the university's responsibility for being a hub for the regional knowledge needs to be reinforced.

- *Increase the orientation of research activities to regional economic and societal needs*

This objective could be realised through a better correlation between research and the priorities of the local economic development strategy, *Salzburg. Business Loca-*

tion Future. Economic programme 2020. The strategy defines Salzburg's mid- and long-term economic policy around four main objectives: (i) attractiveness for business, work and life, and for recreation; (ii) economic integration in national and international activities; (iii) further evolution as an innovation and science-oriented region; (iv) sustainability integration into the economic system. The strategy was developed in 2011 before the political change in Salzburg in 2013, and its viability after 2013 depends on the political decisions of its author, who is now the Salzburg governor and in charge of implementing the strategy. At the same time, a greater focus on societal needs is necessary as the economic strategy in Salzburg focuses more on implementation support processes than on societal needs. The local needs (public and private demand) can be best addressed if the strategy gives a clear and realistic picture of the existing situation instead of a very positive one based primarily on political wishful thinking. It needs to communicate the region's current challenges in a straight and open manner, combining political intentions and vision with clear mechanisms for action.

Strengthening the Innovation Space:

➤ *Improve the entrepreneurial culture and the business environment for start-ups*
The ability to provide good business opportunities, mobilise resources to realise them and provide a favourable business framework (from registration, legal advice, recruitment, accounting, marketing, to IPR protection) are key framework conditions for an innovating region and, at the same time, good incentives for starting up new businesses. New companies need a competitive environment to be able to challenge the established players in the market, and they also need partner institutions that are able and willing to share the risks. These services demand a high amount of upfront investment, and in Europe young companies typically pay for these services like established companies. The links between entrepreneurs who contribute to breakthroughs and larger firms that take them up and further develop them with

continuous incremental innovation are also important. Salzburg shows a traditional pattern of business framework conditions. Legal and tax services are the same as for large companies with high turnover and profits. Evidence in the Innovation Space shows low numbers of start-up intensity and a solid market specialised in services, trade and logistics. A renewal of this regional configuration, which shows strong patterns of path dependency, could be achieved by attracting more STEM graduates to the region and encouraging them to start new businesses. Public investment could be focused on consulting services for start-ups in the fields of tax and legal issues.

➤ *Stimulate both the supply and the demand sides of innovation, especially in connection with the needs derived from the region's rich cultural tradition.*

The discussion of the Innovation Space in Salzburg reflects a low innovative capacity of the region with a relatively weak innovation supply and even weaker innovation demand. Both these aspects could be significantly improved if they were better connected with the needs derived from the region's cultural traditions. Public procurement, a typical instrument for enhancing innovation demand, is not a topic on the political agenda in Salzburg. Neither is a concern for finding cultural industries managers with good technological background that could be relevant for their cultural business profile. At the same time, consumers, as another aspect of demand, need better awareness on how they, and society more broadly, can stimulate the innovative capacity of the region. On the supply side, local researchers need to be encouraged to open their laboratories for a deeper understanding of their work by society. More policy initiatives for innovation diffusion need to be promoted, including technology and market intelligence, organisation of dialogue between users and suppliers, better articulation of the innovation demand. Innovation supply and demand need to be a much broader part of the debate for a sustainable development of the Salzburg region, on the same level and even more important than the main discussion topics of tourism and classical music. The innovation culture needs to be reinforced, based

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on the values and traditions of the region, and government can play an important role in this respect by creating new attitudes and values and ultimately cultural change. Although the expectations for change in the current political establishment are low, future governments could increase the entrepreneurial motivation among society and promote a stronger innovation culture.

Strengthening the Consensus Space:

➤ *Improving the consensus-making process, especially communication*

The Consensus Space in Salzburg suffers from a lack of good communication and trust between the major institutional actors, both locally and with national and international partners. Much of this situation is politically driven and is more difficult to change, but improvements could emerge from enhanced national and international cooperation, which can open new ways of access and exchange of experience and human capital with other innovation cultures.

6 CONCLUSIONS, LIMITATIONS OF THE RESEARCH, DIRECTIONS FOR FURTHER RESEARCH

The historical development of Salzburg made it a region with a rich and vibrant cultural heritage. This cultural legacy is a burden and an opportunity at the same time. The burden comes from the fact that the majority of university graduates are absorbed into Humanities, Social Sciences and especially Cultural Sciences that are not directly transforming knowledge into innovation, while the number of people available for Technical, Engineering and Natural Sciences is low. The opportunity comes from the immense creative potential of the region, demonstrated by successful cultural events and cultural sciences. That opportunity needs to meet the entrepreneurial spirits, and more efforts need to be made to increase knowledge and motivation for entrepreneurial action both among students and society at large. Universities have a big responsibility to develop this knowledge and motivation, but the primary and

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secondary education systems also have their share of responsibility in planting the seeds of the entrepreneurial spirit. Moreover, a stronger innovation culture needs to be developed, in parallel with more incentives to attract and retain well-educated human capital to the region, increase the competitiveness of local firms, motivate knowledge transfer and reduce lifelong convenience.

The main limitations of this study come from the scarce availability of research and innovation indicators at the regional level (NUTS2) to allow a more accurate assessment of the region's innovation performance, as well as from the lack of data on the connections between the cultural base and research and innovation performance. This could be a valuable direction for further research. More specifically, it would be interesting to explore which cultural aspects of the region could support the desired innovation targets, what type of entrepreneurial support and policy measures would be needed to implement that, and how path dependency can help or hinder the process.

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CHAPTER 3

DESIGNING THE FUTURE – WITH OR WITHOUT INNOVATION

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COMPETITIVENESS AND GROWTH POLICY DESIGN

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1 INTRODUCTION

After decades during which governments in developed countries would privilege domestic demand as a main driver of economic growth, the advent of globalization has forced governments to increasingly turn their attention to the competitiveness of the domestic economy, i.e. the extent to which a country can export its production abroad and thereby 'exchange goods and services in which it is abundant for goods and services that it lacks' (Altomonte et al., 2012).¹

Meanwhile, trade economists have themselves evolved with regard to how the issue of competitiveness should be approached. Thus, as clearly explained by Bernard et al. (2011), while theories of international trade used to emphasize inter-industry trade and therefore the view that international competition is between countries, with each country playing on the industries in which it has a comparative advantage, recent theories emphasize firm-level competition worldwide and intra-industry trade. As well put by Altomonte et al. (2012), 'it is not really the country that exchanges [...] goods and services, but rather its firms.' According to that view, what makes a country competitive is primarily what makes its individual firms competitive.

And what makes an individual firm competitive on the world market are both the firm's productivity and the firm's size: here the seminal theoretical contribution is by Melitz (2003), who develops a model of intra-firm trade with heterogeneous firms, where only firms that are sufficiently productive can become exporters, as being

¹ The recent fiscal devaluation in France due to the introduction of the CICE (Crédit d'impôt pour la compétitivité et l'emploi), gave rise to a heated debate between the advocates of demand-driven policies and those who emphasize the need to increase the country's competitiveness.

more productive allows firms to secure a market share which covers the fixed cost of exporting.²

This prediction is confirmed by cross-country firm-level evidence (e.g., see Altomonte et al., 2012), and it has important policy implications for how to enhance the competitiveness of the domestic economy: in particular, departing from 'vertical' or 'top-down' policies that would emphasize national comparative advantage based on current national factor endowment, the new theories call for more horizontal policies to favor productivity growth and size growth of individual firms in the country.

This paper will be organized as follows. In Section 2 we summarize the main arguments in the recent trade literature in favor of a firm-level approach to competitiveness. In Section 3 we link firm-level competitiveness to productivity. In Sections 4 and 5 we discuss potential determinants of firm-level productivity and productivity growth. In Section 6 we consider potential barriers to the growth in firm size. In Section 7 we revisit the role for vertical targeting (or sectoral policies). Section 8 will draw on our discussion to propose some elements of a new growth strategy for China. Based on our conclusions presented in Section 9 we then develop a simple model in which trade liberalization fosters productivity growth.

2 FROM INDUSTRY-LEVEL TO FIRM-LEVEL COMPETITIVENESS

Until Melitz's seminal contribution to trade economics (2003), mainstream theories of international trade would commonly rely on the assumption of a representative firm in each domestic economy. This includes both the Heckscher-Ohlin model emphasizing comparative advantage under perfect competition as the main driver of international trade, and the more recent theories of Krugman (1980) and Helpman

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² In practice, credit constraints, labor regulations, and other types of market imperfections may prevent more productive firms from growing sufficiently in size in order to become viable exporters.

(1981) focusing instead on increasing returns and consumers' preference for variety as drivers of trade. However, recent evidence shows both a high degree of heterogeneity across firms in the same domestic industry, and that this heterogeneity is in firm-level productivity, in firm size, in firm-level skills and wages, and in capital intensity. Moreover, as predicted by Melitz (2003), this heterogeneity, in particular with regard to productivity, is a key determinant of whether and to which extent firms are involved in international trade and of how well they perform as exporters. First, the extent of intra-industry differences is shown for example by Syverson (2004). Thus, within an average US sector, the top 10% most productive firms are twice as productive as the 10% least productive firms. More recently, Hsieh and Kleynow (2009) show that intra-industry differences are even bigger in emerging economies: in China and India, the top 10% produce more than five times as much as the 10% least productive firm in the average industry. Moreover, the distribution of firm-level performance, whether it is measured by productivity or by firm size, tends to be highly skewed (typically Pareto-distributed rather than normally distributed), i.e. with many badly performing firms and only a few high-performing firms. This in turn implies that firm heterogeneity intra-industry is much greater than the heterogeneity in average performance across industries across countries. In other words, ignoring firm heterogeneity within industries and instead looking directly at industry level or country level averages, introduces a significant 'aggregation bias' (Altomonte et al., 2012). And it may lead to inappropriate policy prescriptions if the heterogeneity in firm performance within an industry is mirrored by an heterogeneity in firms' ability to export on the world market. Now let us suppose as in Melitz (2003) that only firms beyond a given cut-off performance level are able to export. Then, as well explained by Altomonte et al. (2012), any policy that simply aimed at increasing average industry-level productivity without affecting the distribution of firm performance within the industry, and in particular

without affecting the number of firms that pass the export threshold, would have no effect on the industry's overall exports, and therefore on its competitiveness. And indeed, as we will see in the next section, there is evidence of a 'happy few' phenomenon, i.e. of the fact that only a few firms above a given performance threshold make it to be exporters or more generally 'internationalized'. Hence the importance of looking directly at firm-level differences and of understanding how firm-level characteristics affect firms' ability to export,³ i.e. not only their individual productivity level but also whether that level gets to pass the export threshold. One remark to conclude this section: here we have tried to explain why more productive firms are more likely to engage in international activities. But there is the reverse causality from trade openness to firm-level productivity growth. For example, using a new firm-level panel data across twelve European countries over the period 1996-2007, Bloom et al. (2011) show that increased competition from Chinese imports have spurred technical change within firms in those countries (whether technical change is measured by IT diffusion, R&D expenses, TFP growth or improvements in management practices). In the Appendix we develop a simple model which rationalizes these effects of trade on productivity growth.

**3 PRODUCTIVITY AND OTHER KEY CHARACTERISTICS
OF EXPORTING FIRMS**

Table 1 (p. 306) from Bernard et al. (2011) is based on 2002 data from the US Census of Manufacturers. It regresses the various firm characteristics (size, productivity, skills,

³ For example, by appealing to the heterogeneity in firm performance within industries, Antras et al. (2010) account for the so-called 'Spanish paradox,' i.e the fact that Spain increased its overall degree of competitiveness (measured by its share of world exports) over the decade 2000-2009, even though average productivity (measured by unit labor costs) deteriorated over that period. What happened is that productivity improved for firms already beyond the export threshold whereas it underwent significant deterioration for firms below that threshold. Thus the same number of firms kept exporting and they exported more due to their increased productivity.

etc.), on a dummy variable indicating whether the firm is an exporter or not. These are all OLS regressions. The results summarized in Table 1 (the first column includes no fixed effect, the second column includes industry fixed effects and the third column includes industry fixed effects plus log firm employment as an additional control) point to an ‘exporter premium’ in terms of firm size (measured by log employment or by log shipments), or productivity (measured by log value added per worker or by the log of Total Factor Productivity/TFP), or skill (measured directly by log skill per worker or by log wages), and of capital intensity (measured by log capital per worker). More recently, Altomonte et al. (2012) have gone somewhat further by looking at the relationship between firm characteristics and firm-level openness over multiple countries and considering several dimensions of openness. In order to perform reliable comparative analysis, with the support of the Bruegel think tank the authors carried out a large cross-country firm-level survey called EFIGE. To construct the EFIGE dataset, the authors selected seven countries, namely Germany, France, Ita-

Table 1 Regression of various firm characteristics on a dummy variable indicating whether the firm is an exporter or not

	(1)	(2)	(3)
Log employment	1.19	0.97	–
Log shipments	1.48	1.08	0.08
Log value added per worker	0.26	0.11	0.10
Log TFP	0.02	0.03	0.05
Log wage	0.17	0.06	0.06
Log capital per worker	0.32	0.12	0.04
Log skill per worker	0.19	0.11	0.19
Additional covariates	None	Industry fixed effects	Industry fixed effects. Log employment

Source: Bernard et al. (2007).

ly, Spain, the UK, Austria and Hungary, and for each of these countries they selected a large number of firms to which they sent a survey questionnaire. All these firms had more than ten employees; the overall sample included 3,000 firms from each of the first four countries, more than 2,000 in the UK, and around 500 firms in Austria and in Hungary. Based on the answers to the questionnaire, the authors constructed ‘openness’ indicators reflecting the nature or extent of firms’ international involvement. Thus a firm would be called ‘an exporter’ if it provides a positive answer when asked if it sold abroad. Similarly, binary indicators were constructed for importing versus non-importing firms or for distinguishing between firms that were involved in Foreign Direct Investment (FDI) or outsourcing and firms that were not.

Table 2 Descriptive statistics of firm performance and indicators of firms’ degree of openness

	No of firms	Avg turnover per firm (in € 1,000s)	Avg no. of employees	Avg capital stock per employee (in € 1,000s)
Non-active abroad	3,402	4,443.33	31.44	152.16
Active abroad	11,357	19,273.46	139.85	196.4
Of which				
Exporter	9,849	20,494.12	151.42	199.03
Importer of services	3,449	38,659.98	332.12	223.57
Importer of materials	7,298	24,976.44	191.17	200.36
Global exporter	4,016	24,777.71	103.43	222.93
Passive outsourcer	5,799	17,052.42	83.96	204.98
Active outsourcer	590	24,657.11	119.55	225.28
FDI	719	77,637.20	334.13	239.55
Whole sample	14,759	15,589.29	114.52	189.59

Source: EFIGE dataset, Altomonte et al. (2012).

Table 3 Descriptive statistics of firm performance and indicators of firms’ degree of openness including firm level productivity

	No of firms	Avg turn-over per firm (in € 1,000s)	Avg no. of employees	Avg capital stock per employee (in € 1,000s)	Total factor productivity	Unit labor cost (in € per unit of added value)	Labor productivity (added value per employee in € 1,000s)
Non-active abroad	1,514	5,298.51	31.67	156,14	0.872	0.77	50.71
Active abroad	5,921	26,104.12	152	200,01	1.024	0.78	57.55
Of which							
Exporter	5,201	26,104.12	164.41	203,19	1.033	0.77	58.09
Importer of services	1,900	50,004.76	372.81	230,61	1.159	0.84	61.81
Importer of materials	3,939	31,647.82	208.25	203,31	1.058	0.79	58.43
Global exporter	2,211	38,345.27	104.42	224,77	1.094	0.79	62.56
Passive outsourcer	2,965	20,763.66	84.31	208,06	1.06	0.79	59.86
Active outsourcer	306	32,991.62	127.39	224,94	1.066	0.76	56.03
FDI	387	98,554.23	359.7	238,08	1.293	1.05	63.35
Whole sample	7,435	20,303.82	125.6	190.39	0.991	0.78	56.05

Source: EFIGE dataset, Altomonte et al. (2012). Note: numbers are weighted averages. TFP is the Solow residual of the production function.

Table 2 from Altomonte et al. (2012) provides interesting descriptive statistics on the mapping between various dimensions of firm performance and various indicators of firms’ degree of openness. In particular we see that larger or more capital intensive firms tend to be ‘more open’ along the various openness scales. Moreover, the export performance threshold appears to be lower than the FDI threshold. Table 3 shows that the same conclusion applies when looking at firm level productivity (whether measured by TFP, by unit labor costs, or by labor productivity): namely,

more productive firms tend to be more open, and again the export performance threshold appears to be lower than the FDI threshold.

That better performing firms tend to be more open appears even more clearly when looking at performance deciles. Thus Altomonte et al. (2012) show that around 85% of firms within the top TFP decile in the corresponding industry are exporters, around 45% of firms in the same decile are global importers, less than 15% are involved in FDI and around 5% are involved in outsourcing.

Next, Table 4 from Altomonte et al. (2012) reports the results from the OLS regression of TFP on the various openness dummies. First, we see that the correlations between TFP and the various openness indicators are all positive and significant. Second, being involved in FDI commands a higher TFP premium than being an exporter, which is again consistent with the notion that the fixed cost of FDI involvement is higher than that of exporting.

A key issue raised by the above tables is of course that of the direction of causality. In particular, do the above correlations reflect the impact of firm-level performance on firms’ ability to become more ‘open’, or do they reflect the fact that increased openness raises firms’ productivity growth? Melitz (2003) models the performance-to-openness causality, whereas the model we develop in the Appendix captures the reverse causality from openness to productivity growth which, as in this model, has both a reallocation effect (towards more productive firms) and an escape-competition-through-innovation effect, both of which contribute to increasing average productivity in the domestic economy. That both causalities should be at work comes out clearly from the recent empirical literature on trade, reallocation and firm heterogeneity.⁴

⁴ In particular, see Sections 2.3 and 2.4 in Bernard et al. (2011).

Table 4 Results from the OLS regression of TFP on the various openness dummies

Dep. variable: TFP	(1) OLS	(2) OLS	(3) O. Probit	N
Active abroad	0.0906*** (0.0132)	0.0353*** (0.0128)	0.261*** (0.0290)	7,259
Exporter	0.0999*** (0.0136)	0.0399*** (0.0131)	0.272*** (0.0298)	6,563
Importer of services	0.171*** (0.0171)	0.0626*** (0.0171)	0.620*** (0.0531)	3,334
Importer of materials	0.118*** (0.0142)	0.0449*** (0.0138)	0.394*** (0.0332)	5,320
FDI	0.257*** (0.0329)	0.0980*** (0.0357)	0.750*** (0.0750)	1,862
Passive outsourcer	0.122*** (0.0151)	0.0558*** (0.0150)	0.329*** (0.0342)	4,372
Active outsourcer	0.134*** (0.0309)	0.0477 (0.0306)	0.364*** (0.0755)	1,777
Global exporter	0.156*** (0.0168)	0.0699*** (0.0167)	0.425*** (0.0368)	3,652
Country fixed effects	Yes	Yes	Yes	–
Sector fixed effects	Yes	Yes	Yes	–
Firm size	No	Yes	No	–

Source: Altamonte et al. [2012].

4 ENHANCING PRODUCTIVITY

This section looks at the determinants of productivity growth, based on the following two questions. First, how can we enhance productivity growth in advanced versus emerging market economies? Second, is there something to learn from observing the big technological waves and their diffusion patterns across different countries? We first present a simple framework to think about the sources of productivity growth. We then look at the sources of productivity growth in advanced countries, and we then turn our attention to the sources of productivity growth in

emerging market economies. We finally analyze the technological waves and draw a few lessons from comparing the differences in their diffusion patterns across countries.

4.1 A framework to think about the sources of productivity growth

In 1956 Robert Solow developed a model to show that in the absence of technical progress, there can be no long-term growth of per capita GDP. On the other hand, historical evidence suggests that productivity growth is an increasingly important component of growth (e.g., see Helpman, 2004). But what are the sources of productivity growth?

A useful framework to think about productivity growth and its determinants is the so-called ‘Schumpeterian’ paradigm. The paradigm revolves around four main ideas.

First idea: productivity growth relies on profit-motivated innovations. These can be process innovations, namely to increase the productivity of production factors (e.g., labor or capital); or product innovations (introducing new products); or organizational innovations (to make the combination of production factors more efficient). Policies and/or institutions which increase the expected benefits from innovation should induce more innovation and thus faster productivity growth. These include in particular better (intellectual) property right protection, Research and Development (R&D) tax credit, more intense competition, better performing schools and universities: all these policies foster productivity growth.

Second idea: creative destruction. Namely, new innovations tend to make old innovations, old technologies and old skills become obsolete. This in turn underlies the importance of reallocation in the growth process.

Third idea: innovations may be either ‘frontier innovations’ which push the frontier technology forward in a particular sector, or ‘imitative innovations’ or ‘adaptive

innovations’, which allow the firm or sector to catch up with the existing technological frontier. And the two forms of innovations require different types of policies and institutions.

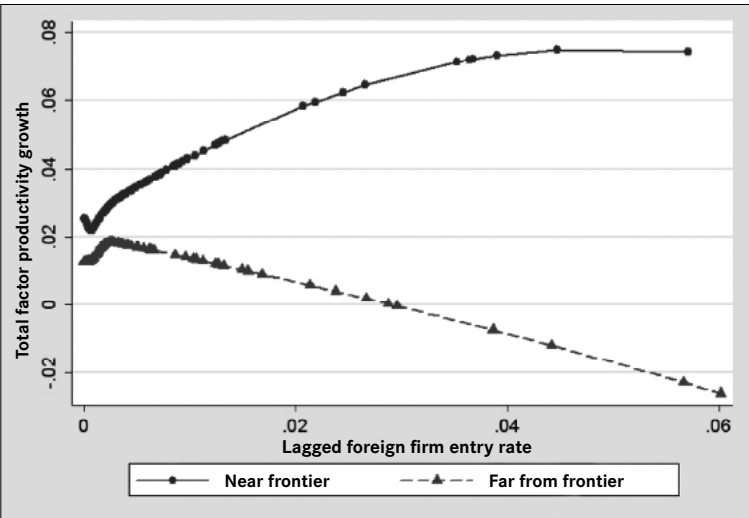
Fourth idea: Schumpeterian waves. Namely, technological history is shaped by the big technological waves, which correspond to the diffusion of new ‘General Purpose Technologies’ (the steam engine, electricity, Information and Communication Technologies/ICT, etc.) to the various sectors of the economy.

4.2 Enhancing productivity growth in advanced countries

To enhance productivity growth in advanced countries, where growth relies more on frontier innovations, it helps to invest more in (autonomous) universities, to maximize flexibility of product and labor markets and to develop financial systems that rely importantly on equity financing.

Figure 1 (from Aghion et al., 2009a) shows how competition (here measured by the lagged foreign entry rate) affects productivity growth in domestic incumbent firms. The upper curve averages among domestic firms that are closer to the technological frontier in their sector worldwide, compared to the median. We see that on average productivity growth in those firms responds positively to more intense competition. This reflects an ‘escape competition effect,’ i.e. the fact that such firms innovate more to escape more intense competition. In contrast, productivity growth in firms that are farther below the technological frontier in their sector worldwide than the median, reacts negatively to more intense competition. This reflects a discouragement effect. The closer a country is to the world-leading productivity level, the higher the fraction of ‘above median’ firms, and therefore the more productivity-enhancing product market competition.

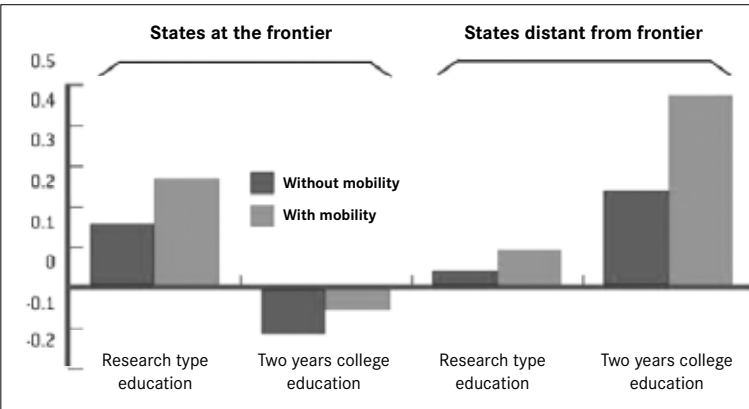
Similarly, one can show that more flexible labor markets (which facilitate the process of creative destruction) foster productivity growth more in more advanced countries.



Source: Aghion et al. (2009a).

FIGURE 1

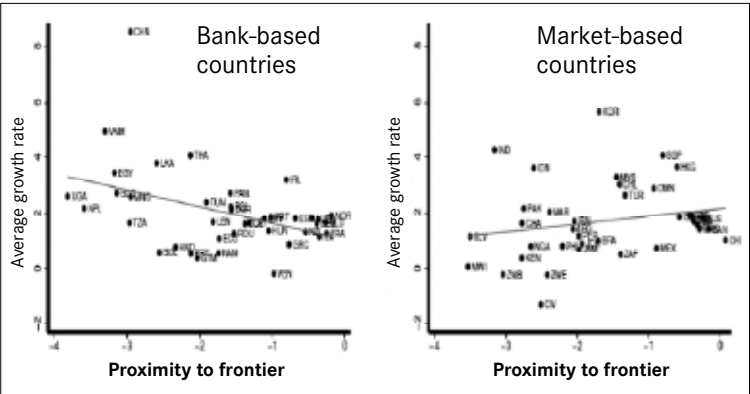
Total factor productivity growth and lagged foreign firm entry rate



Source: Aghion et al. (2005)

FIGURE 2

Long-term growth effects of \$1000 per person spending on education, US states



Source: Koch (2014)

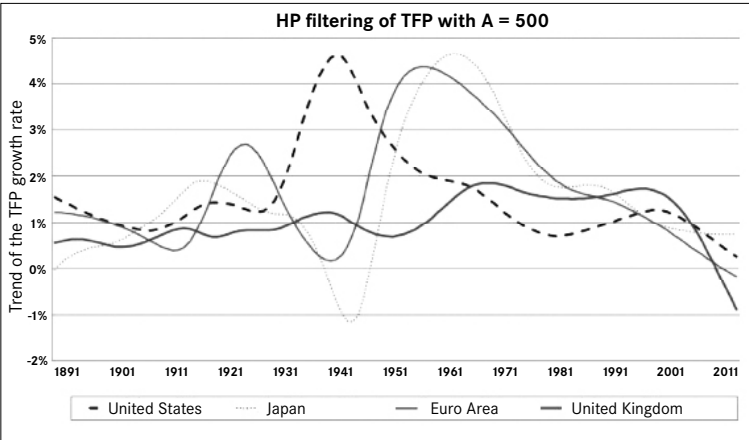
A third lever of productivity growth in advanced countries is graduate education: indeed frontier innovation requires frontier researchers. Figure 2 [p. 313], drawn from Aghion et al. (2009b) shows that research education enhances productivity growth more in more frontier US states, i.e. in states with higher per capita GDP (California, Massachusetts, etc.) whereas two-year college education is what enhances productivity growth more in less advanced states (Alabama, Mississippi, etc.). The same is true across countries: higher (and especially graduate) education enhances productivity growth more in countries with higher per capita GDP.

A fourth lever of productivity growth is the organization of the financial sector. As shown by Figure 3 (drawn from Koch, 2014), choosing a bank-based financial system enhances productivity growth more for less advanced countries whereas choosing a more market-based financial system enhances productivity growth more in more frontier countries.

Aghion et al. (2009c) have performed cross-country panel regressions of productivity growth on the share of ICT in total value added and found a positive significant coefficient (see Table 5 below, first three columns). But interestingly, once they look

FIGURE 3

Average growth rate and proximity to the frontier for bank-based (left) and market-based (right) countries (per capita GDP growth rate)



Source: Cette/Lopez (2012)

at product market regulation, the coefficient on ICT becomes non-significant. This in turn suggests that liberalizing product markets is key to enhancing productivity growth in developed economies, also because they facilitate the diffusion of the ICT wave throughout the various sectors of the economy. This result is confirmed by Cette and Lopez (2012). Figure 4 from Cette and Lopez (2012) shows that the Euro Area⁵ and Japan suffer from a lag in ICT diffusion compared to the US.

And through an econometric analysis, Cette and Lopez show that this lag in ICT diffusion in Europe and Japan, compared to the US, is explained by institutional aspects: a lower education level, on average, of the working-age population and more regulations on labor and product markets. This result means that by implementing structural reforms, these countries could benefit from a productivity acceleration linked to a catch-up of the US ICT diffusion level.

⁵ The Euro Area is here the aggregation of Germany, France, Italy, Spain, the Netherlands, Austria and Finland. These seven countries represent together, in 2012, 88.5% of the total GDP of the Euro Area.

FIGURE 4

Delayed productivity growth waves in other countries

Table 5 Cross-country panel regressions of productivity growth on the share of ICT in total value added

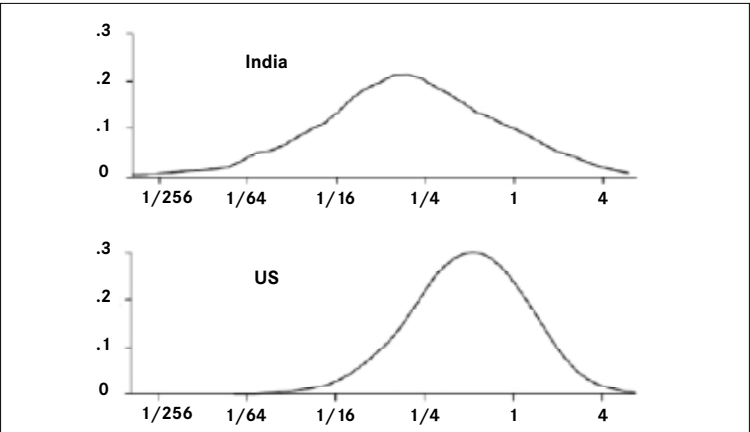
Panel: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Iceland, Italy, Japan, the Netherlands, Norway, Portugal, Spain, Sweden, the United Kingdom and the United States					
Time period: 1995–2007					
Dependent variable: Hourly labor productivity growth (instrumental variables method)					
	(1)	(2)	(3)	(4)	(5)
Changes in capacity utilization rate	0.00200*** (0.000622)	0.00190*** (0.000499)	0.00161*** (0.000475)	0.000908 (0.000648)	0.00634 (0.000702)
Growth in working time	-0.583 *** (0.170)	-0.787*** (0.138)	-0.797*** (0.138)	-0.784*** (0.157)	-0.698*** (0.172)
Growth in the employment rate	-0.529*** (0.177)	-0.641*** (0.165)	-0.653*** (0.160)	-0.878*** (0.203)	-0.809*** (0.217)
Share of ICT production in total VA	0.930*** (0.261)	0.344* (0.195)	0.372** (0.179)	0.0614 (0.164)	0.170 (0.178)
Share of pop. (>15) w/some higher educ.		0.0808** (0.0348)			
EPL			-0.00726** (0.00307)		
PMR(t-2)				-0.0103** (0.00486)	
EMPL*PMR(t-2)					-0.00368*** (0.00130)
Constant	-0.0376** (0.0160)	-0.0199 (0.0153)	0.0107 (0.0118)	0.0296** (0.0137)	0.0197* (0.0113)
Observations	163	149	142	95	95
P-value of the Durbin-Wu-Hausmann endogeneity test	0.00066	0.02912	0.03388	0.02966	0.01112
P-value of Basmann-test of overidentifying restrictions	0.6354	0.2581	0.4140	0.2075	0.7716
Standard errors in parentheses, *** p<0,01, ** p<0,05, *p<0,1					

Source: Aghion et al. [2009a].

Most recently, Cette, Lopez and Mairesse [2013] analyze the impact of anticompetitive regulations in upstream (service industry) sectors on productivity growth in downstream industries that are using inputs from those upstream sectors. Using an unbalanced country-industry panel dataset covering fifteen OECD countries over the period 1987–2007, the authors find that anticompetitive upstream regulations have a significantly detrimental effect on productivity growth downstream, and that this effect operates in part (but not entirely) through R&D and ICT investments in downstream industries.

4.3 Productivity growth in emerging market economies

Now coming to the sources of productivity growth in emerging market economies where adaptive innovation and factor accumulation are the main sources of growth, Hsieh and Klenow [2009] have emphasized the importance of input reallocation effects. In particular if we compare the distribution of firms’ productivities in India versus the United States, we see in Figure 4 (p. 315) that the US have a thinner tale of less productive plants and a fatter tail of more productive plants than India: in other words, it is harder for a more productive firm to grow but also easier for a less productive firm to survive in India than in the US. In other words, the creative destruction process operates more efficiently in the US. This difference is in turn attributable to various potential factors: in particular, more rigid capital markets and labor/product markets in India, also the lower supply of skills in India compared to the US, the poorer quality of infrastructure in India, and finally the lower quality of institutions to protect property rights and to enforce contracts in India compared to the US. These factors in turn operate on productivity growth through several potential channels. One particularly interesting channel is that of management practices: recent work – e.g., Bloom/van Reenen [2010] for a review – shows in particular that management practices are far worse in India than in the US, and that the average management scores across countries are strongly correlated with the countries’ levels of per capita GDP.



Source: Hsieh/Klenow (2009); US mean = 1; higher US TFP due to reallocation – thinner ‘tail’ of less productive plants.

5 TECHNOLOGICAL WAVES

5.1 Two productivity growth waves

Using annual and quarterly data over the period 1890–2012 on labor productivity and TFP for thirteen advanced countries (the G7 plus Spain, the Netherlands, Finland, Australia, Sweden and Norway) plus the reconstituted Euro Area, Bergeaud, Cetté and Lecat (2014, BCL thereafter) show the existence of two big productivity growth waves during this period.

The first wave culminates in 1941, the second culminates in 2001. The first wave corresponds to the second industrial revolution: that of electricity, internal combustion and chemistry (Gordon, 2000). The second wave is the ICT wave. That wave is smaller magnitude than the first, and a big question is whether or not that second wave has ended in the US.

FIGURE 5

Distribution of plant TFP differences in US vs India

5.2 Diffusion patterns

Figure 6 from BCL (2014) shows that Japan, the UK and the Euro Area have benefited from both waves, although with delays in both cases. Thus the first wave fully diffused to the current Euro Area, Japan and the UK only post-World War II. As for the second productivity wave, so far it does not show up in the Euro Area or in Japan. Market rigidities contribute to explaining such delays. The lower quality of research and higher education also appears to matter.

5.3 Global breaks

One observes several global breaks in the evolution of productivity growth over the period 1890–2012. BCL (2014) show that there are three types of global breaks: 1) the global breaks associated with the two world wars; 2) the global breaks attributable to the two global financial crises of 1929 and 2008; 3) the break corresponding to the global oil supply shock.

Several interesting observations are proposed by BCL (2014) from observing these breaks. First, the global war shocks affected different countries differently: more precisely, they were downward shocks for countries like France, Germany and Japan where battles were waged; but they correspond to an upward shock for the US which was not directly submitted to the confrontation. Second, the rebound from the great depression was stronger in the US and Canada than in other developed countries. Also, most countries exited the depression through the war. Third, the impact of the global oil supply shock was generalized, although the US got in and out of it earlier than the other countries, partly through deregulating its markets.

5.4 Country-specific shocks and the role of reforms

Figure 7 from BCL (2014) shows a positive break in labor productivity and in TFP growth in Sweden after 1990. This stands in contrast with the case of Japan shown

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in Figure 8: there, we see no such break but instead decelerating labor productivity and TFP growth since 1980. Our explanation is that Sweden implemented sweeping structural reforms in the early 1990s: in particular a reform of the public spending system to reduce public deficits, and a tax reform to encourage labor supply and entrepreneurship. No significant reform took place in Japan over the past thirty years. Consider from BCL (2014) the four countries which are commonly presented as lead reformers over the past three decades: the reforms initiated in Sweden in the early 1990s made the rate of TFP growth increase from an average of 0.4% over the period 1976–1992 to an average of 1.9% over the period 1992–2008. Similarly, the 1982 reform (Wassenaar Agreement) in the Netherlands is associated with a break from an average TFP growth rate of 0.5% over the period 1977–1983 to an average TFP growth rate of 1.5% over the period 1983–2002. The reforms initiated in the early 1990s in Canada are associated with a break from an average TFP growth rate of 0.3% over the period 1974–1990 to an average rate of 1.1% over the period 1990–2000. Finally, the reforms initiated in the early 1990s in Australia are associated with a break from an average TFP growth rate over the period 1971–1990 of 0.4% to an average growth rate of 1.4% over the period 1990–2002.

These findings are in line with cross-country panel regressions suggesting that structural reforms play a key role in speeding up the diffusion of technological waves.

6 OBSTACLES TO FIRM GROWTH

In Section 3 we have reported on recent theoretical and empirical work pointing at the importance of firm size for competitiveness. More precisely, we are after policies that emphasize productivity growth to an extent which should allow firms to eventually achieve and pass the threshold scales required for becoming ‘open’ (i.e. to first become an exporter and then become involved in FDI and/or outsourcing activities).

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There exists a whole literature on firm dynamics and its impact on aggregate productivity growth. On the theory side, the state of the art on the interplay between growth, reallocation, and firm dynamics are the recent papers by Klette and Kortum (2004), Acemoğlu et al. (2012), and Akçigit et al. (2014). These papers build on the Schumpeterian growth paradigm (see Aghion/Howitt, 1992, and Aghion et al., 2013) to model firms as multi-line producers and innovators. Innovations improve a firm’s productivity in producing a particular intermediate input, and it allows an incumbent firm to expand its scope, i.e. the number of product lines it operates in (namely: if the incumbent firm innovates on a new line, the firm drives out the previous producer on that line through Bertrand competition as it outcompetes the previous producer on that line). And a successful innovation by an outsider on a product line currently covered by an incumbent firm eliminates that line from the incumbent firm’s range of products, thereby shrinking the number of product lines covered by that firm.

This framework generates an ergodic steady-state firm size distribution, which depends upon the innovation technology, upon government policy towards incumbent firms and/or towards potential entrants, and upon regulatory or credit market characteristics which will also affect firms’ ability to enter and/or grow post-entry.

In particular this framework can account for various stylized facts about firm dynamics and firm size distribution. Some of these facts are: (i) the firm size distribution is highly skewed; (ii) firm size and firm age are highly correlated (in this framework, new firms are one-line firms, and to become large with sufficient lines a firm needs to have innovated on all these lines and also survived creative destruction on enough of the lines it used to operate on); (iii) small firms exit more frequently (it takes only one outside innovation to eliminate a one-line firm whereas it takes several successful outside innovations to eliminate an initially multi-line firm), but the ones that survive tend to grow faster than average growth rate (they are more

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likely to be an efficient innovator, and they can also exploit R&D synergies across its multiple lines); (iv) a large fraction of R&D in the US is done by incumbents; (v) reallocation of inputs between entrants and incumbents is an important source of productivity growth.

The framework can also explain why factors that inhibit firm size growth in developing countries also inhibit aggregate productivity growth: for example Akçigit et al. (2014) argue that in developing countries contractual frictions become more dramatic as firms grow in size, it becomes increasingly hard to avoid hold-up by firm managers as the number of product lines controlled by the firm increases. This in turn inhibits the growth of most efficient firms (i.e. of firms with higher innovation capabilities); such firms have lower incentives to grow as firm owners want to mitigate the hold-up problem with their manager. But this in turn enables less efficient firms to remain active for a longer period, before being replaced by more efficient firms.

While contractual incompleteness and lack of trust are obvious obstacles to firm growth, previous studies have also emphasized: (a) adjustment costs induced by the R&D and/or advertising of incumbent firms; (b) the administrative costs of creating a new firm; and (c) labor market regulations.

Thus Aghion, Fally and Scarpetta (2007), henceforth AFS, present empirical evidence on the effect of financial development on the entry of new firms of different size and on the post-entry growth of successful entrants. They use harmonized firm-level data on entry and post-entry growth by industry, size classes and over time for a sample of industrialized, transition and Latin American countries (see Bartelsman et al., 2004). And they consider two main indicators of financial development: namely, the ratio of private credit and stock market capitalization. They instrument these financial development variables using a detailed set of regulatory indicators that characterize the banking and securities markets. Also, following Rajan and Zingales (1998), to minimize problems of omitted variable bias and other mis-specifications, they compare

different indicators of financial development with the relative dependence on external financing of the corresponding sector in the United States.

The main results in AFS are as follows. First, higher financial development enhances new firm entry in sectors that depend more heavily upon external finance. Second, the entry of smallest size firms benefits the most from higher financial development, whereas financial development has either no effect or a negative effect on entry by larger firms. Third, financial development enhances post-entry growth of firms in sectors that depend more upon external finance, even when checking for labor market regulations.⁶

The effect of regulations on firm dynamics and firm size is itself a fascinating topic that has barely been touched upon. An interesting paper by Garicano, Lelarge and van Reenen (2012) analyzes the static welfare effects of the fifty employee regulatory threshold in France, and point to a significant source of allocative inefficiency (namely, an inefficient concentration of firm size just below the threshold). Yet the analysis of how such threshold or other types of regulations more generally affect the size distribution of firms and aggregate productivity growth remains an open question.

7 DO WE STILL NEED VERTICALLY TARGETED POLICIES?

7.1 The debate

The change of emphasis from industry-level to firm-level competitiveness, then the evidence on the relationship between firm-level competitiveness and firm-level productivity, and finally our discussion on the determinants and policies to enhance

⁶ Previous work on the subject includes Beck, Demirgüç-Kunt, Laeven and Levine (2004) who find that financial development is more growth enhancing for industries that rely more on small firms (this is measured by the share of small firms in the respective US industry). In the same vein, Beck, Demirgüç-Kunt and Maksimovic (2004) use a firm survey to assess firms' perception of financial constraints. They find that small firms tend to be more affected by financial as well as legal and corruption issues than larger firms.

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productivity growth: all this points towards giving priority to 'horizontal targeting', i.e. on policies (competition, labor market liberalization, patent and R&D policy etc.) which enhance productivity growth in all sectors, instead of focusing on 'vertical targeting', i.e. on policies aimed at promoting particular industries in the worldwide competition with similar industries in other countries.

Vertical targeting used to be popular in the aftermath of World War II (WWII). Thus, the World Bank and other IFIs welcomed the import substitution policies in Latin American countries, whereby local industries would more fully benefit from domestic demand. Similarly, they would support East Asian countries like Korea or Japan that engaged in export promotion, e.g., through tariffs and nontariff barriers and partly by maintaining undervalued exchange rates. For at least two or three decades after WWII, these policies, which belong to what is commonly referred to as 'industrial policy', remained fairly noncontroversial as both groups of countries were growing at fast rates. However, vertical targeting has come under increasing criticism since the early 1980s among academics and policy advisers in international financial institutions. In particular, it was criticized for allowing governments to pick winners and losers in a discretionary fashion and consequently for increasing the scope for capture of governments by local vested interests. Empirical studies by Frankel and Romer (1999) and Wacziarg (2001) pointing at a positive effect of trade liberalization on growth would of course reinforce the case against vertical targeting, as would recent work on competition and growth (Aghion et al., 2005; Aghion et al., 2008).

However, three phenomena that have occurred recently invite us to rethink the issue. First, climate change and the increasing awareness of the fact that without government intervention aimed at encouraging clean production and clean innovation, global warming will intensify and generate all kind of negative externalities (droughts, deforestations, migrations, conflicts) worldwide. Second, the recent financial crisis, which revealed the extent to which laissez-faire policies have led several countries, in

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particular in Southern Europe, to allow the uncontrolled development of non-tradable sectors (in particular real estate) at the expense of tradable sectors that are more conducive to long-term convergence and innovation. Third, China, which has become so prominent on the world economic stage in large part thanks to its constant pursuit of industrial policy. Also, we now see an increasing number of scholars (in particular in the US) denouncing the danger of laissez-faire policies that lead developed countries to specialize in upstream R&D and in services while outsourcing all manufacturing tasks to developing countries where unskilled labor costs are lower. They point to the fact that countries like Germany or Japan have better managed to maintain intermediate manufacturing segments of their value chain by pursuing more active industrial policies, and that this in turn has allowed them to benefit more from outsourcing the other segments.

As mentioned above, the most recurrent counter-argument to industrial interventionism is the 'picking winner' argument. True, industrial policy is somewhat always about 'picking winners', but as Vincent Cable, the former UK Business Secretary points out, 'the "winners" in this sense are the skills we judge we will need for the future, and the sectors they support.' However, we will argue below that the picking winner argument loses bite, first when the government chooses to pick sectors, not particular firms, and second when it 'governs' its sectoral interventions in a way that preserves or even enhances competition and Schumpeterian selection within the corresponding sectors. A second criticism of traditional industrial policy is the risk of capture and rent-seeking behavior that it involves. Here again, setting clear principles for the selection of sectors and for the governance of support to these sectors (competitiveness, exit mechanisms, etc.) should help address this criticism.

More fundamentally, a main theoretical argument supporting growth-enhancing sectoral policies is the existence of knowledge spillovers. For example, firms that choose to innovate in dirty technologies do not internalize the fact that current advances in

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such technologies tend to make future innovations in so-called 'dirty' technologies also more profitable. More generally, when choosing where to produce and innovate, firms do not internalize the positive or negative externalities this might have on other firms and sectors. A reinforcing factor is the existence of credit constraints which may further limit or slow down the reallocation of firms towards new (more growth-enhancing) sectors. Now, one can argue that the existence of market failures on its own is not sufficient to justify sectoral intervention. On the other hand, there are activities – typically high-tech sectors – which generate knowledge spillovers on the rest of the economy, and where assets are highly intangible, which in turn makes it more difficult for firms to borrow from private capital markets to finance their growth. Then there might indeed be a case for subsidizing entry and innovation in the corresponding sectors, and to do so in a way that guarantees fair competition within the sector. Note that the sectors that come to mind are always the same four or five sectors, namely energy, biotech, ICT and transportation.

7.2 Rethinking the design and governance of industrial policy

To our knowledge, the first convincing empirical study in support of properly designed industrial policy is by Nunn and Trefler (2009). These authors use micro data on a set of countries to analyze whether, as suggested by the argument of 'infant industry', the growth of productivity in a country is positively affected by the measure in which tariff protection is biased in favor of activities and sectors that are 'skill-intensive', that is to say, use more intensely skilled workers. They find a significant positive correlation between productivity growth and the 'skill bias' due to tariff protection. Of course, such a correlation does not necessarily mean there is causality between skill-bias due to protection and productivity growth: the two variables may themselves be the result of a third factor, such as the quality of institutions in the countries considered. However, Nunn and Trefler show that at least 25% of the correlation corresponds

to a causal effect. Overall, their analysis suggests that adequately designed (here, skill-intensive) targeting may actually enhance growth, not only in the sector which is being subsidized, but also the country as a whole.

More recently, Aghion, Dewatripont, Du, Harrison and Legros (2012), henceforth ADDHL, argue that sectoral policy should not be systematically opposed to competition policy. First, they develop a simple model showing that targeted subsidies can be used to induce several firms to operate in the same sector, and that the more competitive the sector, the more this will induce firms to innovate in order to 'escape competition' (see Aghion et al., 2005). Of course, a lot depends upon the design of industrial policy. Such policy should target sectors, not particular firms (or 'national champions'). This in turn suggests new empirical analyses in which productivity growth, patenting, or other measures of innovativeness and entrepreneurship, would be regressed over some measures of sectoral intervention interacted with the degree of competition in the sector, and also with the extent to which intervention in each sector is not concentrated on one single firm, but rather distributed over a larger number of firms.

Data showing how much state aid each sector receives are not available for EU countries, unfortunately. Thus, to look at the interaction between state subsidies for a sector and the level of product market competition in that sector, ADDHL use Chinese firm-level panel data. More precisely, they look at all industrial firms from the Chinese National Business Survey. This is an annual survey of all firms with more than five million RMB sales. The sample period is 1988–2007, and the survey contains information on inputs and outputs, firm-level state subsidies, etc. Product market competition is measured by 1 minus the Lerner index, which in turn is calculated as the ratio of operating profits minus capital costs over sales. ADDHL show that TFP, TFP growth and product innovation (defined as the ratio between output value generated by new products to total output value) are all positively correlated with the

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interaction between state aid to the sector and market competition in the sector. Thus the more competitive the recipient sector, the more positive the effects of targeted state subsidies to that sector on TFP, TFP growth, and product innovation in that sector. In fact ADDHL show that for sectors with a low degree of competition the effects are negative whereas the effects become positive in sectors with a sufficiently high degree of competition. Finally ADDHL show that the interaction between state aid and product market competition in the sector is more positive when state aid is less concentrated. In fact, if one restricts attention to the second quartile in terms of degree of concentration of state aid (this refers to sectors where state aid is not very concentrated), then state aid has a positive effect on TFP and product innovation in all sectors with more than median level of product market competition.

7.3 Climate

Firms in a laissez-faire economy may innovate in 'the wrong direction', for example in polluting energy activities, just because they have acquired expertise on such activities, not taking into account the environmental and also the knowledge externalities that their choice entails. Thus Aghion et al. (2010) explore a cross-country panel data set of patents in the automotive industry. They distinguish between 'dirty innovations' which affect combustion engines, and clean innovations such as those on electric cars. Then they show that the larger the stock of past 'dirty' innovations by a given entrepreneur, the 'dirtier' current innovations by the same entrepreneur. This 'path dependence' phenomenon, together with the fact that innovations have been mostly dirty so far, implies that in the absence of government intervention our economies would generate too many dirty innovations. Hence a role for government intervention to 'redirect technical change' towards clean innovations.

As argued in Acemoğlu et al. (2012), delaying such directed intervention not only leads to further deterioration of the environment. In addition, the dirty innovation machine

continues to strengthen its lead, making the dirty technologies more productive and widening the productivity gap between dirty and clean technologies even further. This widened gap in turn requires a longer period for clean technologies to catch up and replace the dirty ones. As this catching-up period is characterized by slower growth, the cost of delaying intervention, in terms of foregone growth, will be higher. In other words, delaying action is costly.

Not surprisingly, the shorter the delay and the higher the discount rate (i.e. the lower the value put on the future), the lower the cost will be. This is because the gains from delaying intervention are realized at the start in the form of higher consumption, while the loss occurs in the future through more environmental degradation and lower future consumption. Moreover, because there are basically two problems to deal with, namely the environmental one and the innovation one, using two instruments proves to be better than using one. The optimal policy involves using (i) a carbon price to deal with the environmental externality and, at the same time, (ii) direct subsidies for clean R&D (or a profit tax on dirty technologies) to deal with the knowledge externality: this again calls for vertical targeting.⁷

7.4 Summarizing

Overall, our discussion in this section suggests that adequately targeted sectoral intervention, e.g., in more skill-intensive or in more competitive sectors, can be growth-enhancing. Also, we have argued in favor of not concentrating subsidies across firms in a sector. However this is just the starting point in what we see as a

⁷ Of course, one could always argue that a carbon price on its own could deal with both the environmental and the knowledge externalities at the same time (discouraging the use of dirty technologies also discourages innovation in dirty technologies). However, relying on the carbon price alone leads to excessive reduction in consumption in the short run. And because the two-instrument policy reduces the short-run cost in terms of foregone short-run consumption, it reinforces the case for immediate implementation, even for values of the discount rate under which standard models would suggest delaying implementation.

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much broader research program on how to govern industrial policy so as to make it more competition-friendly and more innovation-enhancing. In particular, how can industrial policy be designed so as to make sure that projects that turn out to be non-performing will not be refinanced? How should governments update their doctrine and practice of competition policy so as to factor in renewed thinking on how to design and implement industrial policy? The conjunction of the debate on climate change, of the recent financial crisis, and the new dominance of China on the world market, reinforce our conviction that while market competition is certainly a main engine of growth, specialization cannot be left entirely to the dynamics of laissez-faire. Also, one increasingly realizes that the specialization model whereby the most advanced countries would focus on upstream R&D and services and out-source everything else to emerging market economies, may not be sustainable in the long run.

8 IMPLICATIONS FOR POLICY DESIGN IN EMERGING MARKETS: THE EXAMPLE OF CHINA

China is deservedly admired worldwide for its outstanding growth performance over the past three decades: this forces modesty and humility on people like me who are asked to provide economic advice. Yet, growth in China so far has largely been 'catch-up' growth: that is, growth based on imitating or adapting technologies introduced elsewhere.

This catch-up growth has been spurred by the market reforms under the dual track approach as of the early 1980s, and by the establishment of a system of growth-based yardstick competition between provincial leaders. This in turn has favored the reallocation of resources and investment from agriculture to industry and from SOEs to (credit-constrained) new TVEs and private enterprises. And technological catch-up has been further enhanced by encouraging foreign direct investment.

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While more catch-up or reallocation-based growth can be achieved from improving management practices in existing firms (see our discussion above), from further liberalizing labor flows from rural to urban areas, from further developing the financial sector, and from liberalizing capital flows (as already planned), there are several reasons to believe that this will not be sustainable in the long-run, in particular: (i) the efficiency gains from reallocating resources from agriculture to industry and from absorption of imported technologies will exhaust as the reallocation is completed; (ii) wage increases will reduce China's comparative advantage in what it currently exports to the rest of the world.

Then the question naturally arises: How can China avoid the middle income trap and make a successful transition from 'catch-up growth' to 'innovation-led growth'? And how can China achieve higher quality growth in this process? The discussion above on firm-level productivity growth as the ultimate source of competitiveness, as well as on the drivers of productivity growth, suggests five pillars of an innovation-based economy:

- Competition and creative destruction: frontier-innovation is fostered by competition and free entry, to a much larger extent than imitation: the reason is both that incumbent firms at the technological frontier can escape competition and the threat of entry by innovating, and that most path-breaking innovations are made by new entrants. Checks and balances are in turn necessary to guarantee free entry and full competition because this helps minimize the scope for collusion between (local) politicians and (large) incumbent firms.
- Top research universities, i.e. universities with very high Shanghai rankings: recent work on the subject suggests that to achieve such rankings one needs, not only to invest more in the university system, but also to grant universities autonomy on budget management, wage policy, hiring/firing decisions and the design of programs. This autonomy has to come hand-in-hand with more effective competition

between universities as well as between researchers. Thus as for other sectors of the economy, here also less upward accountability has to be replaced by more downward accountability and competitive pressure.

- A dynamic labor market system which combines: (i) flexibility for firms to hire and fire; (ii) a good training system to help workers rebound from one job to another; (iii) a good social safety net, i.e. with well-developed portable social security and pension rights from job to job and also with a generous unemployment benefit system (in turn conditional upon the unemployed worker training and then accepting new jobs). Such a 'flexsecurity' system makes creative destruction and therefore innovation-led growth work at fuller speed.
- A financial system which relies more on venture capital, private equity, and stock markets: the reason being that innovative investments are more risky and therefore investors require both, to get a share of upside returns and to get control rights.

How can one make sure that innovation-led growth will be high-quality growth? My feeling was that the Chinese leadership is concerned by two negative byproducts of growth so far, namely: the deteriorating environment and the very fast increase in inequality: in other words the challenge is to achieve inclusive and sustainable innovation-led growth! As it turns out, implementing the above pillars helps achieve these objectives, in particular: (i) the combination of competition, education and 'flexsecurity' enhances social mobility; (ii) the checks and balances (at a local level) which guarantee full competition should also help improve the environment.

A natural question then arises, namely: which organizational and/or institutional changes (if any) does China need to introduce in order to move toward full-steam innovation-led growth? Obviously, we do not have the answer to this question at hand because we lack knowledge on how the current institutional system is organized and how it works in practice.

Yet empirical and casual evidence suggests that a smart state can stimulate the innovation-led machinery:

- by setting up a fiscal system which achieves the triple goal of:
 - raising revenue to make innovation-enhancing investments in education, universities, infrastructure;
 - being redistributive to avoid excessive inequality and poverty traps;
 - encouraging innovation by not expropriating innovators;
- by setting up adequate institutional mechanisms to strengthen checks and balances on the different levels of government to make sure, both that competition is fully enforced (as we argued above) and that state investments aimed at enhancing innovation are properly targeted and monitored.

It would look somewhat paradoxical to recommend that China move from imitation-led to innovation-led growth by simply imitating the institutional arrangements of existing innovation-led economies. Instead, China must find its own way to reform its state institutions so as to make the above pillars work fully. It must find its own answers to questions such as: (i) How can we set up fully effective competition policy instruments and mechanisms starting from the current Chinese institutional context? (ii) Which contractual, organizational or institutional changes should we introduce, in particular at the regional/local level, in order for China to gain full steam in implementing sustainable and inclusive innovation-led growth? (iii) How can we factor in environmental and social (i.e. inclusiveness) dimensions in addition to GDP growth when evaluating regional or local leaders and organizing the yardstick competition among them? (iv) How can we improve the tax and welfare system to reach best standards and practices among innovating countries and in particular reconcile the need for redistribution and the need to finance good public infrastructure and services with innovation incentives?

9 CONCLUSION

In this paper we have taken on board modern trade economics, and in particular the idea that a country's competitiveness boils down to the competitiveness of its individual enterprises. Then we have reported recent empirical work showing that firm-level competitiveness is related to firms' productivity and firms' ability to grow. Then we have looked at determinants of firm-level productivity, and also at potential obstacles that may inhibit firm size growth. Finally, we have argued that while enhancing firm-level productivity growth calls first for horizontal policies (product and labor market liberalization, trade liberalization, higher education investments, etc.), there may be a case for vertically targeted (sectoral) policies provided these are properly designed and governed.

To conclude our discussion, we would like to touch upon the delicate issue of macroeconomic policy. Recent studies (Aghion et al., 2009c; Aghion et al., 2012b) conducted at cross-country/cross-industry level, show that more countercyclical fiscal and monetary policies enhance growth. Fiscal policy countercyclicality refers to countries increasing their public deficits and debt in recessions but reducing them in upturns. Monetary policy countercyclicality refers to central banks letting real short-term interest rates go down in recessions while having them increase again during upturns. Such policies can help credit-constrained or liquidity-constrained firms to pursue innovative investments (R&D, skills and training, etc.) over the cycle in spite of credit tightening during recessions, and it also helps maintain aggregate consumption and therefore firms' market size over the cycle as argued in the previous section (Aghion/Howitt, 2009, ch. 13). This in turn suggests that an innovation-based economy would benefit from more countercyclical macroeconomic policies, with higher deficits and lower real interest rates in recessions, and lower deficits and higher real interest rates in booms, in order to help credit-constrained innovative firms maintain their R&D and other types of growth-enhancing investments over the business cycle.

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R&D POLICIES AND ECONOMIC GROWTH

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INTRODUCTION

How should the optimal R&D policy be designed? This question is at the heart of any policy debate which targets technological progress through R&D and innovation. Many governments are providing massive subsidies to foster innovation. As an example, the United States spends more than 130 billion US-Dollar per year at the federal level to support innovation (NSF + NIH + Army Research Office + R&D tax credit).¹ The proponents of R&D subsidy have argued that R&D has spillovers that are not internalized by the innovating firms. The opponents claim that product market competition already provides sufficient incentives to firms and that any additional subsidy would be wasteful.

In this article, summarizing the findings from recent research, I argue that there are at least two more dimensions that the design of optimal R&D policy should consider. First, R&D support could distort the selection mechanism among firms and may be welfare-reducing. Second, there are different types of research investments, for instance basic and applied, and the spillovers associated with each type of research could be very different. Identifying these two margins and incorporating them into the current policy debate is an important step forward. Below I describe two recent studies that take important steps in this direction.

R&D POLICIES AND FIRM SELECTION

The goal of R&D policies is to incentivize firms to undertake greater R&D investment, produce more innovations, increase productivity, and create more jobs. However,

¹ <http://www.whitehouse.gov/sites/default/files/microsites/ostp/Fy%202015%20R&D.pdf>

these policies do not affect every firm in the economy in the same way. For instance, Criscuolo et al. (2012) have shown that large incumbents are better at obtaining government subsidies. Therefore one can argue that R&D subsidies to incumbents might be inefficiently preventing the entry of new firms and therefore slowing down the replacement of inefficient incumbents by more productive new entrants. The turnover and factor reallocation between incumbents and entrants is an important source of productivity growth. Foster, Haltiwanger and Krizan (2000 and 2006) have shown empirically that the reallocation of factors across firms accounts for more than 50% of productivity growth in the US. Given the empirical importance of this reallocation margin, it is necessary that R&D policy take into account the interaction between innovation and factor reallocation. This is our focus in Acemoğlu et al. (2013). Recent literature has emphasized the importance of firm size and age for firm level heterogeneity that are observed in the data (Akçigit/Kerr, 2015; Haltiwanger et al., 2013). In Acemoğlu et al. (2013), we use data from the Census Bureau's Longitudinal Business Database and Census of Manufacturers, the National Science Foundation's Survey of Industrial Research and Development, and the NBER Patent Database. Our analysis focuses on innovative firms that are in operation during the 1987–1997 period.² Our sample contains over 98% of the industrial R&D conducted in the US during this period. The empirical heterogeneities are summarized in Figures 1 through 4. Figures 1 through 4 show R&D expenditures by shipments, employment growth and exit rates between small, large, young and old firms. Small and large firms are defined by their size relative to the median employment in the sample by year; young

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² Non-innovative firms, by definition, do not participate in this process nor do they compete for these resources; hence having firms that do not conduct innovation in the sample would create a mismatch between both our focus and our model and the data. Though it would be possible to add another selection margin to the model whereby non-innovative firms choose to transition into innovation, this appears fairly orthogonal to our focus, and we view it as an area for future work.

Figure 1 Transition Rates

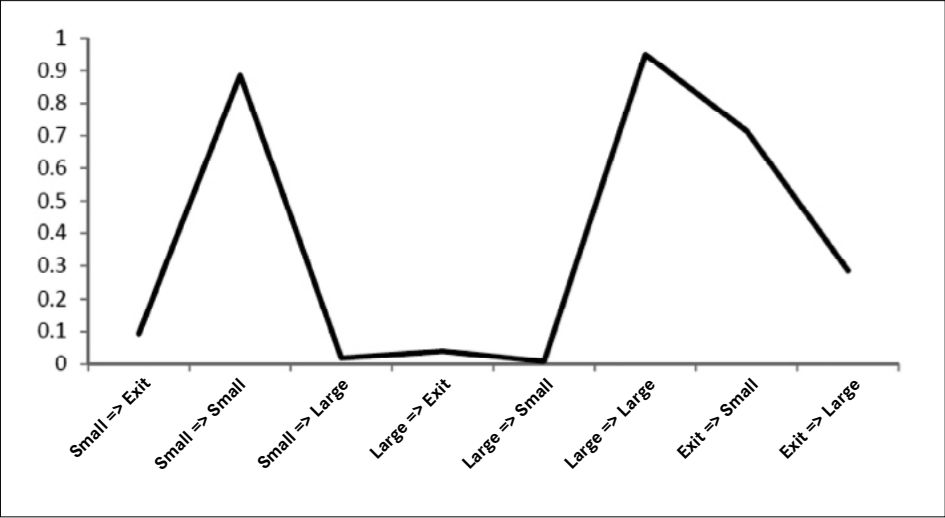


Figure 2 R&D Intensity

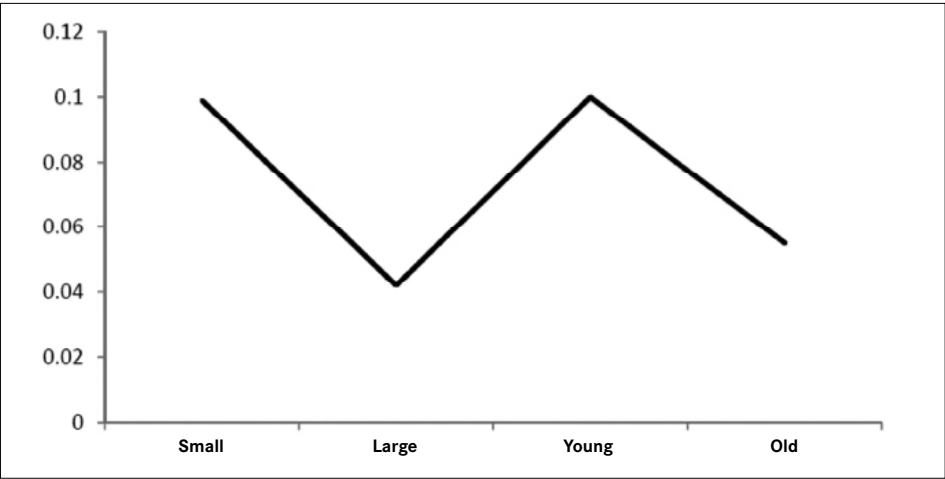


Figure 3 Sales Growth

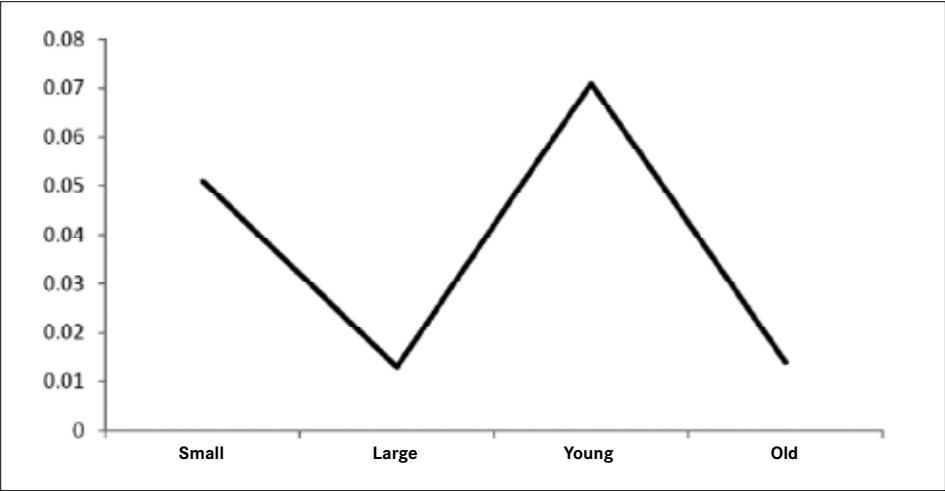
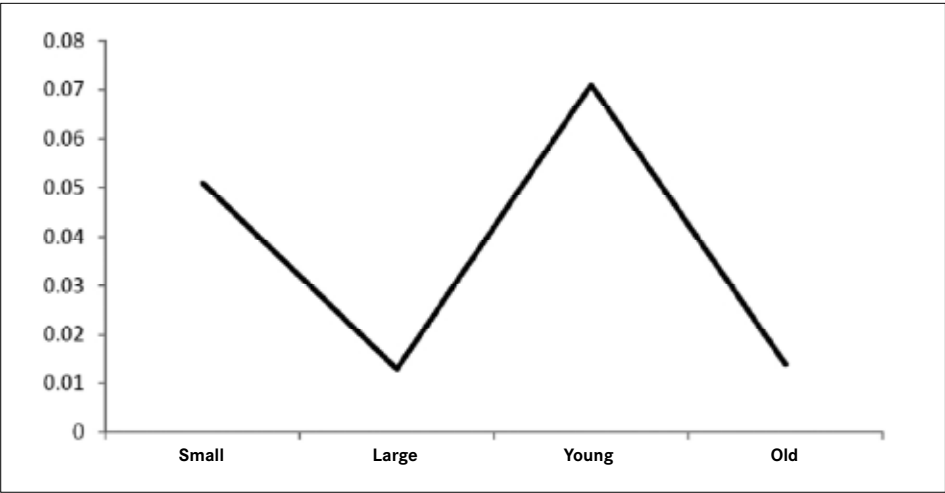


Figure 4 Employment Growth



Notes: Graphs taken from Acemoğlu et al. (2013).

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and old are defined by whether or not the firm is older than ten years. These figures clearly indicate that in this sample small and young firms are both more R&D intensive and grow faster.³ Thus, industrial policies that discourage the reallocation of resources towards younger firms might indeed be costly in that they slow the movement of R&D resources from less efficient innovators (struggling incumbents) towards more efficient innovators (new firms).

In Acemoğlu et al. (2013), we estimate our model by matching empirical moments capturing key features of firm-level R&D behavior, shipments growth, employment growth and exit, and the variation of these moments with size and age (including the ones that are plotted in Figures 1–4). We then use the estimated model as a lab to run counterfactual experiments and test the impacts of various R&D policy designs on economic growth and welfare. The policies that we consider include a subsidy to new entrants, a subsidy to R&D by incumbents, and a subsidy for the continued operation of incumbents.

Our main results can be summarized as follows. Interestingly, all the policies that we consider have small effects, and some of them even reduce welfare in the economy. When incumbents are subsidized, the equilibrium growth rate and welfare decrease. This result might suggest that the decentralized equilibrium is already efficient and any subsidy in this environment is making the economy move away from its efficient level. On the contrary, the decentralized equilibrium is highly inefficient due to the usual intertemporal R&D spillovers and competition (Schumpeterian) effects. However, in this model there is another important margin: firm selection.

In order to understand the role of selection, we first solve for the economy's allocation from the viewpoint of a social planner who internalizes all the externalities of R&D

³ Likewise in Akçigit and Kerr (2015) we regress firm growth on log firm size and find an estimate of -0.04; innovation intensity (number of innovations relative to the firm size) on log firm size we find an estimate of -0.18.

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spending. In particular, we assume that the social planner can observe firm types. What we find is that the social planner forces low-type firms to exit the economy much more frequently, so that all their production resources are reallocated to the high-type firms. Then we turn to the public policy experiments, in which we assume that the policymaker cannot observe firm types and has access to the usual policy tools, such as an R&D subsidy, an entry subsidy and a subsidy/tax to firm operations. What we find is that the optimal policy requires a substantial tax on the operation of incumbents, combined with an R&D subsidy to incumbents. The reason for this result is that taxing operations makes it harder for low-type firms to survive and forces them to exit. This way, the freed-up factors of production are reallocated to high-type firms, which make use of them much more effectively. Our analysis also highlights the importance of the entry subsidy and the incumbent R&D subsidy; these subsidies would not be as effective if the selection margin were ignored.

Overall, our general equilibrium analysis, which incorporates both reallocation and selection effects, highlights the fact that the economy in equilibrium might contain too many low-type firms, and policies that ignore the selection effect might help low-type firms survive. Another point that is highlighted is the fact that intertemporal spillovers are sizable and the overall R&D investment is too little. Therefore a combination of R&D subsidies and taxes on firm operations could be an effective way of providing innovation incentives to firms, while also leveraging the selection margin in the economy.

BASIC VERSUS APPLIED R&D

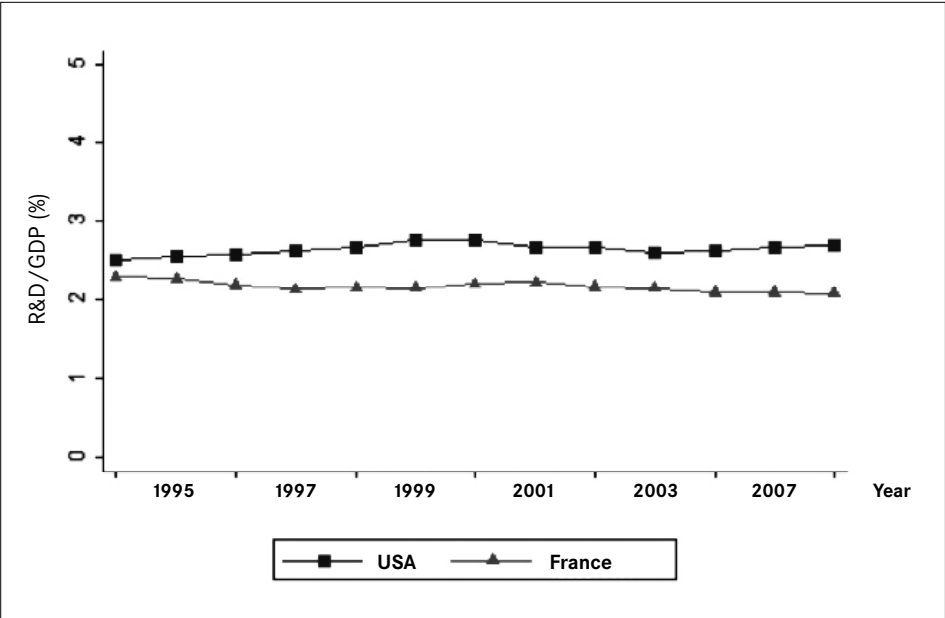
In many countries national funds allocated to basic research have been among the top items in governments' policy agendas. For instance, in a recent report by the US Congress Joint Economic Committee, it is argued that despite its value to society as a whole, basic research is underfunded by private firms precisely because it is

performed with no specific commercial applications in mind. The level of federal funding for basic research is deemed ‘worrisome’, and it is claimed that it must be increased in order to overcome the underinvestment in basic research (JEC, 2010). However, the report also complains about the lack of research studies that actually quantify the extent of this underinvestment, and about the lack of data.⁴ For similar reasons, governments introduce programs to promote collaboration between basic academic researchers and private firms, with the hope that synergies generated from these interactions could lead to breakthrough technological advances. For instance, the United States government has aggressively promoted collaboration between universities and industrial researchers through specific funding programs. Among many others, the National Science Foundation (NSF) sponsors the Fundamental Research Program for Industry-University Cooperative Research (FRP), the Industry-University Cooperative Research Centers Program (I/UCRC) and Grant Opportunities for Academic Liaison with Industry (GOALI). Although the different characteristics of basic and applied research on the one hand and academic and corporate research on the other hand have been widely recognized to be of first-order importance by policymakers, these issues have received insufficient attention in the economic literature on productivity and economic growth. In particular, the endogenous growth literature (e.g., Romer, 1990, Aghion/Howitt, 1992) has mainly considered a uniform type of (applied) research and overlooked basic research investment by private firms. What are the key roles of basic and applied research for productivity growth? How should R&D policy be geared towards basic versus applied research? What are the incentives of private firms to conduct basic research? How does academic research contribute to innovation and productivity growth? In Akçigit, Hanley and Serrano-

⁴ http://jec.senate.gov/public/?a=Files.Serve&File_id=29aac456-fce3-4d69-956f-4add06f111c1

Velarde [2014], we attempt to answer these questions. In order to understand the potential inefficiencies involved in different types of research investments and to design appropriate industrial policies to address them, it is necessary to adopt a structural framework that explicitly models the incentives for different types of research investments by private firms. In Akçigit et al. (2014) we take an important step towards developing this theoretical framework, identifying the potential spillovers and studying their macroeconomic implications for innovation policy. Our analysis starts with an empirical investigation. Figure 5 shows that countries allocate a significant share of their GDP to R&D (around 2–3%) Less well known,

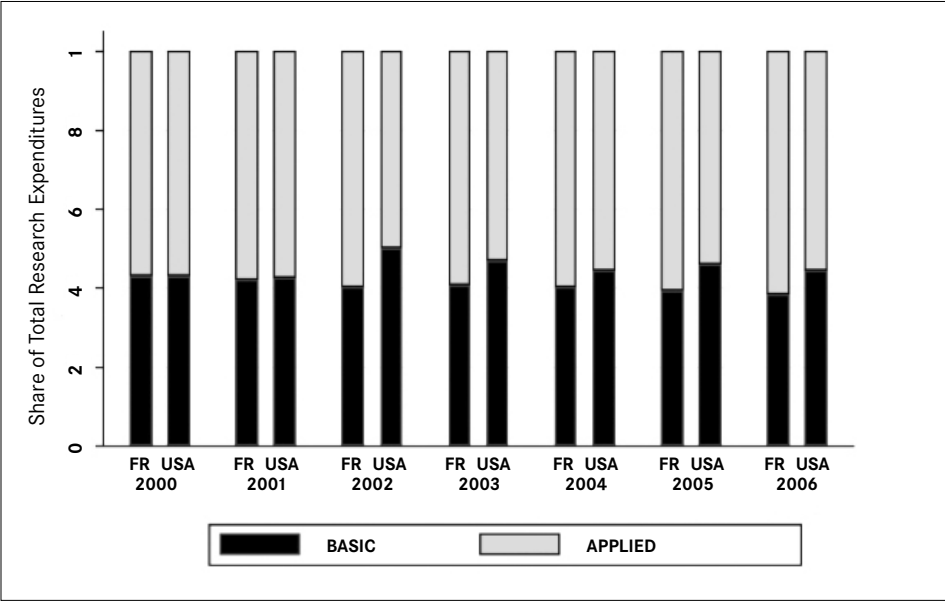
Figure 5 R&D as a Share of GDP



Taken from Akçigit et al. [2014].

however, is what role the composition of this research plays in determining growth, particularly when considering the breakdown between basic and applied research. Before we proceed further, it might be helpful to provide the relevant definitions. According to the NSF, basic research investment refers to a ‘systematic study to gain more comprehensive knowledge or understanding of the subject under study without specific applications in mind.’ Conversely, applied research is defined as a ‘systematic study to gain knowledge or understanding to meet a specific, recognized need.’ Figure 6 shows the composition of the overall R&D spending in the US and in France. The interesting result is that almost half of overall spending goes into basic research. What kind of spillovers does basic research generate? In our analysis, we follow the influential literature on basic science and consider the possibility that basic research not only generates large spillovers within an industry, but that it can also be applicable to many different industries. The historical example of Du Pont de Nemours’ financing of Wallace Carothers’ research serves as a fine showcase of these spillovers: ‘Carothers’ work in linear super-polymers began as an unrestricted foray into the unknown, with no practical objective in mind. But the research was in a new field in chemistry and Du Pont believed that any new chemical breakthrough would likely be of value to the company. In the course of research Carothers obtained some super-polymers that became viscous solids at high temperatures, and the observation was made that filaments could be made from this material if a rod were dipped in the molten polymer and withdrawn. At this discovery the focus of the project shifted to these filaments and Nylon was the result.’ (Nelson, 1959) Nylon is now used in many industries such as textiles, automobiles, and military hardware, three industries in which Du Pont had operations. Ideally, in order to capture the full return from new scientific knowledge in industries where it could have an application but in which the innovating firm is not present, the innovator would first patent and then license or sell the innovation to other firms in

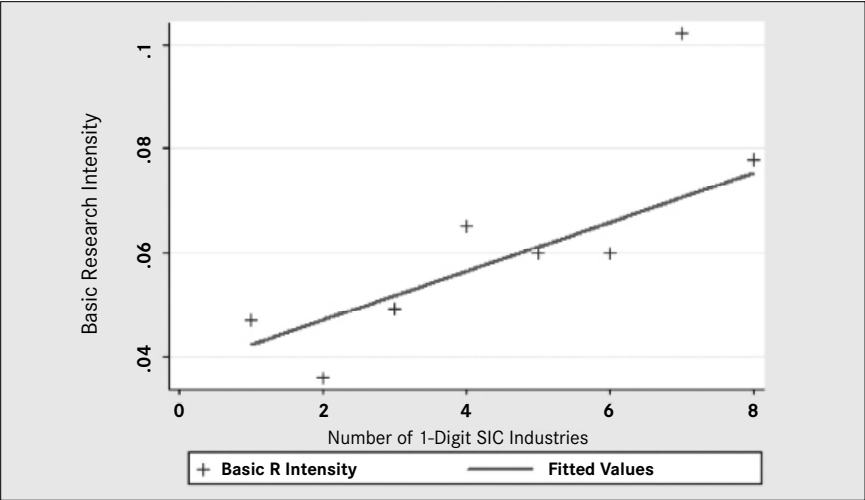
Figure 6 Basic and Applied Share of Total Research



Note: Taken from Akçığıt et al. (2014).

those industries. However, the applications of basic scientific advances are often not immediate, and firms are often only able to transform them into patentable applications in their own industries. This is the well-known appropriability problem of basic research that has been discussed in a vast literature. It follows that firms operating in more industries will be able to utilize more facets of a given basic innovation. As Nelson hypothesized it: ‘It is for this reason that firms which support research toward the basic-science end of the spectrum are firms that have fingers in many pies.’ Note that the key concept that is being emphasized here is not firm size per se, but the diversity of its operations. This interesting argument (which we will refer to as ‘Nelson’s hypothesis’) will be the central building block of our analysis in this article.

Figure 7 Average Basic Research Intensity Against Total Number of Distinct 1-Digit SIC Codes



Note: Taken from Akçigit et al. (2014).

We first test Nelson’s hypothesis, namely that the main investors in basic research would be those firms that have fingers in many pies. According to this argument, as the range of its products and industries gets more diversified, a firm’s incentive for investing into basic research relative to applied research should increase due to better appropriability of potential knowledge spillovers. To measure multi-industry presence, we count how many distinct SIC codes a firm is present in. Using micro-level data on French firms, Figure 7 plots average basic research intensity against the total number of distinct 1-digit SIC codes in which the firm is present. The figure also shows a simple linear fitting line.

Figure 7 shows a positive and statistically and economically significant relationship between multi-industry presence and basic research spending. A broader techno-

logical base is associated with higher investment in basic research relative to applied research. Thus our findings are supportive of Nelson’s hypothesis about the link between multi-industry presence and relative research incentives. These correlations are robust to a large variety of potential confounding factors. This result suggests that cross-industry spillovers are sizable, and using the variation in firms’ technology base, we can estimate the cross-industry spillovers associated with basic research.

In order to study the policy implications of these spillovers, we build a general equilibrium, multi-industry framework with private firms and a public research sector. Firms conduct both basic and applied research, whereas the public sector focuses exclusively on basic research. In our model, basic research generates fundamental technological innovations and spillovers, both within and across industries, that affect subsequent applied innovations.⁵ In line with the ‘Ivory Tower’ theory of academic research, basic research by private firms in our model will turn into consumer products faster than that undertaken by public research labs. Applied research, on the other hand, will be done only by private firms and will generate follow-on innovations building on the existing basic knowledge stock.

We then undertake a quantitative investigation of the impacts of various innovation policies on the aggregate economy. We first estimate the model by targeting some of the key moments in the data, especially public and private spending on basic and applied research in France. We use the estimated model to assess the extent of inefficiencies in basic and applied research and to study the implications of several important innovation policies.

Our main results can be summarized as follows. We find that a large fraction of spillovers from basic research across industries are not internalized. As a result, there is

⁵ By fundamental innovation, we mean major technological improvements that generate larger than average contributions to the aggregate knowledge stock of society. In addition, these will have long-lasting spillover effects on the size of subsequent innovations within the same field.

a dynamic misallocation of research efforts, which reduces welfare significantly. One striking result is that the decentralized economy and the social planner's economy are using the same level of resources for research overall. However, the composition of the total research effort is very distinct. While the social planner is allocating more resources to basic research, it allocates fewer resources to applied research. This implies that the dominant misallocation here is not that between production and research, but among the various types of research activities, in this case, applied and basic research. There is actually overinvestment in applied research in the decentralized economy because of product market competition, whereas there is underinvestment in basic research due to uninternalized within-industry and cross-industry spillovers.

This raises an important question: to what extent can public policies address this inefficiency? The first policy we analyze is a uniform research subsidy to private firms. In this environment, subsidizing overall private research is ineffective, since this will oversubsidize applied research, which is already excessive due to product market competition. Therefore, the welfare improvement from such a subsidy is limited, unless the policymaker is able to discriminate between types of research projects at the firm level, a difficult task in the real world.

Therefore we analyze another policy tool: the level of funding for public research labs. We show that due to the Ivory Tower nature of public basic research, allocating more money to the academic sector without giving property rights to the researchers (ownership over their inventions) is not necessarily a good idea. To demonstrate this, we simulate a policy similar to the Bayh-Dole Act enacted in the US in 1980. We consider alternative scenarios in which public researchers have no property rights, then 50% and 100% property rights. We find a complementarity between the level of property rights and the optimal allocation of resources to academic research. The optimal combination turns out to grant full property rights to the academic researcher and

allocating a larger fraction of GDP to public research. This reduces the welfare gap significantly.

CONCLUSIONS

In this article, I summarized some recent findings from research on optimal innovation policy. The two new elements introduced were firm selection and the distinction between basic and applied research. The former implied that R&D policy could affect firm survival and resource reallocation between more productive and less productive firms, or between incumbent and entrant firms. The latter highlighted the fact that different types of research, in this case basic and applied, could have different spillovers and R&D policy should take into account its impact on the distinct types of research.

There are still many unexplored directions for future research. One direction is the labor market consequences of the R&D policies. While the literature typically assumes frictionless labor mobility across firms, it takes time for workers to find new jobs when a firm has to exit. It would be important to study the potential reallocation costs of such policies. Another important issue are the transitional dynamics. The current focus of the literature is typically on steady-state dynamics. Clearly, any new policy is likely to entail a path of transition, which might generate additional costs on the economy. These are important questions that will hopefully be answered in future research.

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INNOVATION AND GROWTH IN EMERGING ECONOMIES

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INTRODUCTION

How does innovation affect economic growth, and how can emerging economies encourage such beneficial innovation? In spite of the solid gains in wealth and standards of living in recent decades in increasing parts of the world (Ahlstrom, 2010; Maddison, 2006), underdevelopment in many countries remains one of the most significant problems of the 21st century (Bruton et al., 2015; Easterly, 2014; Stiglitz, 2007). Moreover, emerging economies are not catching up to the developed ones as well as is commonly believed. Rodrik (2009) found that before 2000, the performance of the emerging economies did not converge with that of the developed world as the gap in per capita income between them actually widened from 1950 to 2000. Though some countries performed well such as the petro-states and certain East Asian economies, many others did well only for a short while such as the Philippines and Pakistan but then slipped back into slow economic growth (Rodrick, 2009).

In recent years, most emerging economy growth has come primarily from one country: China. Brazil and Russia in particular faced significant slowdowns in the second decade of the twenty-first century with annual growth falling below five percent (Sharma, 2012). Though much has been learned about economic growth (Aghion/Howitt, 1992, 1998; McCloskey, 2006, 2010; Romer, 1986; Lucas, 2002; Mokyr, 1990, 2009; Rodrik, 2009) and development (Ahlstrom, 2014; Bloom/van Reenen, 2010; Landes, 1998; North, 1990; Perkins et al., 2013; Sombart, 1913), the debate continues, particularly with respect to emerging economies (Acemoğlu/Robinson, 2012; Easterly, 2006; Link/Siegel, 2014; Rodrik, 2009; Sharma, 2012) and their firms (Alvarez et al., 2015; Young et al., 2014).

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The conundrum of economic growth is now more vital than ever, especially in emerging economies (Ahlstrom et al., 2004; Sharma, 2012). In spite of steady growth over the past few decades, emerging economies continue to face significant poverty while they struggle with reform (Bruton et al., 2015). It is also feared that even large, fast growing economies in Asia are reaching the Lewis Turning Point¹ (Lewis, 2003) in terms of having used all the surplus and unproductive labor for early development (Sharma, 2012). It is thought, for example, that China may be reaching the Lewis Turning Point, in that the availability of cheap labor in that country has declined and real agricultural wages have substantially increased (Zhang et al., 2011). The concern for many in emerging economies is that easy growth may not continue, even for the fastest growth economies that have had only one or two stalls in growth over the past several decades.

Yet it is important to recall that only about two hundred years ago much of the world's population earned about the present level of Cambodia's per capita annual income of around 1,000 dollars, and many earned less than half of that (Maddison, 2006).² In 1800 the average human consumed around US\$2 a day – today's definition of grinding poverty (World Bank, 2012). In spite of large numbers of poor around the world today on an aggregate basis, economies have been growing and world poverty has been falling, and not just since the poverty programs and aid initiatives of the past three decades, but for nearly two centuries (Easterly, 2006, 2014; McCloskey, 2010). Starting about two hundred years ago, there was a rapid and sustained increase

¹ Lewis Turning Point is the term used in economic development to describe a point at which surplus rural labor effectively reaches zero. This in turn typically causes urban wages to rise dramatically. Upon reaching the Lewis Turning Point, a country or state usually experiences food shortages which lead to a rise in agricultural and unskilled industrial real wages.

² http://en.wikipedia.org/wiki/List_of_countries_by_GDP_%28nominal%29_per_capita – accessed 19 February 2015. 1990 dollars are used by Maddison for standard comparisons.

in annual economic growth in Northern Europe and North America that has since spread to several other parts of the world, most notably East Asia. This growth has been attributed to a variety of causes, for instance, improved institutions and the rule of law (e.g. Gerschenkron, 1962; North, 1990), the industrial revolution (Findlay/O'Rourke, 2009), capital accumulation and innovations (Aghion/Howitt, 1992; Mokyr, 1990, 2009), product variety (Romer, 1990) and generally improved technology and productivity (Phelps, 2015; Solow, 1956, 1957). Although the proximate cause of growth through new inventions and innovations as spurred by the industrial revolution seems obvious enough (Link/Siegel, 2014; Rodrick, 2009), unpacking these observations and summarizing the key causes of the sudden and sustained increases in growth such that further lessons can be drawn is very important (e.g. McCloskey, 2010; Rodrik/Subramanian, 2003).

Casual observers to the problems of economic growth and poverty tend to believe that economies have grown slowly over the past millennium and through a variety of means, often directed by government and institutions or union organization. Though institutions such as property rights or improvements in science are important, they do not explain the fairly sudden and rapid uptick in economic growth from 1800 to the present (Mokyr, 2009). Similarly, related explanations such as geography (Diamond, 1997), colonialism and expropriations fail as these have been present for hundreds (if not thousands) of years, and they did not lead to steam engines and electricity (McCloskey, 2010; Rodrik/Subramanian, 2003).

Evidence is accumulating that economies grow and provide jobs through innovation and new venture creation (Aghion/Howitt, 1992; Baumol et al., 2009; Christensen/Raynor, 2003; McCloskey, 2010, 2013; Schumpeter, 1942). Growth has derived from the invention of entirely new products such as voltaic piles and electric lights and new ways of organizing work (Ahlstrom, 2010, 2014; McCloskey, 2006; Nordhaus, 1997; Phelps, 2015). Research has looked at the many ways in which innovation

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helps to create new product-markets and how innovation that either lowers costs or increases productivity or capabilities can be encouraged (Sombart, 1913). There are many views on how to spur innovation and new ventures ranging from improved institutions (North, 1990; Olson, 1982; Rodrik et al., 2004), the rule of law and the proper roles of the government (e.g. Dam, 2005; Lerner, 2009) to simply an increased acceptance of innovation (and innovators) (Mokyr, 2009; McCloskey, 2010), still there is little doubt about innovation's importance to growth (Ahlstrom, 2010; Rodrick, 2009). Building on the work of Schumpeter (1942) and its extensions (Aghion/Howitt, 1992, 1998; Christensen, 1997; Garud/Karnoe, 2003; Kirzner, 1997; Prahalad, 2006; Raynor, 2011), this chapter seeks to further unpack the concept of innovation, and how emerging economies can benefit.

This is important because while societies, governments, educational institutions all play an important role in encouraging (or discouraging) innovation (Abzug et al., 2000; Lerner, 2009; Rodrik/Subramanian, 2003), in the end, it is not economic sectors or industries that innovate, but primarily entrepreneurs and managers. As Schumpeter emphasized in multiple works (1934, 1942), entrepreneurs and managers choose to spend, invest, conduct research and development, and test the new products that establish markets and deliver important benefits to an increasingly large proportion of the world's population (Ahlstrom, 2010; Hart/Christensen, 2002). Emerging economies can benefit greatly from understanding innovation and its importance to growth, and from implementing policies to encourage innovation (Romer, 1990). To examine this issue, this chapter briefly summarizes the research on economic growth and innovation and how firms in emerging economies might benefit from a fuller understanding of innovation and its application. How innovation may be encouraged is also examined.

BACKGROUND

As noted, economic growth and development is by no means inevitable (McCloskey, 2010). During the first millennium CE (1 through 1000), there was little real economic growth; the average person saw very little increase in his or her annual income. Income stood at about US\$400 throughout that time (Maddison, 2006). From the year 1000 to 1820 average per capita income rose slowly to about US\$667 annually (Maddison, 2006, 30). Some parts of the world such as China and Western Europe were a little less poor, but their per capita incomes were only a little above subsistence levels. Yet starting in 1820, average income started a more rapid trajectory of increase, primarily in Western Europe and North America. Income rose an unprecedented nine times between 1820 and the end of the 20th century, and at a higher rate in the West and Japan, dwarfing all previous historical periods of economic growth (Maddison, 2006). China and India waited until the late 20th century to catch the rising growth trend. The share of world population living on less than US\$1.25 a day in constant prices fell from 1981 to 2008 from 53 % to 22 % (Ahlstrom, 2010).

Economists further hold that these increases in per capita income actually understate the improvements in standard of living derived from new or improved goods and services. For example, Nordhaus (1997) concludes that from 1800 to 1992 in the United States (U.S.) economy, real wages (the monetary wages divided by the prices of average goods), adjusted for product improvement, actually grew not by a factor of about ten, but anywhere from about forty to a high estimate of a factor of 190. History provides some systematic ideas about how economies have improved so greatly and how the emerging economies of the world can learn and benefit from similar growth.

EXPLANATIONS FOR ECONOMIC GROWTH

Rapid growth of real income by a factor of one hundred or more has led to much debate about the mechanism of growth and how emerging economies can more

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effectively encourage such growth. As noted, allied disciplines, such as development economics, economic history, and management have long sought explanations for this economic take-off, beyond proximate explanations of new science and breakthrough technology (e.g., Aghion/Howitt, 1992; Landes, 1998; Perkins et al. 2013). Many explanations of economic growth focus on conditions or incentives at the global or national level correlating growth and prosperity with factors such as geography, demography and natural resources, (e.g. Diamond, 1997), national culture (Landes, 1998), institutions (North, 1990; Olson, 1982; Rodrik/Subramanian, 2003) policy choices (Lerner, 2009), technology (Mokyr, 1990) and (eventually) science (Mokyr, 2009).³ Though many explanations suggest that Europe was more likely to develop because of geography or resistance to germs and cultivatable crops (Diamond, 1997), availability of minerals and energy sources (Wrigley, 2010), or culture and government (Landes, 1998; Dam, 2005), these explanations generally fail to shed light on, for example, why the Netherlands and Britain developed and other parts of Europe with comparable geography and populations did not. Likewise associated explanations of economic growth in Europe that focus on related actions such as colonialism or conquest fail to explain why some of the most aggressive colonizers or expropriators such as Portugal or Spain were very late in industrializing (McCloskey, 2010). Such explanations have little to do with the development and deployment of steam and electric engines, electric lights, improved communications, and the production techniques that impelled faster growth.

Other explanations for growth operate at the industry level in explaining why some sectors prosper more than others (Porter, 1990). A first argument is poor countries, whether in the 1800s or today, simply have less physical, financial, and human capital than richer countries do. A related argument is that the European economies

³ Science did not have a big impact on the early part of the industrial revolution (McCloskey, 2010).

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grew first because of capital accumulation (Romer, 1986) or thrift (Weber, 1905) and just hit a critical point allowing economic take-off in 1820s-Britain and later in other countries – a view that has attracted renewed attention in recent years, albeit with a different focus (Piketty, 2014). Yet the routine repetition of investment, as indicated by capital accumulation in buildings, roads, and machines (not to mention piles of gold and silver), is not sufficient. Accumulation was not central to economic take-off in 1820 as many economists have understood since the pioneering work done by Abramowitz (1956) and Solow (1956, 1957), nor was it what triggered later economic take-off in the Nordic countries and subsequently in East Asia (Ahlstrom et al., 2004; McCloskey, 2010; Vogel, 1989, 2011). The source of industrial investment required early in the industrial revolution was often from friends and family as well as savings and ‘sweat equity’ but generally not in large amounts as 19th century factories were not capital-intensive (McCloskey, 2010; Pollard, 1964). Similarly, colonial conquest, expropriation and enslavement have long characterized history, but they did not yield an industrial revolution or the large increases in income of the 19th and 20th centuries. Something besides the simple accumulation of capital through savings and expropriation occurred to explain a revolution unprecedented in scale and (initially) unique to northern Europe around 1820.

INNOVATION, GROWTH AND ORGANIZATIONS

It is well known that the Romans invented the steam engine and the Chinese developed several early innovations such as gunpowder and paper. But innovation (and commercialization) sped up considerably in the early 1800s. Economists debate about the details, but removing the barriers (both institutional and cultural) for entrepreneurs and other innovators to develop new products and processes and to profit from these likely played a big role in spurring innovation and new ventures (Coombs et al., 1987; McCloskey, 2010; Rodrick et al., 2004). Innovation is particularly valuable

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in that it plays a central role in increased productivity and impelling new businesses (Baumol/Strom, 2007; Christensen/Raynor, 2003). For example, a product that in 1890 required one hour to produce could, just a century later, be produced in about seven minutes (DeLong, 2000). Innovation is a major reason for such increased productivity as well as the enabling of a host of completely new industries (Helpman, 2010; Solow, 1956, 1957). Many new products people use today have yielded entirely new markets and industries by solving problems of consumers that previously went unsolved – often among the middle and lower segments of a society (Anthony, 2009; Nordhaus, 1997). Observing this, Schumpeter (1934, 1942) developed creative destruction growth theory into an integrated framework for understanding not only the macroeconomic structure of an economy's growth but also several microeconomic issues regarding incentives, policies, organizations and entrepreneurs who create that growth. Schumpeter held that growth is generated primarily by innovations motivated by the sponsors' prospects of reliable rents. Also new innovations often replace older technologies: in other words, growth involves creative destruction. Nordhaus (1997) estimates, for example, that until around 9000 BCE it took fifty hours of labor to gather enough wood to have 1,000 lumen-hours of lighting, which is roughly equivalent to having 1,000 hours of an average light bulb. In 1800, the same 1,000 lumen-hours of lighting (with wax candles) required about five hours of labor to create. In 1900, thanks to electric lighting, it took only about fifteen minutes of labor at the earning power rates of that time, while vastly reducing the demand for candles (and candlemakers). In 1992, thanks to the cheapening of electricity-based lighting, it took a mere 0.00012 hours, another radical jump in performance. The net outcome was a reduction in the cost of lighting over the last eleven thousand years by a factor of 417,000 (Nordhaus, 1997). More efficiency improvements have recently come with LEDs, which also has created new markets for lighting. Not all products have achieved this great improvement in both quality and efficiency, though many

ordinary products that were luxury items just a couple of generations ago, such as scissors and pens, have similarly become very cheap and increasingly reliable. This led Nordhaus (1997) to recently estimate that the average person is about 190 times wealthier than someone from 1800, based on increases in income and large improvements in product quality. Moreover, inventors only accrue a small part of that gain. Nordhaus (2004) has found that over the past seventy-five years, an inventor received, on average, about 2.2 % of the economic gain from an invention. This indicates that most of the benefits of many types of major innovations and technological changes are passed on to the consumers rather than the producers. Recent research has put the return to producers a little higher, though primarily for goods with patent protection (Toivanen/Vaananen, 2012).

Management scholars have found that innovations need not always be new (Garud/Karnoe, 2003); opportunities may be discovered at the low end of product-markets (Ahlstrom, 2010; Baker/Nelson, 2005; Prahalad, 2006). As such, management scholars and economists alike increasingly recognize that innovation and new venture creation may offer opportunities for emerging economies for growth from the bottom up, requiring the perspective of firms and entrepreneurs (Baumol et al. 2009; Bruton, 2010; Bruton et al., 2013; O'Reilly/Tushman, 2002). By using a helpful categorization scheme of innovation, four different types of innovation can be identified, along with their potential value for emerging economy firms.

Traditional categories of innovation such as 'revolutionary' and 'evolutionary' or product versus process are not analytically sufficient to give direction to organizational decision-makers or policymakers (Christensen, 2006). Helpful research on innovation and organizations extends the original work by Schumpeter (1942), Kirzner (1997) and other economists in providing evidence for innovation at the firm level and unpacking the definitions of innovation thus facilitating their use by firms and policymakers (Christensen/Raynor, 2003; Garud/Karnoe, 2003)

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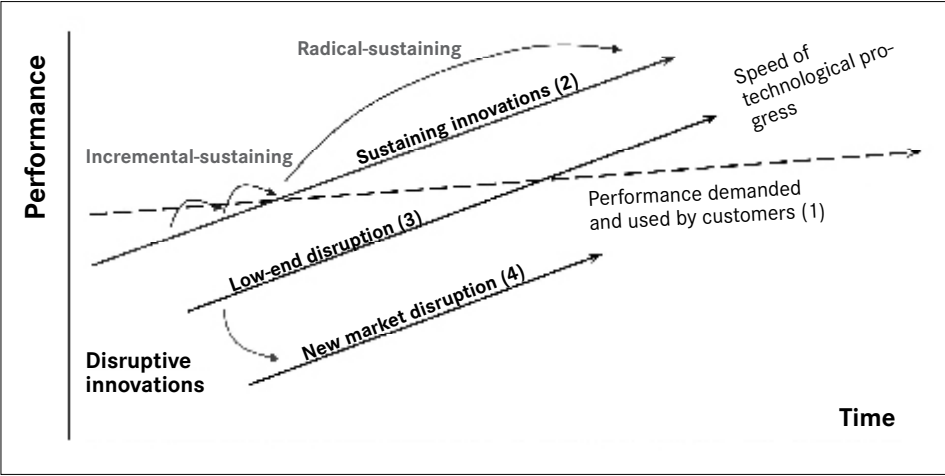
GENERIC TYPES OF INNOVATION

In examining how business organizations can contribute to the development of emerging economies through innovation as Schumpeter (1942) first suggested, a model that uses innovation as the unit of analysis is helpful, since growth is heavily based on entrepreneurial innovation and improved methods of production (Christensen/Raynor, 2003). Building on the work of Schumpeter (1934, 1942), Christensen and his colleagues (Christensen, 1997, 2006; Christensen/Raynor, 2003; Raynor, 2011) argued that virtually every commercial market (and some non-commercial ones) feature four general types of performance trajectories that help understand and categorize innovation, and make predictions about its potential value to organizations under various conditions (see Figure 1)

The first trajectory (1) represents the slowly growing performance demands of mainstream customers and their ability to utilize the new product improvements.⁴ A good illustration of this is Microsoft Word. Microsoft can innovate at a faster pace than customers require, as users are not even aware of most of Word’s functions. Microsoft innovates at the leading edge of product performance to satisfy a range of lead users. They do so at the risk of significantly exceeding average customer demands (as depicted by the dotted line in figure 1), as their needs do not increase as fast as Microsoft can innovate. So far Microsoft has avoided having large numbers of users switch down to cheaper office software as often happens when established products start to become too feature-laden and complex. This is because they own the Windows platform and do not monopoly price (Liebowitz/Margolis, 2001).

⁴ The focus here is on product or business model innovations that are commercial in nature and produce revenue for the organization. Cost-saving productivity improvements are also relevant in that they lead to changes in business models and the sale of the good or service, though the focus here is on commercially-available products (whether developed and sold by the private or public sectors). Productivity improvements are certainly important, though they are examined here only in the context of the sale of commercial products.

Figure 1 Four trajectories of performance



The second trajectory (2) measures the typical pace of innovation and product advancement undertaken by the established firms in a product market. This performance trajectory is called the sustaining innovation trajectory because it describes how a given product on this trajectory basically adds to the ability of the firm to meet (or exceed) established customer needs along an established performance trajectory and technological standard (Christensen, 1997).

The sustaining trajectory itself suggests two broad types of innovations. Most product innovations are usually incremental in nature in that they make small, though steady improvements that are consistent with historical improvements along their performance trajectory, much like the steady advance of Intel’s microprocessors since the 1970s. For incremental-sustaining innovations such as Intel’s chips or Microsoft Word, improvements to the product are similar to improvements made in the past and do not change the technological standard of the product. Thus,

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an incremental-sustaining innovation is generally plug-compatible with previous versions and is thus easy for customers to utilize and for distributors to sell (Christensen, 1997). Most innovations are incremental in nature such as the minor improvements in products that appear each year (Christensen/Raynor, 2003; Raynor, 2011). Improvements to Intel's microprocessors or MS Word in recent decades have regularly given consumers a little more than they had previously, year after year. Though most companies produce regular incremental improvements to products as the customers demand (Christensen/Raynor, 2003), sustaining innovations also occasionally make radical improvements in performance, though usually along the same technological standard. Thus a second type of sustaining innovation is a radical-sustaining one as represented by the larger improvement jump along the sustaining trajectory as illustrated in Figure 1. That is, it makes a larger, more radical performance improvement along the same trajectory of performance. Such innovations are generally competence-enhancing (Tushman/Anderson, 1986) and usually offer an opportunity for the established firms to strengthen their hold on an industry (though very late movers may lose out, such as Blackberry and Nokia in mobile phones). Successful radical innovations, however, are not common. Schumpeter (1942) discusses such 'major innovations' involving significant shifts to an entirely new production function, but provides few examples and does not discuss related issues such as technological standards and the challenges involving major, radical technological 'bets.' Rosenberg (1976) also discusses breakthrough innovation, but he provides little in the way of example. An example of radical innovation is the technological leap from conventional airplane engines to jet engines. More recently, Apple's iPhone is a commercial example of a radical-sustaining innovation that basically added a microcomputer and a clever interface to a mobile phone. Similarly, Whole Foods was able to succeed as a new entrant to the high end of the grocery industry producing a radical jump in performance across several retail

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dimensions.⁵ Yet more radical-sustaining innovations are not as easy to get customers and investors to commit to, and are often thought of as 'bet the company' type of investments, such as the IBM 360 mainframe computer or Boeing's leap up-market to the 747 aircraft. Although a radical-sustaining innovation may lead to an unusually high jump in performance, it is usually along the same (or quite similar) technological standard in that the product is plug-compatible with past generations of the product. A radical improvement such as a jet engine obviously differs a lot from the traditional reciprocating or piston engine that powered early propeller-driven aircraft. However, it was not difficult for the aircraft manufacturers to start switching to jet engines. The end users (flying public, freight and postal services, travel agents, military) also did not have to make major changes to accept the new innovation. In summary, both types of sustaining innovations generally give the existing customers more of what they were using yesterday and thus broadly fit into the existing industrial infrastructure, though the radical-sustaining innovation is more difficult to develop. The iPhone caught the existing smart phone manufacturers like Nokia and Blackberry flat-footed as they continued to develop older models for two years after iPhone's 2007 entrance into the market.

As most innovations are sustaining innovations, they are squarely part of the regular research and development and market research processes in modern firms, presenting challenges for prospective new entrants (Raynor, 2011). But it is also important to note that the sustaining innovation trajectory has a steeper slope than the first customer-performance demands trajectory, which implies (as with the Microsoft Word example) that it is quite common for firms supplying products along

⁵ It is historically difficult for firms to make a radical innovation jump which does make this type of innovation one possible (though expensive) option for emerging economy firms. For example, only a couple of the carriage and wagon makers in North America made the transition to become successful automobile manufacturers (Studebaker is one notable example), and none was able to transfer their market leadership in carriages over to automobiles.

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this (common) trajectory to start to overserve the needs of mainstream customers. This opens the door to firms that can innovate at the lower end of a market, along performance trajectories 3 and 4

These third and fourth trajectories make up the key category of innovation that is collectively called disruptive innovation (Christensen, 1997; Christensen/Raynor, 2003). Christensen and Raynor (2003) have subdivided this into low-end and new market disruptions as illustrated in figure 1. The low-end disruption (3) is an innovation that helps a firm produce more for less – essentially a less expensive version of an established (sustaining) product. Opportunities for low-end disruption become greater when an established, sustaining innovation in the market is on a trajectory of performance improvement that starts to significantly overserve the average customer in terms of price, features and functions. In this case, customers may still buy the product, but they would like to trade down to something cheaper and simpler and will do so as soon as a lower-end (disruptive) product becomes available. Similarly, the newer, ‘late adopting’ customers entering an established market will often seek simpler and cheaper products, as opposed to full-featured ones (Moore, 2014). Such low-end disruptive innovations which are weak substitutes for the established, sustaining products, are a good choice for these customers as well. The Model T Ford disrupted the early custom cars that were higher quality and much more expensive. Many customers were able to switch to the Model T immediately rather than waiting for many years to buy the more expensive brands, and its lower price made it available to average workers in North America and other markets.

Similarly, the early Apple computers of the late 1970s were (at best) weak substitutes for the mini-computers of Digital Equipment Corporation and Data General. Customers started to drop mini-computers and adopted large numbers of Apple II computers (and shortly thereafter, the IBM PC) primarily when the first spreadsheet programs became available in 1979. This allowed many business users to switch to

smaller and more convenient personal computers and away from the more expensive and difficult to use minicomputers.

The PCs did not outperform the mini-computers – they did not have to. At the time of PCs’ increased diffusion in the market, the larger computer companies such as IBM and DEC started to take notice of microcomputers and developed their own (the IBM PC became a success, but DEC’s PC made few inroads into the business or home market). In a competitive economy, such lowend disruptive innovations that are often lower-cost, more efficient innovations are critical to an economy’s growth. They can substitute for the established products but also may create larger markets; PCs helped to significantly grow the market for computing and enabled numerous ancillary industries and applications, much as the tablet computers are doing in the 21st century.

The other type of disruptive innovation (4) is a new market disruption (Christensen/Raynor, 2003). New market disruptive innovations create products and services that are accessible enough to reach entirely new customer groups that had no easy access to a given product class before. Though the PC was a low-end disruption in the late 1970s and early 1980s with the advent of the spreadsheet, it was initially a new market disruption upon its introduction as it brought many new users into the market for computing for the first time. For example, the Apple II was marketed as a toy or gaming computer in the mid-1970s to hobbyists (the only people who had access to computers in the 1970s worked for the largest firms or universities and government). Similarly, online equity trading, social media, and home medical test kits are additional examples of new market disruptive innovations that brought many new users into the market for these goods thus creating major new product-markets and giving access to less affluent customers. Because new market disruptive innovations are also weak substitutes for established products, and often simpler and lower cost, existing sales and distribution systems in the previously established industry are less likely to support them. This ma-

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kes it necessary to develop new ways of monetizing and distributing the product. New supply chains or distribution, initially requiring vertical integration (Fisher, 2001) may be a key part of building the market around the disruption innovation.

Disruptive innovations create new growth and new jobs (Ahlstrom, 2010). The early PCs brought a lot of new users into the market for computing. These were users who had had little or no access to computers in the past. In just five years' time, the PC entrepreneurs created a multibillion dollar industry for microcomputing – initially in California, but now in multiple production and job centers from Britain and the Baltic States to Africa and India. Kenya's M-Pesa service (pesa is Swahili for money), for example, has succeeded in addressing the lack of access to banking services across the country by using a simple wireless data communications platform to bring large numbers of users into the market for banking there. When M-Pesa was released in 2007, fewer than 20% of Kenyans used banks while recently, more than 80% use them; about half use M-Pesa to help them with cash transactions (Jack/Suri, 2011). Many regular banking customers also use M-Pesa as it has expanded existing markets for mobile cash and also created a new market among customers that had no credit (Graeber, 2014). This fulfils Prahalad's (2006) vision of companies serving the base-of-the-pyramid customers, but it has also led to the creation of new base-of-the-pyramid industries (Hart/Christensen, 2002; Bruton et al., 2015; Bruton et al., 2011).

Disruptive innovation has another key advantage for emerging economies in that the established firms have significant legacy investments in the old innovations. This makes switching to the newer, disruptive innovations more difficult for established firms as these firms are more dependent on resource providers, such as mainstream customers, key institutions, and government (e.g. Christensen, Craig/Hart, 2001; van Wolferen, 1990). These characteristics of market change, that is, the eventual overserving of markets by sustaining innovations, and the demand of consumers for simpler, cheaper products creates major lower-end opportunities for disruptive inno-

ventions. These opportunities are especially salient for emerging economy firms that are able to connect with customers with somewhat lesser needs and simply require a product that is 'good enough.'

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UNDERSTANDING AND BENEFITING FROM INNOVATION

Over roughly the past decade, firms and researchers have accumulated a database of disruption and sustaining innovations that have produced nearly 3,500 predictions about business survival or failure linked to the introduction of new innovations (Raynor, 2011). These predictions helped to explain more than US\$ 100 billion in internal investment and organic growth, venture capital, and acquisition. When the models predicted success (in terms of a revenue measure), they were right about two-thirds of the time (Raynor, 2011). When the model predicted failure, such as a new entrant to an industry trying to enter a market simply with an incremental improvement to an existing (sustaining) innovation trajectory, the model's predictions also proved correct nearly 90% of the time.⁶ Adding all survival and failure predictions together, the net accuracy was 84% (Thurston, 2013). The accurate use of the theory of disruptive and sustaining innovation by organizations produces successful new products and start-up firms, growth, new product-markets and industries, in that the theory helps decision-makers in selecting the type of innovation to pursue. New industries can be seeded with a simple disruptive innovation coupled with enabling technologies that

⁶ Research using the disruptive-sustaining model of innovation has shown that it is very difficult for new entrant organizations to enter an industry using a sustaining innovation product. That is, it would be very tough (though certainly not impossible) to 'out-Intel Intel' with a faster microprocessor. The new entrant would probably have to spend billions of dollars entering the industry in direct competition with one of Intel's main products. Research by Christensen and Raynor (2003) and more recently by Raynor (2011) has found that the probability of success for a new entrant entering with a sustaining (directly competitive) innovation to be less than 5%. This is why increasingly, venture capitalists and other investors ask entrepreneurs if their new product or service is disruptive in some way to existing product lines (Bernardi, 2011).

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support the disruptive innovation (Raynor, 2011). Emerging economies in particular are in a position to create new innovations, and especially disruptive ones that target non-consumption and base-of-the-pyramid customers and use their base to build an understanding of the product and the industry and to expand outward if the opportunity exists (Hart/Christensen, 2002). Much investment and aid for emerging economies has been conceived from the top down and is often focused on sustaining innovations such as improving a process or producing some established product more efficiently, and thus a limited number of globally competitive firms have been built in emerging economies – apart from more protected industries such as telecommunications, banking, and resources industries (Sharma, 2012). To improve future aid, both the public and the private sector in emerging economies should work to support market-creating, disruptive innovations for their home markets.

In terms of research, the academic literature has long framed questions of innovation in technological terms: Will this new technology become better than that technology and thus ‘beat’ the older technology? This can be confusing for firms and policymakers and interfere with their ability to see the benefits from disruptive innovation.⁷ Disruptive innovations do not necessarily technologically surpass the performance of the established, sustaining innovation. Rather, the more salient question is whether the disruptive innovation will improve to the point that it becomes good enough for the lower and (later) middle tiers of a market (corresponding roughly to the new market and low-end disruption customers). The success of a disruptive innovation can bring a key good or service to people who had little or no access to that product before, and

⁷ Analysis of tools like technology S-curves is interesting in its own right, because it can help in visualizing the competitive battles among alternative technologies as firms compete on the sustaining innovation trajectory in their industry. Yet a sustaining innovation usually embodies multiple S-curves as new versions of a product are developed as older ones are discontinued. Thus combining these new products together produces a stylized sustaining innovation improvement trajectory as depicted in figure 1 (see Christensen, 1992).

will also yield organic growth in the creation of new product-markets, major productivity improvements and new jobs (Ahlstrom, 2010), and it is thus in the interest of emerging economies to foster such innovations.

ENCOURAGING INNOVATION

How can countries encourage the effective application of innovation, and particularly disruptive innovation? There is much literature on development by economists particularly in terms of financing and improved institutions (Acemoğlu/Robinson, 2009; Lerner, 2009; Mokyr, 2009).

As noted, many entrepreneurs and policymakers focus on introducing products and services into existing, established markets – sustaining innovation – which the evidence says is very difficult to do. Airbus was an example of such a sustaining innovation developed by a new entrant to a well-established market, but successes like this are rare (Christensen/Raynor, 2003; Raynor, 2011). In contrast, disruptive innovation has a much bigger chance of yielding the creation of successful firms (or new divisions) and new product-markets for emerging economies (Raynor, 2011).

EDUCATION AND FINANCING

To help entrepreneurs and firms draw on the plentiful opportunities available in emerging economies, adequate education and training programs should teach entrepreneurs and business people about spotting and developing opportunities in markets and understanding the value of creating simple disruptive products.⁸ It was once thought

⁸ More research needs to be done on the topic of idea generation. Helpful research from management and innovation studies include Anthony (2014), Sims (2011), Hamel (2002), and Lerner (2009). William Duggan's (2007, 2012) research at Columbia University on a key aspect of the creative process in terms of both new ventures and new strategies is particularly valuable. Geoffrey Moore (2014) also has several works that are helpful to entrepreneurs and can be of use to policymakers. Also see Hang et al. (2015).

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that entrepreneurs were 'born' or had a particular personality. But recent evidence has shown that entrepreneurship can be taught (Hamel, 2002; Sarasvathy, 2008) and new ventures within firms can be encouraged (Christensen/Raynor, 2003; Wolcott/Lippitz, 2007). Innovation (and new venture creation) is not the black box it was once thought to be (Ahlstrom, 2010; Hang et al., 2015).

In coordination with universities and firms, such programs should study how market-creating innovations have taken hold in other emerging economies and identify emerging high-potential goods and services. Several case studies and studies of related business models are already available that can teach policymakers and entrepreneurs the key elements of market creation (Hang et al., 2015). One example of a disruptive innovation that has the potential to both create a new growth business and have a major positive impact on people's well-being is the new water filter technology coming from Hindustan Unilever and Tata. Many people in developing countries still struggle to get access to clean water: Patients with water-related diseases fill about half the hospital beds in the poorest countries, while dirty water and related sanitation problems kill some 5,000 children a day and significantly hurt GDP (Collier, 2008; *The Economist*, 2010, 4). The well-known Pureit water filter made by Hindustan Unilever is cheaper than the more established, higher-end filters, but at US\$40 is still too expensive for most of the base-of-the-pyramid consumers, and cannot be assembled locally. Another filter that has emerged in recent years and is even simpler and cheaper than Pureit is Tata's Swach. From the Hindi word for clean, Swach is a disruptive, very low-cost water purifier that can be manufactured using locally available resources. Swach uses commonly available rice husk ash, pebbles, and crushed cement to form a filter base that can trap almost all of the common harmful coliform bacteria. Costing less than US\$10, it is affordable for people living at subsistence levels. Early Tata studies have suggested a large reduction in water-borne diseases from the use of this filter (Rodrigues, 2010). As with many disruptive innovations, the Swach filter

does not work as well as other similar products, nor does it satisfy the requirements of the World Health Organization (WHO). However, Swach can purify water at the rate of about four liters every hour and can thus bring clean water to large numbers of consumers in the developing world, often for the first time. Similar new ventures have created relatively simple products such as the ChotuKool affordable refrigerator, and the new portable solar panels for providing limited power for home appliances. Case studies of these disruptive products can educate entrepreneurs and managers about how creativity and patience can bring life-changing products to segments of the market in emerging economies for which the higher-end versions of the product were out of reach. The new industries also create jobs across the supply chain (European Commission, 2012; Hart/Christensen, 2002).

Another key move to boost disruptive innovation would be to put in place platforms and incentives that would accelerate financing between investors and market-creating innovators (Gerber, 2004; Lerner, 2009). Financing, particularly the bridge financing between start-up funding and subsequent rounds of venture and bank funding are key to the development of start-up firms (Harnish, 2014). Indeed a major reason a new venture may fail is the well-known capital gap, where a business is not yet big enough to attract the capital it needs (Harnish, 2014). Such bridge financing helps new firms grow beyond the start-up phase into medium-sized enterprises.

Making the capital more widely available involves adapting existing tools to the particular challenges of investing in emerging economies. Online investment platforms, such as Gust and AngelList, which directly connect investors to entrepreneurs, have the potential to accelerate many market-creating investments. Microfinancing initiatives, though they have experienced some difficulties, are also potentially helpful for entrepreneurs (Bruton et al., 2011). Crowdfunding networks, such as Kickstarter, can also be targeted more precisely at disruptive innovation, with a particular focus on products that address needs in emerging economy communities. In addition, such initiatives can

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give individuals from developing countries' ethnic diasporas the opportunity to invest (Mullins, 2014).

AVOID 'CRAMMING'

Established firms do not always miss the advent of disruptive technologies, but often attempt to 'cram' such innovations into their existing business models and the market (see Christensen et al., 2004, chapter 3). In the process of trying to make the disruptive technology as good as or better than the established products, they are not usually successful. They try to sell the 'crammed' disruptive product as a direct substitute for the established product. A current example would be the way electric cars have been sold to the general public (with the exception of Tesla, which has pursued a strategy of disrupting high-end sports cars with its sporty electric vehicle). But in the end – because they have pushed the disruptive innovation prematurely up against well-established products – the disruptive product will usually have difficulty in meeting the reliability tests of those existing products (even if it has a couple of new and appealing features that the established, sustaining product does not have). This in turn hinders the product's diffusion into the market. Both case studies and empirical research on the success rate of new entrants to a market using a 'crammed' innovation shows a very poor success rate (Anthony et al., 2008; Christensen et al., 2004).

As a further example, solar energy panels were often a product that the solar firms have incorrectly 'crammed' into the sustaining space in North America and Europe. Early attempts by companies (and by sponsoring governments that often subsidized these efforts) to introduce solar panels to homes and office buildings were focused on positioning the panels as a replacement for not one, but two old, but well-developed and reliable products: the power grid and the roof tiles. Most vendors ignored simpler applications for solar panels such as providing power for small devices like calculators as a supplement to batteries that would have likely worked well with the early

solar panel technology. As predicted by theory in disruptive innovation, the early roof-based solar panels did not perform well in that they were incapable of replacing the two reliable older technologies. They were unreliable providers of power due to cloudy or cold weather, nor did they adequately replace roof tiles as they regularly leaked. People had to seek repairs, and as the early firms had often closed their doors, the panels had to be discarded.

More recently, however, solar panels have been positioned in emerging economies as a disruptive innovation. Rather than attempting to replace the power grid, solar panels are being sold for limited applications where power was previously not available, such as for rural road signs or for remote communities. They have been succeeding in markets where they are valued for their limited and unique capabilities. The newer, inexpensive solar panels bring power to locations that are relatively sunny, but have no easy access to power lines. In countries such as Kenya and Mongolia, for example, simple, portable solar panels have sold well as they provide limited power to portions of the population in rural areas. The portable panels and their storage batteries are competing against non-consumption, so any power they can provide is welcomed by consumers in such remote markets (Rosenthal, 2010). This also gives the product, which is now being sold in volume for these limited applications, a chance to improve and gradually move upmarket.

Emerging economies can encourage lower-end, disruptive innovation which introduces a simpler product on to the market, especially those which provide access to the base-of-the-pyramid consumers. This contrasts to spending money to seed higher-end products (and factories) to compete directly against market leaders with established, sustaining innovations, such as building a chip foundry to compete directly with say, Intel or the U.K. Chipmaker ARM. Entering a new market with a sustaining innovation is historically difficult because the established firms are watching that space carefully, and unlike disruptive innovations, the established firms

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have no resource commitments that prevent them from responding to a competitor entering and competing directly with them. In contrast, disruptive innovations can give people access to the products that previously were only available to higher-end customers, but also develop improvements that often create major new markets and industries, seeded from the lower end of a market. New industries from micro-computing to simple fast fashion to solar products have been introduced in remote markets away from the (previous) centers of those industries based on creating lower-end, disruptive products and targeting them at customer groups that would value the simpler performance and the more convenient or mobile aspect of the disruptive product.

AVOID MODERN 'GUILDS'

While entrepreneurs and managers can learn more about disruptive innovation, and emerging economies encourage the funding of such new ventures, the emergence of these innovations will eventually threaten established products (Christensen, 1997).

Firms and professions often treat disruptive innovations as threats and try to restrict their diffusion (Abbott, 1988; Gilbert, 2005, 2006). As a comparison, the old merchant guilds used to control access to a range of professions and vocations. These privileged associations of businesspeople and artisans were particularly important to the European economy after 1000 CE. In the Middle Ages, the guilds enforced standard training and good quality standards. But as the first industrial revolution unfolded in the mid-eighteenth century, the guilds provided ways for the rich and powerful to increase their wealth, at the expense of consumer welfare and the economy as a whole. They would often lock out alternative ways of conducting business in their domain (Ogilvie, 2004). Ogilvie (2004, 2011) describes how the more powerful merchant guilds were able to delay the emergence of alternative public institutions for trade

and exchange until their power was weakened early in the 19th century by more powerful states and institutions. For example, Edmund Cartwright's early vertical power looms in Manchester were destroyed by workers' associations (Ayres, 1989). Early sewing machine factories were similarly sabotaged as were early light bulb workshops. By the mid-nineteenth century, the nation-state had become strong enough to deter mass sabotage and to allow the development of new intellectual property and protection for the owners (Khan, 2013; Sokoloff/Khan, 1990). The legal and ideational changes necessary for societies' acceptance of disruption to traditional technologies and ways of trading, educating, doctoring, and many other industries, vocations, and professions, were quite large and generally required an enormous amount of effort (McCloskey, 2006, 2010; Cruz-Suarez et al., 2015).

The reform of medical education in the U.S. in the early twentieth century was similarly very difficult as entrenched elements of the medical profession and the medical schools of the day fought against scientific and educational reforms aimed at getting science, medical education and hospitals together to establish new treatment regimes. It took quite a great deal of money from the Rockefeller Foundation to reform the medical schools and hospitals along the German-Austrian model that had existed in Europe for a number of years (Flexner, 1972, 1910). Similar changes opening up lower-end innovations in other professional and vocational fields likewise required enormous efforts for the legal and cultural milieu to be changed (Ahlstrom/Garud, 1996; Dunbar/Ahlstrom, 1995; Garud/Ahlstrom, 1997; Levitt/Dubner, 2014).

The history of innovation is such that many useful innovations faced opposition and sat on the shelf for many years or decades. Emerging economies need to learn from the reform of institutions and the protection of private and intellectual property so that innovation and particularly disruptive innovation can proceed and not be impeded by powerful interests.

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CONCLUSION

Since Schumpeter's (1934, 1942) seminal contribution to the theory of economic growth, along with later developments (e.g., Solow, 1956; Romer, 1986; Aghion/Howitt, 1992, 1998; Helpman, 2010; McCloskey, 2010; Phelps, 2015), researchers have understood that innovation can contribute significantly to economic growth, jobs, and the provision of goods to a wider range of the population. Although much attention is given to macroeconomic, redistribution schemes, and financial aid, steady economic growth is the most reliable mechanism for raising the world's living standards broadly across a population (Barro/Sala-i-Martin, 2004; Helpman, 2010). In spite of the upheavals of the past two centuries and pockets of stubborn poverty (Bruton et al., 2015), the majority of the world's population is far better off than their parents and grandparents were (McCloskey, 2010). This is particularly true in emerging economies such as China and India where, in recent years, hundreds of millions of people have left poverty and entered the middle class (The Economist, 2009; Nair et al., 2007). Many studies have shown that a large and rising share of economic growth in recent decades – and with it living standards – is derived from innovation (Aghion/Howitt, 1992, 1998). Disruptive innovations such as PCs, home healthcare, and mobile telephony create significant new growth in industries as they enable the less skilled and less affluent to use products previously available only to wealthier people and organizations. A better understanding of innovation options can help organizations in emerging economies as well as policymakers trying to encourage innovation. It helps them avoid getting stuck in trying to outdo well-funded competitors with 'something better' when they could be introducing products at the lower end of markets, often locally, or creating new product markets. This understanding also helps firms avoid 'cramming' a potentially disruptive product into the established sustaining space, as happened with products such as electric cars and solar power for many years, possibly impeding their development (Christensen et al., 2004). Although disruption leads to some

destruction of older ways of doing things as Schumpeter theorized, that creative destruction also yields the creation of new products and markets (McCloskey, 2010). It is argued here that effectively applied sustaining and disruptive innovation leads to growing firms and an expanding economy, especially when coupled with institutions to encourage entrepreneurship and protect property rights (Rodrick et al., 2004). Emerging economies have almost unprecedented opportunity to address customers and experiment in particular with new disruptive products, often within their own borders as their markets are more geared to base of the pyramid products and do not have sunk cost investment in the more established sustaining innovations.

Yet as research by Sharma (2012) and others shows, this does not happen automatically (Wang et al., 2008). Emerging economies can help by being open to effective innovation of all kinds, particularly disruptive innovation. This is not always easy as traditional industries and markets will be challenged along with the wealth of well-connected principals and other elites (Young et al., 2008). Long-established industries and their supporting institutions will also inhibit disruption, as happened in Japan after its economic growth stalled in the late 20th century (Christensen et al., 2001). Powerful labor movements and inflexible institutional and professional systems can also fight disruption much the way the old guilds and their powerful sponsors hindered sewing machines and looms (Abbott, 1988; Ahlstrom/Garud, 1996; Ayres, 1989; Dunbar/Ahlstrom, 1995; van Wolferen, 1990). These forces are still present; in the United States the opponents of telecommunications deregulation tried everything they could to stop upstart competitors such as MCI and Sprint from entering the U.S. market in the late 20th century. For almost one hundred years, it had been illegal to even attach an answering machine to the phone lines in the U.S., until the upstarts were victorious in the U.S. courts. Established interests are similarly fighting to block Uber taxi services in many cities today. Emerging economies need to fight these tendencies toward protecting established industries and interests while

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allowing for experimentation in technology, institutions and the professions (Abbott, 1988; Acemoğlu, 2003; Olson, 1982).

Finally, entrepreneurship education can be helpful to emerging economies. It was once thought that entrepreneurs were 'born' or had a particular personality. But recent evidence has shown that entrepreneurship entails behaviors that can be taught (Ahlstrom/Ding, 2014). New ventures within established firms can be encouraged. Managers with more suitable professional training and experience will be more able to press new ventures forward (Christensen/Raynor, 2003; McCall, 1998). Innovation and new venture creation are no longer black box mysteries (Furr/Dyer, 2014). They can be systematically studied, encouraged, and improved upon. Understanding disruptive and sustaining innovation and its relevant theory and evidence (Anthony et al., 2008; Christensen/Raynor, 2003; Raynor, 2011) can be very helpful toward that goal. Emerging economies in particular are well positioned to encourage innovation, particularly disruptive innovation. Enabling and encouraging effective and widespread innovation and the new ventures and product-markets it engenders represents perhaps the most effective approach to foster the economic growth needed to help emerging economies more fully emerge from poverty and continue their development (Alvarez et al., 2015; McCloskey, 2010).

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REGIONAL VARIATION IN VENTURE CAPITAL: CAUSES AND CONSEQUENCES

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INTRODUCTION

Entrepreneurship is a central element of the Schumpeterian process of creative destruction (Schumpeter, 1942). Startups have been associated with the birth of important new industries such as semiconductors and computers, the internet and biotechnology, and there is increasing evidence of the important role that startup firms play in driving aggregate productivity growth in the economy (Aghion/Howitt, 1992; Foster et al., 2008; King/Levine, 1993). The availability of finance, and in particular venture capital (VC), seems to be an important part of this phenomenon, despite its extremely small size. Kerr, Nanda and Rhodes-Kropf (2014) highlight that there are less than 500 active VC firms investing in startup ventures across the US in a given year, and Ewens and Rhodes-Kropf (2015) find that approximately 2,000 individuals accounted for 84% of all dollars invested in venture capital in the US between 1987 and 2012. In fact, only about 1,000 of the 600,000 new firms that are founded each year receive initial venture capital financing, but VC backed firms constitute over 50% of the initial public offerings (IPOs) on US stock markets (Kaplan/Lerner, 2010) and about 10% of private sector employment², highlighting the disproportionate impact that this industry has on the economy.

¹ The ideas contained in this brief for the Alpach Economic Forum arise from a number of other pieces we have written including a similar brief written for the NBER's Innovation Policy and Economy entitled 'Financing Entrepreneurial Experimentation' and the paper, 'Entrepreneurship as Experimentation', co-authored with William Kerr, in the Journal of Economic Perspectives. All errors are our own.

² Venture Impact (6 ed.). IHS Global Insight. 2011. ISBN 0-9785015-9-4 based on data provided by the National Venture Capital Association.

Several papers have documented the role that VC plays in the economy. For example, Kortum and Lerner (2000) find that increased venture capital availability leads to increased levels of patenting. Samila and Sorenson (2011) find that an expanded supply of venture capital raises employment and aggregate income within different regions in the United States. This work also suggests that in most regions even within the US, a dollar increase in VC would lead to more than a dollar increase in local employment. Kerr, Nanda and Rhodes-Kropf (2014) use census data in the US to compare startups that received venture capital to those that did not. Looking at firms founded in the 1986–1997 time period, Kerr, Nanda and Rhodes-Kropf (2014) find that by 2007 75% of the VC-backed firms had shut down, compared to 66% of the non-VC-backed firms. The surviving VC-backed firms had grown to the point where their total employment was equal to 364% of the total employment of the original firms at the time of VC investment (including those that eventually failed). On the other hand, the larger number of non-VC-backed firms still only employed 67% of the original sample. Puri and Zarutskie (2012) also find that venture-backed firms grow larger and employ more people. Chemmanur, Krishnan and Nandy (2011) report that venture backing improves the efficiency of firms. Several additional papers have documented the role that VC plays in driving innovation through the venture capitalists' roles in monitoring and governing startup ventures (Bernstein et al., 2014; Chemmanur et al., 2011; Hellmann/Puri, 2000, 2002; Puri/Zarutskie, 2012; Sorensen, 2007). This suggests that the availability of VC may be a central factor that determines the degree to which radical new ideas are commercialized in a given region or point in time (Gompers/Lerner, 2004; Kaplan/Schoar, 2005; Gompers et al., 2008).

A notable feature of venture capital is the uneven nature of VC investment across regions and time. For example, VC investment per capita is a lot larger in the US than in Europe, and even within the US, Silicon Valley, New York and Boston account for a lion's share of VC investment. In addition, venture capital investment has been documented to

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occur in cycles, where certain industries receive a disproportionate share of investment relative to others across time.

This article develops a framework within which to understand the uneven distribution of venture capital across industries, regions and time periods. We highlight how the extreme uncertainty facing startup ventures at their earliest stages leads VCs to engage in a process of experimentation across multiple rounds of funding, abandoning investments where intermediate information is negative and investing more into startups where intermediate information is positive. While these real options are a central element of the investment process, we also point out that financiers, rather than markets, dictate investment and continuation decisions as they choose which experiments to attempt, how to interpret the results, and whether to continue or abandon the investment. These financier's actions are impacted by a myriad of incentive, agency and coordination problems that shape their ability to effectively experiment. We document two important costs to experimentation – constraints to exercising abandonment options when intermediate information is poor, and shocks to the supply of capital that impact the ability to raise capital even when intermediate information is positive. We show how these vary across regions and time, and thereby not only impact the distribution of venture capital across regions but, in doing so, also impact the rate and trajectory of startup innovation. The financial benefit of running an experiment stems from an ability to abandon the investment if intermediate information is poor (or to replace the founder with a new CEO (e.g. Ewens/Marx, 2014; Hellmann/Puri, 2002; Kaplan et al., 2009). The first constraint we consider is that it is often difficult or costly to shut down a firm. One cost to quickly shutting down a firm, for example, is the disutility felt by the entrepreneurs who rapidly lose their job. This and other costs create a trade-off between the rapid abandonment of projects, which encourages investors, and failure tolerance, which encourages entrepreneurs (Manso, 2011). Nanda and Rhodes-Kropf (2015) note that this trade-off is even more troublesome when it cannot be solved optimally for each

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project but is set by a law, culture, or level of bureaucracy that will apply to all projects. Countries with laws designed to make it difficult to fire employees and shut down firms may encourage innovation but financiers in these countries will be unwilling to back very experimental projects. This may help explain the remarkable dearth of venture capital backing of innovation in some European countries (Nanda and Rhodes-Kropf, 2015). More generally, this work develops how formal and informal institutions in an economy play an important role in the level of innovation through their role in promoting the amount of experimentation that investors undertake.

The next constraint on the use of abandonment options is that those experiments that turn out well will need to be funded in a future, unknown capital market. The financing available for startups engaged in innovation is notoriously volatile (Gompers et al., 2008; Gompers/Lerner, 2004; Kaplan/Schoar, 2005), leading entrepreneurs and VC investors to worry about the availability of capital, even if initial experiments go well. Nanda and Rhodes-Kropf (2014) model investors' responses to this financing risk. They show that times or places with high financing risk (low capital availability) are times/places when high expected value, but safe, projects will be run. This fits the intuition that good, solid firms are funded when capital is not freely available. The results also suggest, however, that investors are more willing to experiment in boom times or places with a great deal of capital.

Nanda and Rhodes-Kropf (2013) examine early stage investments from 1984 to 2004 and follow them to 2010 to allow time for exits. The authors find that increased venture capital availability leads to increased rates of failure among venture-backed firms, but also that those that succeed are more successful and more innovative.³

³ The authors show that firms financed at more active times have higher valuations when they go public, controlling for the level of the stock market and the year they go public. Thus, the finding compares firms funded in hot times to those funded in cold times that go public at the same time. Furthermore, those funded in hot markets filed for more patents and their patents were more highly cited.

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This suggests that increases in capital caused investors to not just back more risky firms but more innovative firms. Money did not only chase deals (Gompers/Lerner, 2000) but also changed the deals funded to more innovative projects.

The results from Nanda and Rhodes-Kropf (2013, 2014) suggest that the most innovative startups may need hot financial markets to facilitate their initial diffusion. Investors cannot fund experiments in areas with low capital availability because there is no future funding. This creates a 'chicken and egg' problem in that available capital in an area cannot be deployed if there is not enough other capital in the same area. Therefore, policies may have larger effects if they are able to encourage a concentration of investors that breaks the bad equilibrium. Alternatively, policies that help the local successful experiments reach the resources they need may allow much more local experimentation.

Overall, our framework can be used to help guide policy by helping to provide an understanding about where the costs of experimentation can be reduced.

THE IMPORTANCE OF EXPERIMENTATION

High-impact entrepreneurship requires, almost by definition, going against the grain. Rajan (2012) argues that an entrepreneur 'must be willing to strike out, largely on the basis of intuition, on courses of action in direct opposition to the established settled patterns.' A consequence of this environment is extreme uncertainty about whether a particular technology, product, or business model will be successful.

In the context of extreme uncertainty, experimentation plays a powerful role in increasing the chances that the most promising ideas succeed. One form of experimentation entails a variety of different entrepreneurs commercializing what they believe to be the superior product or technology, and where the ensuing competition leads to the 'survival of the fittest'. As Stern (2005) argued, 'a favorable environment for entrepreneurship and a high level of economic experimentation go hand in hand.'

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For example, Klepper (1996) has documented a consistent pattern where a multitude of new startups emerge at the birth of an industry, followed by a shakeout once the dominant technology has been found. Indeed, Rosenberg (1994) has argued that one of the defining features of capitalism is the freedom it provides entrepreneurs to pursue novel approaches to value creation in the pursuit of economic gain. The promise of large rewards drives entrepreneurs to experiment with new ideas, helping to create a dynamic and growing economy. An institutional environment that facilitates this form of experimentation is thus central to maintaining a vibrant entrepreneurial ecosystem. This not only requires an environment where it is easy to start new ventures but also one where it is easy to shut ventures down (given the high failure rates of startup ventures).

This first form of experimentation depicts experimentation at the level of the economy. A second form of experimentation is one in which investors learn about the potential of individual startups over time, by investing in stages instead of providing the full amount upfront. The ability to invest in stages with the possibility to abandon the investment along the way (see Gompers, 1995; Cornelli/Yosha, 2003; Bergemann/Hege, 2005; Fluck et al., 2007; Bergemann et al., 2008) is particularly valuable for high potential ventures, where it is extremely hard, even for professional investors, to know the true potential of a startup without providing money and learning about the startup's viability over time. A good example of the difficulty in determining how well a new venture will do comes from Kerr, Nanda and Rhodes-Kropf (2014), who study internal data from a single large and successful US VC firm. They look at ratings the partners at this firm gave each deal at the time of the first investment and study how this score relates to the ultimate outcome of the same startups. They find that the correlation between initial scores and ultimate performance of startups was 10%, showing how even successful professional investors have a hard time distinguishing among the most promising startups at the earliest stages of investment. Using si-

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milar data from an angel investment group, Kerr, Lerner and Schoar (2014) find the correlation among the interest levels assigned to funded deals and their ultimate success was less than 10%. More generally, the fact that the majority of VC investments fail (nearly 60% of this VC firm's investments returned less than the money invested) is itself indicative of the difficulty in predicting which firms will be successful and which will fail.

VC firms therefore invest in stages and learn about the viability of startups through a sequence of investments over time. Since each stage of financing is typically tied to achieving milestones that create information about the future prospects of the venture, each round of funding can be seen as an experiment that generates information about the venture's probability of success and its value conditional on that success. Experiments that generate positive information therefore increase the value of the company and allow the entrepreneur to seek the next round of funding without giving up as much equity. On the other hand, experiments that generate negative intermediate information allow the investor to abandon the investment without committing the full amount upfront. Therefore, this process of experimentation, where investors learn about the viability of a radical new idea through an initial investment, interpret intermediate results, and decide whether to continue or abandon their investment, is a key aspect of entrepreneurial finance. It is this second aspect of experimentation that is the focus of the article, although we highlight important interactions and policy implications that stem from the first notion of experimentation as well.

A SIMPLE MODEL OF MULTI-STAGE FINANCING

In this section, we set up a simple model of multi-stage financing that we use to demonstrate the key benefits and costs associated with experimentation across rounds of funding. We use this to highlight how costs to such experimentation that can arise in certain regions or points in time can have important implications for the

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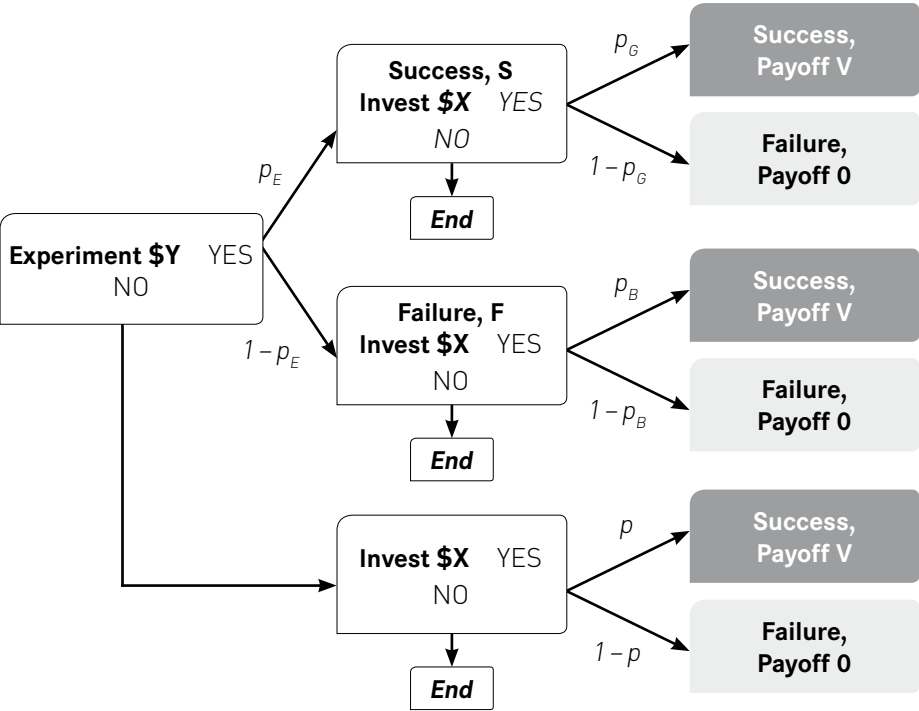
degree to which investors are willing to finance startups commercializing the most radical innovations. In doing so, we hope to demonstrate that costs and constraints to experimentation can play a first-order role in impacting the supply of VC and hence play a central role in driving the rate and trajectory of innovation – independent of the availability of novel ideas and talent to commercialize such ventures.

Consider the following investment: A startup requires $\$X$ to commercialize its technology that may or may not work. With a probability p it will be successful and worth V while with probability $(1-p)$ it will be worth nothing. The expected value of the project is $pV - X$. Thus, this project will not be financed if $X > pV$.

Instead, imagine that the entrepreneur can conduct an experiment before fully funding the startup. The likelihood that the experiment generates positive intermediate information is p_E , while the likelihood of intermediate information being negative is $(1-p_E)$. If results from the experiment look promising (the Good outcome), the chance of ultimate success is p_G , while if the results from the experiment are not promising (the Bad outcome), the chance of success is p_B . The experiment costs $\$Y$ to run. To be equivalent to the project when no experiment is run $p_G * p_E + p_B * (1-p_E) = p$, i.e. the unconditional probability of success is the same whether or not the experiment is run. Thus, the experiment reveals information about the quality of the project.

To make this example concrete, consider a project that requires $\$11$ million (X) to commercialize, will be worth $\$0$ with 99% probability, and will be worth $\$1$ billion (V) with 1% (p) probability. This project will not be pursued as its expected value is negative ($-\$1$ M), i.e. $\$11M > 0.01 * \$1B$. But what if the entrepreneurs can conduct an experiment that will reveal that the project either has a 10% (p_G) chance of working or a zero percent chance of working (p_B)? Furthermore, assume this experiment will reveal the more promising news with a 10% probability. Thus the ex ante probability of success is the same whether or not the entrepreneurs conduct the experiment, i.e. $0.10 * 0.10 + 0 * (1 - 0.1) = 0.01 = p$. The decision tree of the investor is shown in Figure 1.

Figure 1 Investor's Decision Tree



The question facing the investor is whether it is worthwhile to finance the initial experiment. Intuition might suggest that since running the experiment increases the amount the investor has to pay from $\$X$ to $\$X + \$Y$ the experiment is not worth pursuing. However, the value in the experiment arises because it may prevent the investor from spending $\$X$ at all.

The experiment can thus be thought of as an investment that pays off $p_G * V - X$ (\$89M) with probability p_E and pays off $Max[p_B * V - X, 0]$ (\$0) with probability $(1 - p_E)$. Note that if

the results of the experiment are not promising, the investor will only invest $\$X$ if the project has an expected value greater than zero – the max function accounts for this decision. In our example, $p_E = 10\%$, and therefore the expected value of the experiment is $10\% * \$89 \text{ million} = \$8.9 \text{ million}$. Thus as long as the experiment costs less than \$8.9 million, it should be run.

Even though the original investment of \$11 million (X) was not a good idea, an investment of up to \$8.9 million followed by an investment of \$11 million if the experiment is successful is a good idea – it is positive expected value. Spending an additional \$8.9 million to learn about the viability of the project is more valuable than simply directly spending \$11 million. This is the benefit of experimentation.

We emphasize that the value of experimentation is not driven by the specific numbers chosen in this example. Rather the experiment is valuable any time

CONDITION 1

$$p * V - X < p_E * (p_G * V - X) + (1 - p_E) * Max[p_B * V - X, 0] - Y$$

i.e. when the expected value without the experiment is less than the expected value with the experiment. When is this true? This cannot hold, for example, for any project that has a positive expected value even after the experiment fails. In this case, $Max[p_B * V - X, 0] = p_B * V - X$. Since $p_G * p_E + p_B * (1 - p_E) = p$, we see that $p_E * (p_G * V - X) + (1 - p_E) * (p_B * V - X) = p * V - X$ and running the experiment really is just a waste of resources. This is because it changes no decision as the investor invests $\$X$ no matter what the experiment reveals. However, if $p_B * V - X < 0$ then the investor would like to avoid investing when the true probability of success is p_B . The investor would therefore be willing to pay to learn whether the probability is p_G or p_B . How much the investor is willing to pay depends on how much the investor learns from the experiment.

In an extreme, an experiment might demonstrate nothing, i.e. $V^*p_G = V^*p_B$. That is, the probability of earning V is the same no matter what the experiment's outcome. Alternatively, the experiment might provide a great deal of information. In this case, V^*p_G would be much larger than V^*p_B . We can think, therefore, of $V^*p_G - V^*p_B$ as the amount or quality of the information revealed by the experiment. $V^*p_G - V^*p_B$ is larger if the experiment revealed more about what might happen in the future.^{4,5}

Overall, we see that experimentation is very valuable in situations when relatively small dollars invested can reveal information that results either in a valuable project going forward or preventing a mistaken investment. We next demonstrate two important constraints to experimentation and document how institutional features that govern experimentation can play a role in leading these costs to be systematically different across regions. This naturally sets up potential roles for policy.

Costs to Exercising Abandonment Options

As was seen above, the benefit of running an experiment from the investor's perspective stems from an ability to abandon the investment if intermediate information is poor (or to replace the founder with a new CEO (e.g. Ewens/Marx, 2014; Hellmann/Puri, 2002; Kaplan et al., 2009). This form of failure can be frustrating to entrepreneurs who often tend to feel that a breakthrough requires only a little more funding and patience. Thus, entrepreneurs often look for investors willing to allow

⁴ Note that we can think of p_G and p_B as posterior probabilities with a prior of p . Thus, one special case is martingale beliefs with prior expected probability p and updating that follows Bayes Rule. In this case, projects with weaker priors would have more valuable experiments.

⁵ Note also that the experiment is not more or less important if the project is riskier – a riskier project might be one with a larger V and smaller probabilities of success, p_G and p_B , but the information revealed by the experiment, $V^*p_G - V^*p_B$, could be the same. Thus, the value of the experiment and the risk of the project are related but not the same.

them a second go if intermediate information is negative, or even look for investors who are willing to fund the project more fully upfront. In an extreme, entrepreneurs may not be willing to take an investment from investors who have a reputation for exercising their abandonment options.

To incorporate this idea into our simple model, we will assume that the effort decision by the entrepreneurs is all or nothing, i.e. they either start the new venture or they do not. They also face a cost of u_F if the project is shut down after the experiment. This can be thought of as the disutility they experience when they fail. In this case, even for firms where experimentation may be valuable ($p_B^*V - X < 0$), disutility for failure may hamper experimentation.

The total value of experimentation including both the financial payoff and the costs borne by the failed entrepreneur is

EQUATION 2

$$p_E^*(p_G^*V - X) - Y - (1 - p_E)^*u_F$$

Including a cost of early failure reduces the value of experimentation by $(1 - p_E)^*u_F$. Note that this will also affect the financiers even though they do not directly pay the failure costs. This is because the financier and entrepreneur must negotiate over any surplus generated by the project. The loss from early failure lowers the entrepreneur's expected payoff. If the total expected value of the project does not generate enough to cover the costs borne by both the entrepreneur and investor, then the entrepreneur and investor will not be able to find a deal that will induce them to both participate.

If the costs of early failure are too high, then the entrepreneur will not participate in the project if it is funded via experimentation. For example, one can imagine that an aspiring entrepreneur who would receive a \$100,000 investment but then be forced to shut down in six months due to a lack of further funding may be less willing to quit his

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day job than if funded with millions of dollars, even if the quality of the project is the same in either case. This is the intuition of failure tolerance – an investor may have to agree to fund the project significantly in order to induce the entrepreneur to start the project. In Manso (2011), for example, principals decide how to reward agents in an interim period as well as when the final output is revealed. Manso (2011) demonstrates how the optimal payments may involve leniency in the case of bad interim outcomes. This reduces incentives for effort but simultaneously induces the agent to experiment. Hellmann and Thiele (2011) also suggest that low powered incentives may induce low effort on standard tasks but encourage experimentation. This is a very intuitive result and a number of empirical papers consider the impact on innovation of policies that create a failure tolerance (Acharya/Subramanian, 2009; Aghion et al., 2009; Burkart et al., 1997; Ferreira et al., 2011; Myers, 2000; Tian/Wang, 2012). Interestingly, however, many innovations are commercialized by new ventures that are backed by VC investors, who tend to be remarkably intolerant of early failure (Hall/Woodward, 2010). It is standard for venture capitalists to negotiate control rights that allow the investors to fire management and/or abandon the project (see Gompers/Lerner, 2004; Hellmann, 1998; Sahlman, 1990). Even among venture-backed firms that are ‘successful’, Hellmann and Puri (2002) and Kaplan, Sensoy and Stromberg (2009) show that many end up with CEOs who are different from the founders. Nanda and Rhodes-Kropf (2015) explain this apparent contradiction by arguing that the principals who are financing innovation (VCs, corporations, and even governments) cannot set an optimal failure tolerance policy on a project-by-project basis. Bureaucratic constraints, laws, policies, or possibly a desire to maintain a consistent reputation lead investors to fix an, ‘innovation policy’ upfront. They may do so by committing not to shut down projects quickly. Alternatively, a company culture or level of bureaucracy will apply to all projects. Or, for example, a government looking to stimulate innovation may pass laws making it harder to fire

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employees. These levels of ‘failure tolerance’ will apply to all employees, regardless of the project. Put differently, a principal often has an innovation policy that is set ex ante – one that is a blanket policy that covers all projects in the principal’s portfolio. This preset policy, culture, or bureaucracy may then affect what projects the principal chooses to pursue. Intuition can again be gained from our simple model by assuming that a failure tolerant investor commits to fund the project regardless of the outcome of the experiment. Thus, the expected value of the project if run by a committed investor is $p^*V - X$ (because the experiment is not run). With the alternative uncommitted strategy, the expected value of the project is as in equation (2). Thus a project will be done by an uncommitted investor if

CONDITION 3

$$p^*V - X < p_E^* (p_G^*V - X) - Y - (1 - p_E^*)u_F$$

In this case, the value of the project is large enough with an uncommitted investor that enough value can be shared with the entrepreneur to make up for their potential disutility from failure.

When will this be the case? In those companies where the experiment reveals a large amount of information. As we saw above, when the value of the experiment is high then $p^*V - X < p_E^* (p_G^*V - X) - Y$. Since entrepreneurial disutility lowers the value of the experiment, the information from the experiment has to be even more valuable to be financed. Thus, it is the uncommitted, failure-intolerant investors that will select the very experimental projects. Meanwhile, those organizations that are more failure-tolerant will only be willing to back the less experimental projects, because with safer projects they will not need to extract value by terminating if bad information occurs. Combining this with the idea of failure tolerance in Manso (2011), we should expect that large, bureaucratic corporations may encourage innovation but will be unwilling

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to back very experimental projects, as it would be negative expected value to do so without shutting them down after early bad news. VCs, on the other hand, will choose to fund radical experiments but many entrepreneurs may be unwilling to leave safe jobs to pursue these projects since they have a significant chance of early failure. Interestingly, corporate venture capitalists are thought to be more failure tolerant than regular venture capitalists, and Chemmanur, Loutskina and Tian (2012) report that this encourages greater innovation. Nanda and Rhodes-Kropf (2015) suggest that this might explain why corporate VC earns lower returns than typical VC.⁶

In the same vein, countries with laws designed to make it difficult to fire employees and shut down firms may encourage innovation but financiers in these countries will be unwilling to back very experimental projects – again, those that would be negative expected value if they could not be shut down after early experiments. This may help explain the remarkable dearth of innovation in some European countries (Bozka-ya/Kerr, 2014; Saint-Paul, 1997).

The standard culprit for the lack of entrepreneurship in Europe is that there is thought to be a higher stigma of failure (see Landier, 2002). We can see the intuition for this from equation (2): if u_F is larger, then the value of experimentation is lower. Thus, there will be a tendency toward more certain or less experimental projects. However, although a stigma of failure can explain a reduction in entrepreneurship, it has more challenges explaining the virtual absence of radical new economy companies emerging from many countries. Surely some entrepreneurs are willing to take the risk? In fact, what entrepreneurs complain about in many countries is that they cannot get their idea funded. Even Skype, a huge venture-backed success that was started by European entrepreneurs Niklas Zennström and Janus Friis, received its

⁶ Corporate venture capitalists do not seem to have had adequate financial performance but Dushnitsky and Lenox (2006) have shown that corporations benefit in non-pecuniary ways (see theory by Fulghieri/Sevilir, 2009).

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early funding from US venture capitalists Bessemer Venture Partners and Draper Fisher Jurvetson.

A stigma of failure by itself cannot explain this phenomenon. In an environment with a high stigma of failure, capital will be even cheaper as it fights to attract entrepreneurs (Landier, 2002). But European entrepreneurs complain that they cannot find capital to fund their novel ideas even if they are willing to take the risk and potentially suffer the consequences of failure. Nanda and Rhodes-Kropf (2015) build on Landier (2002) to show that the problem is two-sided: venture capitalists look for less experimental projects to form reputations as failure-tolerant because most entrepreneurs want a more failure-tolerant backer. But doing so potentially results in an equilibrium with no investor willing to fund radical experiments, even if they are positive expected value and the entrepreneur is willing to take the risk. Martin Varsavsky, one of Europe's leading technology entrepreneurs, noted in an interview with *Fortune* magazine that 'Europeans must accept that success in the tech startup world comes through trial and error. European [investors] prefer great plans that don't fail.'⁷

More generally, this work implies that formal and informal institutions in an economy can play an important role in the level of innovation through their role in promoting the amount of experimentation that investors undertake. First, certain financial intermediaries are, by design, limited in the amount of experimentation they can engage in. Banks, for example, do not share proportionately in the benefits when a startup does extremely well, but do suffer the losses when the startup fails. Banks cannot, therefore, fund an experiment with a high chance of failure, even if it is a positive expected-value experiment. Indeed, Black and Gilson (1998) argue that bank-oriented economies are less likely to encourage startups engaged in innovation. In a similar vein, regulations surrounding the amount of money that can be committed by pen-

⁷ See <http://tech.fortune.cnn.com/2012/08/14/europe-vc/>

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sion funds to asset classes such as venture capital can have important implications for the amount of capital available to support the financing of experimentation (e.g. Kortum/Lerner, 2000).

Second, policies that are aimed at motivating experimentation by entrepreneurs can limit the degree to which investors are willing to finance this experimentation. For example, lenient bankruptcy laws may encourage entrepreneurs to take on bolder experiments but at the same time make investors less willing to fund the experimentation, since their return if things go badly is reduced (Guler, 2007b,a; Nanda/Rhodes-Kropf, 2015; Cerqueiro et al., 2013). On a similar note, employment protection laws might encourage employees in large companies to engage in more experimentation but can limit the attractiveness for VC investors, who need to hire and fire employees to effectively engage in experimentation (Bozkaya/Kerr, 2014).

Finally, societal norms can have important interactions with the formal institutional environment and with the organizational strategies of investors. Cultures where there is a high stigma of failure are ones where entrepreneurs are less likely to want financing from investors with a reputation for shutting down projects. This can lead investors to pick more failure-tolerant strategies and, in doing so, only finance the less experimental startups in the economy. Thus programs aimed at celebrating the entrepreneur and venture investors, even if unsuccessful, may have important effects.

SHOCKS TO THE AVAILABILITY OF CAPITAL

Having discussed the costs associated with exercising abandonment options when intermediate information is bad, we turn next to constraints associated with experimentation even when intermediate information is positive. This is because the financing available for startups engaged in innovation is notoriously volatile (Gompers et al., 2008; Gompers/Lerner, 2004; Kaplan/Schoar, 2005), leading entrepreneurs and VC investors to worry about the availability of capital, even if initial experiments go well.

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VCs refer to this concern as ‘financing risk’: the risk that the survival of an otherwise healthy startup might be threatened by a negative shock to the supply of capital in its sector when it is looking for the next round of funding.⁸

This worry seems rational given the ebbs and flows of capital that have occurred within various venture sectors at different times and in distinct places.

Nanda and Rhodes-Kropf (2014) model investors’ responses to financing risk and explain why investors’ responses have a larger effect on the most novel technologies in the economy. Investors can respond to financing risk by providing firms with more upfront funding, hence making startups less vulnerable to the future state of the capital markets. This response can effectively eliminate financing risk but it also comes at a cost: providing firms with greater upfront funding reduces investors’ ability to abandon their investment if intermediate information on its prospects is poor. In fact, the value of the lost real option can be high enough that it makes the investment unviable. This tradeoff between wanting to protect firms from financing risk and wanting to preserve the option to abandon the investment is most salient for firms engaged in radical innovations. Thus, startups most susceptible to financing risk are the ones commercializing radical innovations – these are the ventures that are most likely to be funded when financing risk is low and most likely to be constrained when financing risk is high. Their work thus provides an intuitive mechanism linking hot and cold financial markets to innovation in the real economy.

Nanda and Rhodes-Kropf (2014) show how investors with small pools of capital, who depend more on other investors’ willingness to fund the startup at its next round of funding, are more exposed to financing risk. Regions with a small number of investors and investors with small funds are therefore more likely to be subjected to

⁸ Large firms who finance with debt face a similar risk referred to as ‘rollover risk’ when trying to issue new bonds to replace maturing bonds (see Acharya et al., 2011; He/Xiong, 2012b,a)

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financing risk. As shown by Kortum and Lerner (2000), the Prudent Man Rule in the United States, which allowed pension funds and other large, institutional investors to make substantial commitments to private equity, seems to have been pivotal in generating a large pool of capital to fund innovation. A big distinction between the US and Germany, for example, is the number of active 'large' VC firms (e.g. with more than US\$300M under management). The size of the fund can have a direct bearing on the degree to which VCs push for bold commercialization strategies but, as seen above, can be reinforced by the presence of financing risk, which is much more salient for smaller VC investors.

This insight from Nanda and Rhodes-Kropf (2014) can be seen in the context of our model by assuming that there is a probability $(1 - \Theta)$ that the firm cannot find $\$X$ when it is ready for the next round of funding. Since $\Theta < 1$, including financing risk in the model shows how it reduces the value of experimentation.

CONDITION 4

$$p_E * \Theta * (p_G * V - X) - Y < p_E * (p_G * V - X) - Y$$

The introduction of Θ implies that some experimental projects will no longer be undertaken. These are firms that were not viable without an experiment (that is, the most novel investments), but are now also not profitable even with an experiment because of the presence of financing risk. Other startups are likely to be financed with all-or-nothing bets. These latter startups are firms for which

CONDITION 5

$$p * V - X > p_E * \Theta * (p_G * V - X) - Y$$

i.e. rising financing risk (smaller Θ) causes the expected value with the experiment to be less than without the experiment. These are startups that were not particularly

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novel so that the value of the lost abandonment option is not as high. They are better off being protected against financing risk and being funded all in one go.

These results show that times or places with high financing risk (times with low capital availability) are times/places when high expected-value but safe, projects will be run. This fits the intuition that good, solid firms are funded when capital is not freely available. The results also suggest, however, that investors are more willing to experiment in boom times or places with a great deal of capital. Thus these become times when, or places where, more novel, experimental startups are financed. Startups funded in boom times/places should be more likely to fail (when investors exercise their abandonment options) but also likely to have bigger successes. This is what locations with limited capital available for new ideas miss: the great success that comes from the few remarkable outcomes (Nanda/Rhodes-Kropf, 2013).

This way of thinking about the funding of innovation suggests that there can be 'good' equilibrium that increases innovation in places like Silicon Valley and in booming time periods, and alternative equilibria that are bad for innovation in other places and times. If we believe that this is an important part of the phenomenon, then policy designed to increase innovation should be aimed at trying to 'break' the 'bad' equilibria and switch it to the 'good' equilibria. This is easier said than done as there are many arguments for why one equilibrium or another might currently exist. However, two notions are helpful guides to thinking about policy in this context.

First, concentrated policies are likely to have a larger effect. That is, something that encourages investing in a particular area or sector is more likely to have an impact than a broad-based initiative. In this framework, a policy will have a large impact if it increases the perception that several investors are interested in backing a certain sector, thereby lowering potential shocks to the availability of capital. Thus a broad policy designed to have a small effect on many companies seems fundamentally less likely to engineer a regime switch. The analog to policies aimed at encouraging innovation

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are those aimed at popping technology ‘bubbles’ or preventing investors from losing money in risky ventures. What may look to policy makers like unsound investments into areas with a great deal of failed companies may be vital to experimentation and innovation. In fact, the results from Nanda and Rhodes-Kropf (2014) suggest that the most innovative startups may even need hot financial markets to facilitate their initial diffusion.

The second notion that stems for our model’s intuition is that local areas could potentially break the ‘bad’ equilibrium and encourage local innovation by, counter-intuitively, creating a mechanism to help the best local companies leave to go to innovation hubs. This should encourage local entrepreneurs and small investors to fund and start companies locally because they would know if the companies work locally they could be moved to areas where they could get the funding and other resources needed to scale the idea. Once a vibrant startup community formed locally, investors would naturally arise trying to fund the best before they moved away. Thus this idea breaks the chicken and egg problem.

CONCLUSION

A large body of literature in entrepreneurial finance has shown how financing frictions arising from asymmetric information between entrepreneurs and VC investors can lead to credit constraints for high-potential ventures. This article complements prior research by focusing on another possible source of financing frictions: the fundamental uncertainty facing startups in their earliest stages, where neither the entrepreneur nor the investor knows about the true potential of the venture without investing to learn about the viability of the idea. In this context of extreme uncertainty, multi-stage financing allows investors to learn about a venture’s potential over time without committing the full amount upfront. These real options can be particularly valuable in the context of entrepreneurship because most new ventures fail com-

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pletely and only a few go on to become extremely successful. We have shown how constraints to staged financing reduce the value of these real options and hence influence the degree to which investors can effectively experiment. We show how this has important consequences for the degree to which radical new technologies are commercialized across regions, with important consequences for policies looking to stimulate high potential entrepreneurship.

Formal regulations and informal cultural institutions that make it harder to abandon investments when intermediate information is bad can lead investors to only finance startups where the value of abandonment options is low. These are startups with safer, less novel innovations, with the implication that regions or firms where it is harder to engage in experimentation are likely to see fewer startups engaged in innovation. In addition, potential shocks to the availability of capital can reduce the value of staged financing. This risk is more salient in regions with a small number of investors or investors with smaller funds. Again, these constraints to experimentation impact the most novel startups in the economy. Overall, these insights also suggest caution in trying to prevent failure of startup ventures. Failure is a natural part of the experimental process and, in fact, extreme failure and extreme success may be two sides of the same coin.

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PATENT RIGHTS AND CUMULATIVE INNOVATION: **CAUSAL EVIDENCE AND IMPLICATIONS FOR POLICY**

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1 INTRODUCTION

Cumulative research is a dominant feature of modern innovation. New genetically modified crops, computers, memory chips, medical instruments and many other modern innovations are typically improvements on prior generations of related technologies. Of course, cumulative innovation is not new. Economic historians have emphasized the role of path dependence in the development of technology, documenting how past successes and failures serve as ‘focusing devices’ that guide the direction of later technological inquiry (Rosenberg, 1976). However, the increasing importance of basic science in shaping the direction of technological development has intensified this process.

Cumulative innovation is underpinned by knowledge spillovers, as later innovators build on earlier research. This process lies at the heart of the recent macroeconomic literature on innovation and growth – so-called endogenous growth models (Acemoğlu and Akçiğit, 2012; Aghion/Howitt, 1992; Grossman/Helpman, 1991). At the same time, there is a large body of evidence showing that R&D creates positive ‘knowledge spillovers’ that increase productivity growth and subsequent innovation (e.g. Bloom et al., 2013). This consensus on the centrality of knowledge spillovers to innovation, and innovation to productivity growth, is the primary justification for government policies to support R&D.

There has been an intensifying academic and public policy debate over the role of patents in stimulating innovation and growth. The debate has been driven by several factors. The first is the recognition that modern economies are increasingly based on intangible knowledge assets and that this is no longer limited to particular sectors. As a consequence, an effective growth strategy requires policies and institutions

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that promote the generation and diffusion of innovation. The patent system is one of the main instruments governments use to increase research and development incentives while at the same time promoting follow-on innovation. However, there is growing concern among academic scholars and policy makers that patent rights are themselves becoming an impediment, rather than an incentive, to innovation. The increasing proliferation of patents and the fragmentation of ownership rights among firms are believed to raise transaction costs, constrain the freedom of action to conduct research and development, and expose firms to ex-post holdup through patent litigation (Heller/Eisenberg, 1998). In the extreme case, where bargaining failure in patent licensing occurs, follow-on innovation can be blocked entirely.

These issues are thought to be particularly acute in ‘complex technology’ industries where innovation is highly cumulative and requires the input of a large number of patented components held by diverse firms – leading examples are information technology, software and biotechnology. On top of that, critics claim that (large) firms strategically accumulate patents to use them to resolve disputes through cross-licensing, and this puts small firms without such patent ‘chits’ to trade, at a disadvantage in enforcing their patent rights. These dangers have been prominently voiced in public debates on patent policy in the U.S. (National Research Council, 2004, Federal Trade Commission, 2011) and recent decisions by the Supreme Court (e.g. eBay Inc. v. MercExchange, 547 U.S. 338, 2006). Similar concerns have also been raised in European policy discussions on the implementation of a unitary European Patent and European Patent Court (European Commission, 2011).

In order to design evidence-based government policies that effectively address this potential problem, it is first important to quantify the extent to which patent rights *do* in fact impede follow-on innovation and to identify whether their impact is pervasive or instead is localized in particular types of technology fields and transacting firms. Broad reforms of the patent system may be required if this blocking effect is wide-

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spread and has a substantial blocking effect on follow-on innovation by firms across different technology areas. At the other end, more targeted policies may be preferable if patents appear to block innovation only in very specific environments.

To date, most of the economic research on the impact of patent rights on cumulative innovation has been primarily theoretical. The main conclusion from these studies is that anything can happen – patent rights may impede, have no effect, or even facilitate subsequent technological development. It depends critically on assumptions about the bargaining environment and contracting efficiency between different generations of innovators. In an early contribution, Kitch (1977) argues that patents enable an upstream inventor to coordinate investment in follow-on innovation more efficiently and to mitigate the dissipation of profit from downstream competition that can lead to underinvestment. By allowing the upstream innovator to serve as the gatekeeper to coordinate downstream investments, patent rights can facilitate cumulative innovation. In contrast, Green and Scotchmer (1995) show that upstream patent rights will not impede follow-on innovation that increases total value (joint profit) as long as bargaining between the parties is efficient – i.e. if there are no transaction costs and perfect information. While these assumptions are not likely to hold perfectly in most environments, this work is important because it focuses our attention on bargaining failure as the source of any blocking effect patent rights might create. The question then is, in what kind of environments is bargaining failure more likely?

Finally, a number of papers have shown how patent rights can block innovation when bargaining failure occurs. This can arise from two main sources. First, asymmetric information about the value of the initial or follow-on innovation can lead to the parties failing to agree on a license even though there is joint profit that could be shared (Bessen/Maskin, 2009). Second, bargaining failure can occur when downstream innovators need to license multiple (complementary) upstream patents that are held by distinct patent holders. Not only does this increase transaction costs but, since

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bargaining is typically done bilaterally rather than coordinated across the different licensors, this creates the ‘complements (or royalty stacking) problem’ – value maximization requires coordinated resolution which is ignored by independent claimants (Galasso/Schankerman, 2010; Shapiro, 2001).

This diversity of theoretical models highlights the need for empirical research. It is important not only to establish whether patent rights block subsequent innovation but also to identify how this effect depends on the characteristics of the bargaining environment and the transacting parties. Who exactly is blocking whom and in what settings? Understanding these issues is essential in order to design appropriate policy remedies.

In order to provide a solid foundation for formulating policy in this (and other) areas, we need credible evidence of the *causal relationship* (not just correlations) between patents and later innovation. Given the importance of the issue, there is surprisingly little econometric evidence on this link. In two influential papers, Murray and Stern (2007) and Williams (2013) provide the first causal evidence that patent rights block later research in the biomedical field. Murray and Stern exploit patent-paper pairs to study how citations to scientific papers are affected when a patent is granted on the associated invention. They show that citations to scientific publications fall (by about fifteen per cent) when a patent is granted on the innovation associated with that publication. Williams studies the impact of contract-based intellectual property (not patents) on specific genes on subsequent human genome research and a measure of medical diagnostic tests developed on the basis of the specific genes. Interestingly, both papers find roughly similar magnitudes – property rights appear to cause roughly a fifteen to thirty per cent reduction in follow-on research. These important studies focus on very specific (albeit significant) innovations in human genome and biomedical research and it is hard to know whether their conclusions generalize to other industries.

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In this article we report on recent evidence of how patent rights affect the process of cumulative innovation, based on Galasso and Schankerman (2015). This research adopts a novel identification strategy to estimate the causal effect of patents on cumulative innovation. We use the decisions to invalidate patents by the U.S. Court of Appeals for the Federal Circuit, which has exclusive jurisdiction in appellate cases involving patents. Because patents constitute prior art, later applicants are still required to cite patents when relevant even if they have been invalidated and thus put into the public domain. This allows us to trace how the loss of the patent right affects the rate of subsequent citations to that patent, relative to those patents that are upheld by the Court.

The main concern is that unobserved factors might be affecting both the decision to invalidate a patent and the follow-on innovation, leading us to conclude wrongly that the loss of the patent causes the later change in innovation (this is called the ‘endogeneity’ problem). We are able to avoid this potential problem by exploiting the fortunate institutional fact that Federal Circuit judges are assigned to patent cases through a computer program that randomly generates three-judge panels, with decisions governed by majority rule. This random allocation of judges allows us to pin down the causal relationship between the loss of the patent right and later innovation by other firms.

There are three main empirical findings. First, the loss of patent rights causes about a fifty per cent increase in subsequent citations to the focal patent on average and this finding stands up to a wide variety of tests for robustness. Second, this average impact is misleading because there is a huge amount of variation in the effect of patent invalidation on later innovation. For most patents, there is no statistically significant effect; the positive (blocking) effect of invalidation on citations is concentrated on a small subset of patents which have unobservable characteristics that are associated with a lower probability of invalidity (i.e. stronger patents).

There is also large variation across broad technology fields in the impact of patent invalidation and the effect is concentrated in fields that are characterized by two features: complex technology and high fragmentation of patent ownership. This finding is consistent with predictions of the theoretical models that emphasize bargaining failure in licensing as the source of blockage. Patent invalidation has a significant impact on cumulative innovation only in the fields of computers and communications, electronics, and medical instruments (including biotechnology). We find no effect for drugs, chemicals, or mechanical technologies. Importantly, we also are able to confirm these results using measures of later innovation that do not rely on patent citations. In two technology fields – pharmaceuticals and medical instruments – we use data on new product developments (available because of government registration requirements) and in both fields our findings are the same as with citations – patents have no blocking effect in drugs, but do in medical instruments.

Lastly, we show that the effect of patent rights on later innovation depends critically on the characteristics of the transacting parties. The impact is entirely driven by the invalidation of patents owned by large firms, which increases the number of small innovators subsequently citing the focal patent. We find no statistically significant effect of patent rights on later citations when the invalidated patents are owned by small or medium-sized firms. This result suggests that bargaining failure between upstream and downstream innovators is not widespread but is concentrated in cases involving large patentees and small downstream innovators.

Taken together, our findings indicate that patent rights block cumulative innovation only in very specific environments, and this suggests that government policies should be targeted at facilitating more efficient licensing in those environments. Since innovation is the key to sustained productivity growth, policies that improve the market for licensing will make an important contribution to promoting economic growth over the long term.

2 STRATEGY FOR IDENTIFYING THE CAUSAL EFFECT OF PATENT RIGHTS ON INNOVATION

There are two main challenges in studying the impact of patent rights on cumulative innovation. The first is that we need to identify comparable technologies with and without patent protection. The second is that follow-on innovation is difficult to measure. In our analysis, we exploit patent invalidation decisions by the U.S. Court of Appeals for the Federal Circuit, established in 1982. We use comprehensive data on 1,357 Federal Circuit decisions from 1983 to 2008 and record whether each patent was invalidated. About forty per cent of the decisions in our sample lead to a loss of patent protection for the technology. We use the number of citations by subsequent patents to the ‘focal’ patent as a measure of cumulative innovation. Patent applicants are required to disclose known prior art that might affect the patentability of any claim and any wilful violation of this duty can render the patent unenforceable. Importantly for our purposes, the expiration or invalidation of a patent has no impact on its prior art status, so the requirement to cite it remains in place. Citations have been widely used in the economics of innovation literature as a proxy for follow-on research (Griliches, 1992) and are the only practical measure of cumulative innovation for studies such as ours that cover a wide range of technology fields. We also show that our results are robust to non-patent measures of cumulative innovation that we are able to construct for two technology fields, pharmaceuticals and medical instruments.

To estimate the effect of patent rights on follow-on innovation, we compare the number of citations received by patents that are invalidated to those that are upheld by the Federal Circuit Court in a five-year window following the decision. A fundamental challenge with this approach is that invalidated patents may differ from those that are upheld in a variety of dimensions that may affect patent citations. For example, patents covering technologies with greater commercial potential are both more likely to be an attractive target for follow-on innovation and to induce the

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patentee to invest heavily in the case to avoid invalidation. It is crucial to address this ‘endogeneity’ issue in order to estimate the true causal impact of patent protection on cumulative innovation. We show that failure to do this leads to misleading and incorrect findings.

Our empirical strategy exploits the fact that judges are assigned to patent cases through a computer program that randomly generates three-judge panels, with decisions governed by majority rule. We show that judges on the Federal Circuit Court exhibited very different ‘propensities to invalidate’ in their tenure at the Court – some voted for invalidation much more often than others (varying from about 25% to 75%). The random allocation of judges to case, together with this variation in their propensity to invalidate patents, essentially means that invalidation of patents is a randomised outcome and thus can be used to identify the true causal impact of removing patent protection (econometrically, we implement this approach using instrumental variables). In conducting this exercise, we control for a number of patent characteristics such as the age of the patent, the technology field, the number of patent claims, and the number of citations received before the Federal Circuit decision. This approach allows us to identify the *causal impact of removing patent rights on later innovation*.

3 WHAT DOES THE EVIDENCE SHOW?

3.1 THE ‘AVERAGE EFFECT’ OF PATENTS

The baseline finding, using our instrumental variable identification strategy, is that the removal of patent protection on a patent leads to about a fifty per cent increase in subsequent citations to that patent, on average. This evidence shows that, at least on average, patents block cumulative innovation, and we emphasise that this is evidence of a causal relationship. It is critically important to use an appropriate identification strategy to pin down causal effects here, especially if one wants to

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make policy recommendations on the basis of the evidence. If we instead use simple (OLS) regression that fails to account for the fact that the patent invalidation decision is endogenous, the results indicate that there is no effect on subsequent citations. But this is a false result, since formal statistical tests confirm that patent invalidation is in fact endogenous (i.e. influenced by unobserved factors that also affect subsequent citations). This highlights the importance of using an appropriate identification strategy, and the dangers of drawing policy conclusions from evidence that is not causal.

As additional checks on this key finding, we examine other possible explanations. First, we show that the jump in later citations following the invalidation of a patent is not simply due to a ‘publicity effect’ from the court’s decision – where subsequent innovators become more aware of the patent and thus cite it. The impact begins only after about two years following the court decision, which is consistent with the onset of follow-on innovation rather than simply being a media effect from press coverage associated with the court decision, and when we introduce a measure of the actual press publicity around the case, the results are the same: on average, patents block later innovation. Second, we examine whether part of the jump in later citations that we observe might reflect greater use of the invention covered by the invalidated patent by later innovators, because it is now cheaper to use when no longer protected by the patent. There is some evidence of this kind of ‘substitution’, but it can only account for a small part (about fifteen per cent) of the overall blocking effect we find.

While the average blocking effect of patents is large, we also find that the impact of patent invalidation on subsequent innovation is highly heterogeneous. This means that the average effect is misleading and should not form the basis for policy prescriptions. There is a lot of variation across patents – there is essentially *no significant blocking effect for most patents, but a strong effect for a minority of patents*. From a policy perspective, it is very important to understand when patents block and when they do

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not, so that appropriate, targeted policy remedies can be designed. In our research, we show that the blocking effect depends critically on key features of the technology area and the contracting environment, as we summarize in the next section.

3.2 UNBUNDLING THE IMPACT: WHEN DO PATENTS BLOCK?

3.2.1 In which technology fields does blocking occur?

Previous empirical studies emphasize two features of the innovation environment that affect bargaining between upstream and downstream firms and thus the incentives to invest in follow-on innovation. The first is the *fragmentation of patent ownership* in the technology field (Zeidonis, 2004). When patent ownership is fragmented rather than concentrated in a few hands, downstream innovators need to engage in multiple negotiations, which exacerbates the risks of bargaining failure and thus make it more likely that patents end up blocking later innovation. The second feature is the *'complexity' of the technology field*. In complex fields, new products embody numerous patentable elements, such as mobile telephones or medical instruments – as contrasted with 'discrete' technology areas where products build only on few patents, such as pharmaceuticals or chemicals. When products typically incorporate many patented inputs, and they are held by different owners, licensees need to engage in multiple negotiations and the risk of bargaining failure is higher. Thus we expect the impact of patent rights on cumulative innovation to be more pronounced in complex technology fields.

To test these ideas, we construct two variables. The first is a measure of how concentrated patenting is in the technology field of the litigated patent – we use the share of patenting accounted for by the four largest patent owners in that technology subcategory during the five years preceding the Federal Circuit Court decision. The second is a control variable that identifies which technology fields are complex and which are not (building on earlier survey research by Levin et al., 1987, and Cohen et al.,

2000). Complex technology fields include electronics, computers and communication, medical instruments and biotechnology. Noncomplex fields include pharmaceuticals, chemicals and mechanical technologies.

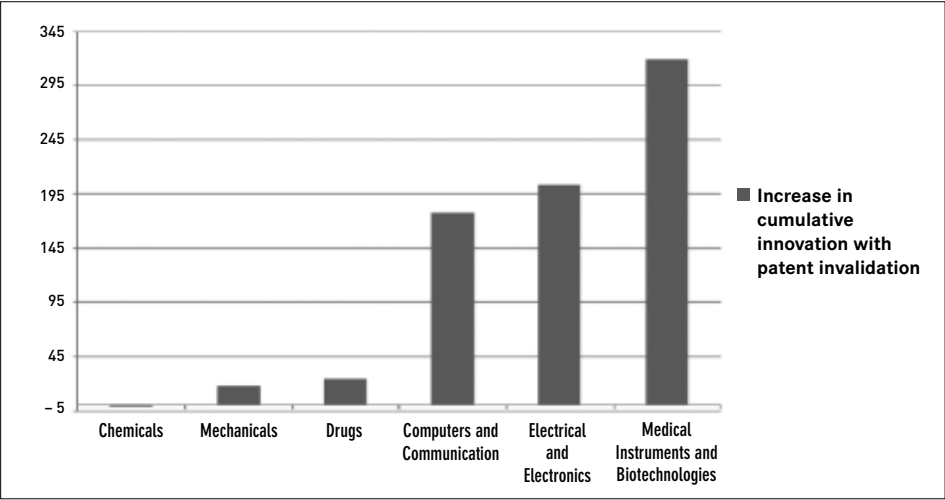
The evidence strongly confirms these hypotheses. We find that the 'blocking effect' of patents is much stronger when patent ownership is fragmented (i.e. where concentration is low) and in complex technology fields. The results indicate that the effect of invalidation is more than twice as large in complex technology areas as compared to the non-complex technology fields and the blocking effect is much weaker when concentration of patent ownership is greater. Increasing the level of concentration by one standard deviation reduces the blocking effect of patents by about thirty-two per cent in complex technology fields.

We can use these econometric estimates of the effect of concentration and complexity to compute the implied effect of patent invalidation on citations for each of the technology fields, based on the observed values of concentration and complexity that correspond to each field. The results are summarized in Figure 1 below, and they are striking. Patent rights have no statistically significant effect on cumulative innovation in the pharmaceuticals, chemicals and mechanical technology fields. By contrast, the effect is large and statistically significant in the fields which are complex and where patent ownership is more fragmented: patent invalidation raises citations by 320 per cent in medical instruments/biotechnology, 203 per cent in electronics and 178 per cent in computers and communications.

We want to emphasize that these key findings continue to hold when we use alternative measures of cumulative innovation that do not rely on patent citations. We are able to construct more direct measures of follow-on innovation for two of our technology fields, pharmaceuticals and medical instruments – thanks to government regulation that requires registration of new product developments. These two fields encompass both a 'complex' technology area (medical instruments), where we found a strong

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FIGURE 1 Impact of patent invalidation on follow-on innovation



blocking effect, and a non-complex technology field [drugs], in which we found no blocking effect using the citations measure. We begin with the medical instruments technology field. The Food and Drug Administration (FDA) in the United States has primary authority to regulate medical devices sold in the U.S. These products are subject to a regulatory process that requires detailed product information and evidence of safety from clinical trials. The FDA releases data on approvals requested for medical instruments. To use these FDA approval requests as a measure of follow-on innovation, we link them to the medical instrument patents in our sample using two different approaches (for details, Galasso/Schankerman, 2015). Using these FDA approval requests of new medical devices as the measure of follow-on innovation in our empirical model, we find again that patent invalidation increases cumulative innovation by about the same magnitude as when we use patent citations to measure follow-on innovation. This analysis confirms

our conclusion that patent invalidation has a significant impact on cumulative innovation in the complex technology field of medical instruments. We were also able to do something similar for the pharmaceuticals technology field, again made feasible by exploiting FDA data on approvals of subsequent clinical trials. We construct a measure of follow-on innovation by identifying the subsequent clinical drug trials that are related to the active ingredient of the litigated drug patent. We are then able to match Federal Circuit drug patents with clinical trials by several different methods (details in Galasso/Schankerman, 2015). Using this clinical trials measure of cumulative innovation in our empirical model, we find that the loss of patents through invalidation has no statistically significant effect on cumulative innovation in the non-complex field of pharmaceuticals. Overall, this analysis with product-based measures of innovation confirms our earlier conclusions from regressions based on patent citation data.

3.2.2 Who is blocking whom?

We showed that the blocking effect of patents on later innovation depends on how concentrated patent rights are, i.e. on the structure of technology markets. However, the influence can also run in the other direction. Patent rights can shape the industrial structure of innovation by impeding the entry of new innovators or the expansion of existing firms, and this potential blocking effect may be stronger for certain kinds of patentees or downstream innovators. We also examine this issue and show that the blocking effect of patents depends critically on the size of the patentee and the downstream innovators. To understand better where bargaining (licensing) failures occur, we examine whether the blocking effect is stronger for certain kinds of patentees or downstream innovators. We split patentees and citing innovators in three size groups, based on the size of their patent portfolio: 'small' (less than 5 patents), 'medium' (6–101 patents), and

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'large' (more than 102 patents, which is the 75th percentile of the distribution). This means that we can study the effects of patent invalidation on later citations for six different pairings of patentees and later innovators in terms of their size: small-small, small-medium, small-large, medium-small, medium-medium, medium-large, large-small, large-medium and large-large. The results are very striking: we find that the loss of patent rights has a statistically significant effect only for the large-small pair: that is, patents appear to block only when the patent is owned by a large firm and their impact is only on later citations of small firms.

This finding indicates that patent rights held by large firms appear to impede the 'democratization' of innovation among small innovating firms. This is of public policy concern, especially because of the increased focus on entrepreneurial, high technology firms. However, it is equally important that we find that patents do not have any significant blocking effect among other types of patent holders and potential licensees. The blocking problem appears to be highly localized, both in terms of the types of technology fields, as described earlier, and the types of contracting parties. These findings show that fragmentation of patent ownership and complexity of technology fields, and the types of contracting parties (in particular their size) are key empirical determinants of the relationship between patent rights and cumulative innovation. Of course, other factors can also affect the impact of patent rights on subsequent innovation. One is product market competition. Aghion, Howitt and Prantl (2013) provide evidence that strong patent protection stimulates innovation only when product market competition is fierce. A second factor is the degree to which 'tacit cooperation' can be used by firms to mitigate potential bargaining failures and litigation that might otherwise arise from dispersed ownership of patent rights (Lanjouw/Schankerman, 2001, 2004). Understanding where and how these differences operate is a valuable direction for future theoretical and empirical research.

4 POLICY IMPLICATIONS AND CHALLENGES

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Governments use the patent system as an important policy instrument to provide incentives for innovation, and thereby to promote long run productivity and economic growth. In recent years, however, many scholars and other commentators in the public debate over patent reform have argued that patents are getting in the way of innovation and have recommended scaling back patent rights in various ways. The core concern is that patents are increasingly making it harder for firms to license inputs required for their research, exposing them to hold-up through patent litigation and generally raising the cost of doing R&D.

If this is true, we should see evidence that patent rights are blocking follow-on innovation. A few recent, high-quality studies have provided credible, causal evidence that patents block cumulative innovation in very specific biomedical sub-fields. Our research, using a completely different identification strategy to pin down causal effects, demonstrates that, while there is some blocking effect of patents, it is localized and not pervasive. We find that patents block only in very specific technology areas (including biomedical) and only between specific types of contracting parties (large patentees and small later innovators). In other technology fields and between other contracting parties, there is no evidence that patents block follow-on innovation.

The fact that the impact of patent rights on cumulative innovation is localized rather than pervasive suggests that remedial government policies should be targeted. In particular, a 'broad-based' scaling back of patent rights is unlikely to be the appropriate policy. As we argued, blocking occurs when patent owners and potential licensees fail to exploit profitable opportunities for follow-on research. This could be because they are unaware of these opportunities, or because bargaining between the parties breaks down for some reason. In the first case, an appropriate policy response is to promote private institutions, or if necessary to set up public ones, that disseminate information to potential licensees – some form of information repository that can be

easily and affordably accessed. If the source of the problem is bargaining failure – in particular, as we have shown, between large patent owners and small follow-on innovators – the appropriate response is to design policies and institutions that facilitate more efficient bargaining (e.g. as with arbitration and other dispute resolution mechanisms). One interesting example of such institutions is the biological resource centres in the United States studied by Furman and Stern (2011), which reduce the transactional costs of accessing knowledge inputs for biomedical research.

The key focus in patent reform should be on finding ways to reduce transaction costs and bargaining failure in licensing. In this way, governments can promote the process of cumulative innovation (and the long run productivity growth it creates), without diluting the innovation incentives that patent rights provide.

Finally, while we have focused on the link between patents and cumulative innovation, in formulating public policy toward patent rights it is also important to bear in mind that patents can encourage innovation through a variety of other channels. Perhaps the most important of these is their role in facilitating access to the capital markets for high-technology entrepreneurial firms, both as a source of investment capital and as a means of exit for successful start-ups. For such firms, whose primary assets are their innovations, patents help secure their rights in these assets and thus allow them to signal their potential more effectively to venture capital and the stock market. There is growing evidence of the importance of this function of patents (Conti et al., 2013). And beyond the capital markets, patents enhance knowledge and technology diffusion across firms (and countries) by allowing innovators to capture part of the benefits from such transfers, most notably through international trade and foreign direct investment (Branstetter et al., 2006; Delgado et al., 2013). These other socially valuable functions of the patent system must also be considered in any evaluation and policy proposals for patent reform.

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THE PERVASIVENESS OF INNOVATION AND WHY WE NEED TO RE-THINK INNOVATION POLICY TO RESCUE IT

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INTRODUCTION

In recent years, the terms ‘innovation’ and ‘innovation policy’ have become pervasive. Innovation appears to be the key not only to growth, but to coping with societal challenges and transforming socio-technical systems. In this contribution, we would like to reflect on the tensions that arise from this increasing pervasiveness of ‘innovation’ in societal, political and academic discourse and policy practice. We argue that an appropriate understanding and design of policies to support innovation needs to understand conceptually the connection between the underlying innovation models (the ‘how’) and the normative claim of innovation policy (the ‘what for’). By the former, the innovation model, we mean a stylised and simplified concept of the fundamental mode of the generation, drivers and directionality of innovations. By the latter, we mean the basic intentionality of policy, ranging from improving the conditions for innovation with no particular direction to supporting specific directions of innovation to change socio-technical systems in order to cope with societal challenges. Currently, the debates on innovation and innovation policy in Europe appear to add new claims without reflecting on this crucial link of the ‘how’ and the ‘what for’. We argue that the increasing link of innovation to societal needs and grand challenges, this broad pervasiveness, necessitates a radical change in the way we support innovation capacities and activities. This would have to have serious organisational repercussions for sectoral policies (e.g. energy, transport, etc.), science policy and innovation policy alike. To develop our argument, we first outline the pervasiveness of innovation in societal, policy and academic discourses and policy practice (section two). In section three, we then discuss some of the key innovation models and concepts underpinning this

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debate, reflecting on different claims in policy practices and policy discourses. We then accentuate the developments in Europe by shortly reflecting on the innovation model and innovation policy debate in the US, which we see as much less ambitious and focused on a simpler model of innovation and innovation policy. The article concludes by arguing that broadened claims for innovation policy need to take the lessons of innovation studies and the different conceptual models of innovation processes seriously. This would mean more carefully designed and more differentiated innovation policies. While accepting the limits of steerability of the innovation process, innovation policy would have to be built on a better match of the innovation modes, the 'how', and politically defined innovation purposes, the 'what for'. In particular, it would have to take the demand and mission orientation more seriously, enabled by a radical shift of policy responsibilities. We also caution against stretching the claims of innovation policy too far without an adequate conceptual model of innovation.

INNOVATION, INNOVATION POLICY, INNOVATION STUDIES: CONCURRENT PERVASIVENESS

We start our argument by observing three interrelated developments in the discourse on innovation, i.e. an increasing pervasiveness of innovation as a societal and political concern, a broadening of innovation policy in Europe to include societal missions and challenges, and the development of a strong academic field of innovation studies and innovation policy scholars.

As Godin has nicely shown, 'innovation' is an old concept with an illustrious history, originally mainly used in the context of political innovation and often in a pejorative way. Only in the second half of the last century did innovation become an object of policy, mainly linked to technological innovation and economic competitiveness and progress (e.g. Godin, 2012). In the last thirty years or so, innovation has become an ever more ubiquitous and dominant concept in highly intertwined political and

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societal discourses. Innovation is no longer only an engine of growth but a means to cope with societal challenges (Kallerud et al., 2013; Kuhlmann/Rip, 2014) and to a broad systems transformation (Borras/Edler, 2014). We have come to realise that innovation is pervasive beyond traditional industries, in the service economy and the creative industries, but often hidden and thus not captured in traditional analyses and policy approaches (Abreu et al., 2010; Cunningham, 2013; Miles/Green, 2008). Like a virus, the concept of innovation has strongly spread into science policy and science practice (Lundvall/Borras, 2005), whereby scientific activity is firmly linked with the expectation of innovation as a result, and into other aspects of social change.

Second, in line with these broader claims of innovation as a driver of economic growth and societal welfare, policy discourse – and increasingly practice – in Europe has shifted. The early policies targeting innovation explicitly were mainly concerned with technological innovation in firms and with the need to improve the innovation capabilities of actors (Steward, 2012a), avoiding picking sectoral or technological winners. Innovation policy thus was by and large horizontal and undirected, firmly located in ministries of economic affairs or innovation ministries. However, this changed in the 2000s. Demands for challenge-oriented policies were first strongly raised at EU level in 2006, with the Aho report (Aho et al., 2006) turning out to be a forerunner for the focus on societal challenges that became one of the three pillars of H2020, the current EU framework programme. After half a decade of a disappointing Lisbon strategy based on the traditional growth rationale, Europe was now supposed to become the most advanced knowledge economy in the world by linking economic growth and coping with grand societal challenges through means of innovation and innovation policy (Edler, 2012). Now innovation policy moved to centre stage. It was about direction, about making conscious policy decisions on the specific kinds of innovation society wants to adopt for specific kinds of challenges. The most explicit and ambitious form in which this understanding is expressed is in H2020, the EU framework

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programme. In addition, a strategy was set up 'to create an innovation-friendly environment that makes it easier for great ideas to be turned into products and services that will bring our economy growth and jobs.' This strategy, the Innovation Union, is expected to coordinate national and EU innovation policies.¹

Observers have thus seen a comeback of mission-oriented policies, whereby old technological missions were complemented by societal missions to form a 'new mission orientation' (Gassler et al., 2008). The notion of 'new mission orientation' is used by those observers to indicate that STI policy and ministries responsible for STI policy have refocused and shifted the balance towards funding models and implementation structures that are oriented towards societal goals. Consequently the policy target and anchor for funding programme designs is not a certain technological or scientific area, but inferred societal needs. Meanwhile, a number of mainly European OECD countries have developed innovation policies orientated towards grand challenges (Izsak/Edler, 2011, OECD, 2011a). In parallel we have seen a shift of the policy debate towards demand-side innovation policies in the context of a more effective innovation policy. Again, the formulation of policy starts with the imputed needs of the state or private end consumers. Here, 'market and system failures' on the demand side – such as lack of user awareness and ability, information asymmetries between demand and supply, high switching costs – provide the intervention rationale (Edler, 2010; OECD 2013). For reasons that are not entirely clear, the debates on and the practice of demand-based policy have not as yet systematically been linked with the mission orientation but are located in the discourse on more effective innovation policies. In a further, more radical development, academic and policy discourse is even shifting towards innovation policy for the sake of system's change (Weber/Rohracher, 2012; Steward, 2012b). The overall trend is clear: innovation is in the process of becoming a

¹ See <http://ec.europa.eu/research/innovation-union/>

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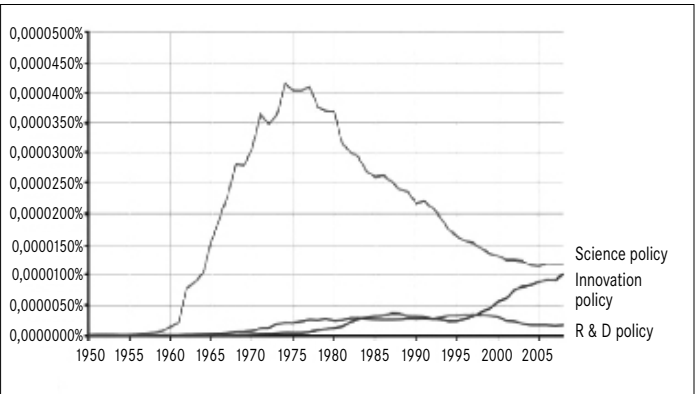
societal end in itself. On the political level, the shift towards innovation is even more pressing, as many politicians hope to 'innovate' Europe out of the crisis.

Third, this discursive and policy development has been strongly influenced and shaped by academic debates and concepts. It is no coincidence that the field of innovation studies emerged in the 1970s as a branch of (enlightened) economics, mainly associated with evolutionary economics (Fagerberg/Verspagen, 2009). Meanwhile, innovation studies are firmly established and have again branched out into science and innovation policy studies, innovation management studies, etc. (Martin, 2012). A strong feature of this academic field has been the 'interactive and co-evolving process' of 'policy learning and innovation theory' (Mytelka/Smith, 2002), as illustrated by the involvement of academic experts in developing measurement systems for scientific (Frascati Manual) and innovation (Oslo Manual) activity, or Bengt-Ake Lundvall's activity within the OECD to push for an enlightened innovation system approach.

Against this background, it comes as no surprise that innovation policy, introduced in the early 1970s, took off strongly in 1995 and has become a dominant feature in policy and academic discourse (see Figure 1, p. 436), quickly catching up with the much earlier established science policy. If the trend continues, it will soon overtake it.

INNOVATION MODEL DISCOURSE AS BACKDROP OF EUROPEAN INNOVATION POLICY IN THE MAKING

The increasing pervasiveness of innovation and the broadened claims of innovation policy unfold against the backdrop of different innovation models. As Godin and Lane (2013) have noted, a model in innovation studies is not an instrument to explore and manipulate a theory or to simulate what happens, but it is a mere scheme, a conceptual framework. Any such model therefore tends to be short-lived, linked to its proponents and/or the effectiveness of their critics. Yet models of innovation remain powerful in the sense that they shape how innovation is understood. The policies that



Source: Authors, based on Google title search, May 2014

are formulated follow – often unconscious to policymakers – this understanding. It therefore matters to understand which models and hence which understanding of innovation dominates innovation policies at present, and which understanding of innovation must be rescued from drowning in an incoherent flood of innovation policies. In the following, we recollect some debates on innovation models and concepts for two reasons. First, this demonstrates the shift over time in terms of the dominant understanding of what drives innovation. Second, and more importantly, these different models and concepts have different implications for innovation policy discourse. If we want to inform current policy discourse, we need to understand these underlying, and often competing, models and inject their different implications back into the debate. Obviously, the choice of a model is neither arbitrary nor innocent. From a normative perspective, we would like to privilege those models that attempt to link the ‘what for’ with the ‘how’.

Much has been written about the linear model of innovation, its alleged obsolescence, and which among competing models successfully replaced it (if, indeed, it has been replaced). Godin and Lane (2013) remind us that in the 1960s authors from different

FIGURE 1:
The increasing
importance of
innovation policy

Share of titles in Google
that contain any of the
terms displayed out of all
titles in Google

disciplines looked at technological innovation from different perspectives. Based on the idea that technological innovation is stimulated by market demand rather than by scientific discoveries, a demand-pull model emerged and became formalised in the 1970s–1980s. Its demise followed after a devastating critique by Mowery and Rosenberg in 1979, who concluded that ‘the “demand-pull” approach simply ignores, or denies, the operation of a complex and diverse set of supply-side mechanisms which are continually altering the structure of production costs’ (Mowery/Rosenberg, 1979, 142). The article also pointed to the failure to distinguish between need and demand, as needs are only vaguely defined and in principle unlimited and therefore not capable of driving decisions about research, while market demand is either current or potential, but in any case identifiable using precise economic criteria.

Thus, the focus returned to scientific discoveries as the ultimate causal factor in generating innovation, with demand continuing to play a (reduced) role. The distinction stressed by Keith Pavitt between incremental innovation, which largely takes place in firms and is not necessarily based upon research, and radical innovation, which always is science-based and hugely dependent on fundamental research as well as unpredictable in their technical and commercial outcomes, served to underline the emphasis accorded to scientific discoveries (Pavitt, 2005). Launching the idea of ‘technological paradigms’, Dosi saw technological opportunities (‘paradigms’) channelling the direction that innovation takes (Dosi, 1982, 1988). Finally, the demand-pull model lost its autonomous status and was integrated into what Godin and Lane call the Fifth Generation of innovation models, System Integration and Networking models (SIN). They are multidimensional rather than single-factor oriented. Their interactions are described as iterative, interactive, recursive and systemic.

However, although officially disavowed in the innovation studies community – but less so in the policy community (Edquist, 2014) – the linear model continues to lurk in the background with layers of complexity that have been added. This as such creates

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already a tension as it rests on a contradiction. Complex adaptive systems are characterized and pervaded by non-linear dynamics, overriding linearity or any simple cause-effect relations. The multidimensionality of the current innovation models acknowledge the need for integration, multiple feedback loops and iterative processes. But the relationship between mechanistic images coming from engineering like the 'innovation chain' is rarely integrated with economic considerations and hardly able to cope with the multidimensionality ascribed by Godin and Lane to the Fifth Generation of innovation models. Instead a (con)fusion of different technological and economic concepts prevails. While the distinction between supply and demand is at least clear in economic theory, it remains unresolved to distinguish in empirical practice.

Another murky and unresolved question concerns the above-mentioned distinction between need and demand. As we shall see, both are in the process of becoming re-defined in different ways. The demand-pull model of the 1960s is being shifted from its strong market orientation, which conceded only a nod towards some unspecified and potentially unlimited societal needs. It had the advantage that demand could be located and studied as innovation occurring in firms and in the related context of markets. Its disadvantage was to ignore not only the 'users', who started to emerge at the time when the model became more formalised. It also neglected public organisations that could act as sponsors of still to be articulated societal needs (Godin/Lane, 2013, 638).

Today we witness a return to societal needs, as governments are implicitly brought in through the back-door through the importance which is accorded to public-private partnerships. This basic idea goes together with conceptual approaches which attempt to enrol governments and the state in (re)setting 'directions' for innovation. There have also been widely acclaimed as well as criticised analyses to demonstrate the indispensable yet sometimes deliberately obscured role which the state and public funding have played in such legendary innovations as touch-screen technology

and other publicly funded basic research that underpins the commercialisation of iPods, iPhones, iPads and similar products (Mazzucato, 2013). NIH-funded research is shown as being responsible for almost three-quarters of the new molecular entities that emerged between 1993 and 2004 (Janeway, 2013).

Revisiting the demand-pull model of the 1960s to 1980s allows also to briefly analyse the changes that have occurred on the supply side, which is predominantly equated with the role played by science and research. The linear model of innovation was originally rooted in the experience of the Second World War. It was no coincidence that it emerged at the same time as Vannevar Bush's famous manifesto 'Science – The Endless Frontier' which later led to the establishment of the US National Science Foundation. Due to the experience during the US war effort, it was taken for granted that basic research 'with no specific applications in mind' would somehow automatically move or be moved towards application and eventually turn up in the form of commercialised products on the market. Today, more than half a century later, the research and innovation landscapes have changed beyond recognition. This applies not only to the ubiquitous quest for innovation and the publicly expressed hopes that politicians put into its capacity to create jobs, but also to the newly assigned role for fundamental research.

While the pressure and expectations on researchers to deliver often short-term and hence measurable socio-economic societal 'impact' has considerably increased through a close alignment of governments and funding agencies; at the same time a remarkable recognition of the importance of fundamental research has occurred at EU level by establishing the European Research Council. With its generous funding of bottom-up, PI-centered projects on the basis of scientific excellence only, a novel space offering high scientific reputation has been created in which no thematic priorities exist. At the same time, the mere existence of the ERC and the high rewards it brings to universities and research organisations through a pan-European

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competition has introduced for the first time a competitive mechanism among universities across Europe. This has led to numerous improvements and benefits, especially for younger researchers. Perhaps somewhat paradoxically, the ERC through its 'proof-of-concept' scheme has also provided visibility to the innovative potential that comes with breakthrough discoveries, but has done so in guaranteeing space for high risk research not orientated towards impact in the first place.

At the same time, we see a renewed interest in supporting research activities and organisations that are oriented towards finding concrete solutions for industrial problems by translating academic research into application contexts and by linking them through utilising methods and approaches of more basic research. We observe that the stakes and expectations to speed up the translation of new scientific discoveries and of research technologies into the innovation process continue to rise. Policy concerns about 'additionality' and short- and medium-term socio-economic impact have become paramount, as have attempts to establish more of an 'entrepreneurial culture' at universities. At EU and at national level, various translational infrastructures and funding arrangements, mostly in the public-private funding mode, are being set up (e.g. the Catapult Centres in the UK, trying to follow some principles of the Fraunhofer model in Germany). There seem to be two slightly different models at play here, albeit both with the same orientation towards innovation. First, the older idea of technology 'transfer' is being supplanted by 'translational' schemes, mechanisms and arrangements, whereby academic research can be translated into application contexts. Second, there is a genuine discrete research activity situated between industrial research and academic research, using techniques and methods from both, but establishing its own approaches, rather than translating from one to the other. Nevertheless, in both approaches, it is 'innovation' that has become the overarching political goal.

In this context, more attention should also be given to the widespread association of entrepreneurship with innovation. Many policymakers and universities feel compelled

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to adopt policies to stimulate innovation by promoting entrepreneurship, be it through introducing courses in entrepreneurship or through other measures designed in the hope of increasing start-ups, incubators, accelerators and spin-off companies. In this context, it is symptomatic that the rationale behind setting up the EIT in 2007, the European Institute of Technology, was to foster innovation by bringing industry into closer contact with universities and other public and private research organisations by 'promoting and integrating higher education, research and innovation of the highest standards'². This was to be achieved through a competitive process at EU level by creating KICs, Knowledge and Information Communities. These new entities are expected to bring together various partner organisations from the public and private sector alike with a common focus on themes like climate change or mobility. After the initial start-up phase, which took somewhat longer than expected, the focus was broadened by including an educational strand with entrepreneurship at its core. Each KIC is now expected to offer through one or more of their partner organisations, usually universities, adequate training opportunities in the form of courses in entrepreneurship.

Yet it is often overlooked that innovation is not the same as entrepreneurship and it is known that the majority of new, independent ventures are not innovative at all. Autio et al. have examined the importance of different types of context that stimulate entrepreneurial innovation. Context regulates the behaviour, choices and performance of individuals and institutions alike, mainly through selection effects and strategic choice effects. The authors conclude by highlighting the multidimensional nature of different contexts and the ties and interdependencies that exist between them. From a policy perspective, entrepreneurial innovation requires a specific policy mix for a particular combination of mix of contexts (Autio et al., 2014). It remains an open question whether such findings can be generalised. In any case, they are not a

² See <http://eit.europa.eu/regulation>

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sufficient reason to question the benefits of more widespread offers in entrepreneurship courses, especially at technical universities, and to support other measures in view of strengthening an entrepreneurial spirit within academia and across different layers of society.

This recent development with an ostensive and politically supported turn towards innovation must also be seen against the backdrop of rising scepticism and outright hostility against the austerity measures that were introduced in many countries in the wake of the financial and economic crisis. 'Innovation' is risking to be taken hostage by waves of disaffection with the neo-liberalism associated with EU and many national policies. In this debate, the instrumental use of innovation as a political goal gives rise to a different quality of demand-oriented discourses in the public space thus created, whereby 'demand' is becoming almost as encompassing as 'innovation'. These discourses may take the form of advocating a 'democratising science' (Stirling, 2014) and, more generally, 'getting innovation policy out of the ghetto of a too narrow focus on science and technology, whilst also being realistic about both the opportunities and limitations of innovation' (Schot, 2014). More ambitious even, an innovation policy is wanted which aims at 'transformative change'. While the need for continuing investment and stimulating new investment is acknowledged, the new goal is to ask for more and better 'directions' for innovation. This includes a greater diversity of options, exploration and experimentation outside the narrow band of the current policy discourse. In brief, innovation policy is being redefined as involving fundamental political questions and is even being charged with 'reinvigorating the future of our fragile democracies' (ib.).

While such voices may appear to come from, or in close alignment with, social movements and attempts to redirect the way in which economics is taught and performed, a similar development has already made its entry into the official EU policy documents. Partly due to what seems to be the same pressure from below and in response to dis-

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trustful citizens, Responsible Research and Innovation, RRI, is now an integral part of EU policies. However, beyond its place in EU policy documents and a recent 'Rome Declaration' on RRI³, RRI still has to find its way into actual practice. It is already obvious, however, that the term provides a broad umbrella beyond the various interpretations it already receives. 'Responsibility' is acknowledged to be a multidimensional concept. It includes anticipatory governance, with its emphasis on (more) deliberative democracy and a stronger role for the social sciences and their integration into research and innovation practices (Owen et al., 2012; see also the editorial in Nature, 2015). It is sensitive to the normative dimension for the design of technologies as well as fostering responsible innovation under legal auspices, be it of hard or soft law. It asks for new governance models and wants to embed responsible innovation in emerging technological practices. Above all, it presents itself as a means to direct research and innovation towards the global 'grand challenges', ranging from climate change to sustainable agriculture, from healthy aging to cyber-security (in H2020 called 'societal challenges'). RRI thus affirms the close links between research and innovation. At the same time it makes a powerful plea to see innovation as a much broader concept and in a much larger context (von Schomberg, 2016).

US INNOVATION POLICY – STICKING TO PRAGMATISM

To accentuate these far-reaching, ambitious and overtly normative goals that pervade European policy discourse and practice, we may remind ourselves that the US approach is far more pragmatic. For reasons which are connected to the widespread distrust of any government action, state interventions to influence directionality are scarce and the term 'industrial policy' has practically become taboo in the US. Instead, to take but one example, concerns have shifted towards production and manufacture

³ See www.sis-rri-conference.eu

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in what is called an 'innovation economy'. In a report of the MIT Production in the Innovation Economy (PIE) Commission, the focus is on innovation as a rationale for why manufacture still matters to the US economy. Against the backdrop of deindustrialisation, off- and on-shoring in a competitive global environment, the importance of (often local) ecosystems to facilitate the innovation-production nexus is emphasised. Seen from the point of view of the innovator, workers, firms, industry and the manufacture system, the link between innovation and manufacturing is seen as key to maintaining the US innovation economy. This is exemplified in advanced manufacturing. At each stage of this process, new technologies are generating change, ranging from materials design and the creation of synthetic materials to the knock-on effects of integrated recycling processes on the environmental impact of production, moving on to integrated solutions replacing the finished products of old by the bundling of services (de Weck/Reed, 2014). The pragmatic policy conclusions of these empirical studies recommend targeted investments into infrastructure that support industrial ecosystems, be they financial, energy, educational or R&D-related.

And, indeed, a comprehensive recent policy report on the US innovation system (Wessner/Wulff 2012) reconfirms that innovation policy practice in the US, especially at federal level, adheres to this model of innovation as an enabler of a more effective industrial system with strong competitiveness (Shapira/Youtie, 2010). Governmental policy is, by and large, indirect, focusing on infrastructure, legal framework conditions, enhancing capabilities to absorb new process technologies (e.g. through the long-running Manufacturing Extension Program) as well as on pre-commercial public procurement, which is in essence a connection of departmental needs with the support of R&D services to develop solutions and novel products. The underlying idea behind this framework is innovation, and mainly technological innovation, as a means to foster global competitiveness across the board of industries. Interestingly, in the US debate the shift of US policy discourse from a neo-classical model towards an

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evolutionary approach which focuses on capabilities, variety, framework conditions and relationships is still seen to be noteworthy (Wessner/Wulff, 2012, 20), while the European debate has long made this shift.

However, while explicit innovation policy as such is 'rather absent' in the Congress and also has no explicit home in the Federal Executive branch (Benjamin/Rai 2009), the US also has a tradition of mission-oriented research policies at US federal level (see already Ergas, 1987), which means that research programmes to develop new technologies and procurement programmes are structurally linked to societal needs as expressed by departmental action. One rather successful example can be found in the energy sector. Steven Chu, a Nobel laureate, was Secretary of Energy under the Obama administration from 2009 to 2013. He secured funding for ARPA-E (Advanced Research Projects Agency-Energy)⁴, an agency promoting 'transformational' energy technologies, and set up several energy innovation hubs as regional innovation clusters in promising research fields like solar energy, advanced batteries etc., each of which arguably held the promise of meeting broadly defined societal needs. Thus the absence of any meaningful explicit innovation policy at federal level goes hand in hand with research and technology support programmes and procurement activities which in fact give directionality by defining technological areas (for research) or concrete departmental needs (for pre-commercial procurement). In fact, there are, albeit few, activities that are more explicit about need-orientation, linking different activities of various federal and local agencies around selected solutions.⁵ In general, however, the US style of dealing with challenges remains largely scientific and technological. It can do with a supply focus, hoping that new technologies coming from and with research will translate into growth and societal benefits.

⁴ See <http://arpa-e.energy.gov/>, ARPA-E is modelled after DARPA, the Defense Advanced Research Projects Agency.

⁵ One example of those coordinated activities are the 'energy-innovation hubs' – regional innovation clusters in solar power, energy-efficient buildings, nuclear energy, and advanced batteries (Wessner/Wulff, 2012, 54).

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FUTURE INNOVATION POLICY: OF INNOVATION MODELS AND DIRECTION

What to make of the pervasiveness of innovation in European innovation policy discourse and practice? This short discussion on academic and policy discourses and policy practice leads us to conclude that we are at a crossroads for innovation policy, certainly in Europe. The conceptual discussion above has shown a lack of a strong, clearly articulated and broadly convincing innovation model that could translate into a clear-cut innovation policy design. Moreover, while the discourse at EU level percolates down to the national level, where the annual outcome of the comparative ranking of member states in the European Union Innovation Scoreboard is closely followed by politicians and the media, and with H2020 entering the implementation phase, the coordination at the interface between national and EU level remains extremely challenging. This includes the current development of the ERA, the European Research Area, through the ERA roadmap for 2015–2018. Although not addressing innovation directly, the five priorities of ERA arguably address also conditions like optimal transnational cooperation and competition, effective national research systems or an open labour market for researchers, that count among the preconditions for strengthening the innovation capability in member states. The lack of a coherent policy can also be seen in the fact that ERA stakeholders at present do not include representatives from industry. They have found their policy niche in the Innovation Union, but the – obvious – connection between ERA and Innovation Union remains elusive.

These and other examples remind us that, as innovation, innovation policy itself will constantly be an experiment, iterative, recursive, with failures and with effects that are often unforeseeable. This does not render the attempt to improve innovation policy meaningless. But it should caution us against the promises of 'intelligent' innovation policy being a mechanistic answer to all those broadened claims.

Nevertheless, a number of conclusions can be drawn. Our reflections above lead us to conclude that we should think of innovation policy as having basically two functions:

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(1) sustaining an innovation ecosystem by supporting capabilities and connectivity, entailing proper regulatory framework conditions both for the development of (fundamental) science and innovation, and (2) giving direction for the generation and diffusion of knowledge and innovation by taking into consideration the supply *and* the demand side. This does not call for a holistic innovation policy which 'integrates all public action that influences or may influence innovation processes [...] in an integrated manner [...] and must be coordinated with other policy areas and in some cases has to be given higher priority than other areas' (Edquist, 2014, 4). Instead, our argument is straightforward: we need to end the disconnect between the radical policy claims on the one hand and the organisational path dependency as to the locus for shaping innovation policy in Europe on the other. This simply means that greater conceptual clarity of how innovation actually works, what it can and what it cannot achieve, is called for if policy is to become more effective. Only a differentiated policy, with different entry points of responsibility for these related but distinct purposes can lead to the desired objectives. It follows that quite different policy approaches and quite different organisational set-ups are needed, with some basic level of coordination but not full integration.

The first basic function of innovation policy is a clear articulation of those innovation models that stress the need for skills, interaction, the capacity of learning, thus enabling the innovation systems to create variation, variety and generate the pool out of which selection takes place (Metcalf, 2005). If the supply and demand side are to find their place in the idea of innovation as an ecosystem, the temporal range must be extended. The preparation of the next generation for the labour market then becomes crucial. OECD studies show that the demand for non-routine skills is growing (OECD, 2011c), which can be linked with the necessity of anchoring entrepreneurship more firmly throughout society. An undirected but broadened model of innovation leaves space for various kinds of policy measures and initiatives, limiting itself to creating the enabling conditions for both supply and demand.

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Much of European and certainly most of the US innovation policy is still and mainly about competitiveness and growth, where the market of ideas and innovation decides which direction knowledge production and innovation will take. This cements the case for strong funding for research not directed towards immediate impact, as well as the case for a range of innovation policies that link actors and overcome systemic bottlenecks. Importantly, the history of the juxtaposition of supply and demand models and the recent economic arguments for demand-based models tell us that also in this model it is not merely the supply side that needs strengthening but, increasingly, the demand side as well. The more innovation is generated or subsequently modified through user-producer interaction, the more the capabilities and connectivity of users are the key. As Godin and Lane have shown (2013), this neglect of the user has been a problem even in those approaches that claimed to address the demand side for horizontal innovation policy.

In general, this traditional, horizontal innovation policy often resides in ministries, agencies or departments with a designated innovation remit. In addition, in the understanding of horizontal innovation policy the role of science policy is to provide the skills and forefront knowledge that will enable directed innovation in the future. We surmise that the linear model is still lurking in the background. Even excellent science which is inherently uncertain of the outcome and when it will occur is funded with the expectation that it will generate innovative products or processes, thereby establishing at least in retrospect a causal link between research and innovation. We thus need to protect a sufficiently robust balance of undirectionality both in innovation policy and in science policy. This can only succeed if undirectionality is clearly stated and in practice pursued as a policy goal.

As for the second function of any innovation policy, directionality, we argue that two different modes need to be distinguished. They are connected but have different inherent logics and should be expressed in different organisational forms: one is the

directionality of technology and the other the directionality of the challenges that are to be met. Technology directionality means the need to prioritise decisions on specific research and/or technological areas over others on the basis of the anticipated understanding of their potential for having economic or societal impact. Such an understanding is always preliminary and risky. It can and will be politically contested. The most important task of governments is to deploy intelligent discursive means to define those areas that warrant prioritising and organisational structures that allow emerging technologies to flourish and be translated into application contexts.

Challenge directionality obviously is strongly linked to the technologies that are believed to hold the solution for meeting the challenge. In this perspective, the challenge is the goal and technologies provide the means, but such a relationship must be framed in a systemic context. In order to tackle a given challenge, the starting point is the insight for some kind of systemic change. This necessitates the articulation of the challenge and how it can be translated into innovation demands and in support requirements. The *initial* focus shifts entirely to the demand side, as already the very nature of the demand articulation matters a great deal (Kuhlmann/Rip, 2012). Systems change only takes place if innovations that are generated are absorbed and used in great numbers and on a vast scale. The role of the government becomes paramount in making choices between challenges, in supporting the articulation of the challenge and the reasons why it meets an underlying *need*. Next, governments must demonstrate their willingness and capacity in supporting the uptake of innovation, i.e. the translation into demand, be it through its own purchasing or through supporting demand conditions and capabilities in the system more broadly – by bringing in the user. Thus challenge directionality, if taken seriously, means a radical shift of responsibility for innovation policy to those ministries, departments and agencies which are responsible for the challenge. This may include coordination with other organisational units, as many challenges do not neatly fit governmental

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structures. However, the ministries responsible for a given challenge are in the driver's seat, and ministries or funding agencies responsible for horizontal capabilities and connectivity turn into supporting agents. Seen in this perspective, the call for responsible research and innovation is one of the institutional devices to underpin and translate the support of challenge directionality within science and innovation policy. As such, it is an intelligent, albeit limited means of soft challenge coordination.

This leaves us with one last puzzle: do we accept that innovation has a part to play in a normative directionality that goes beyond our understanding of societal or grand challenges but targets the radical transformation of the very economic system our current innovation models are built upon? We certainly see the enormous challenges that innovation has produced or at least not prevented from emerging. But currently we are far from having any theoretical or conceptual innovation models at our disposal that would support a journey towards a radically different economic model. And as the history of erratic innovation policy has shown, such a new concept of innovation would have to accompany decisive policy action. While this is an urgent task not only for the innovation studies community, for the time being we may have to revert to intelligent challenge directionality based on the conceptual models we know. The reason is a simple one: the process of innovation, much like the process of fundamental research, although different in the way it is expressed, is inherently uncertain. Any policy, be it innovation or science policy, attempts to contain this uncertainty and channel it into the desired direction. This is as much as intelligent challenge directionality can hope to achieve. The rest is up to the cunning of uncertainty and the surprises it holds in store (Nowotny, 2015).

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ON THE LIMITATIONS OF CLASSICAL APPROACHES TO INNOVATION: FROM PREDICTING THE FUTURE TO ENABLING 'THINKING FROM THE FUTURE AS IT EMERGES'

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1 INTRODUCTION

(New) Knowledge and innovations have always been important for economic and social systems as well as for organizations; however, over recent decades creating new knowledge has become a key driver for almost all industries and in many social fields (European Commission, 2010; Fagerberg et al., 2006). We have experienced a radical shift from focusing on efficient mechanistic production processes of more or less standardized physical products towards an increase in the importance of knowledge (creation) and new services or business models (Drucker, 1985, 1993). As an implication, the production of knowledge and, more specifically, of *new* knowledge has become the new focal point in our postindustrial era in the fields of economy, (applied) science(s) and technology.

This article aims at investigating and questioning current trends in the field of innovation. It will be shown that classical approaches to innovation are primarily based on two strategies: (a) extrapolating the past to the future, (b) generating a large quantity of (relatively) low-quality ideas (e.g. by applying so-called creativity techniques) and (c) a subsequent selection of these ideas by questionable selection criteria that are –again – mainly based on past experiences and/or (almost exclusively) business-driven factors, e.g. in stage-gate innovation processes (Cooper, 1990). In the first part of this article we will show that – in most cases – such a strategy leads to optimizing existing products, services, or business models or to incremental innovations only, whereas radical innovations are almost always eliminated in the very first stages of such selection processes, as it seems – according to the applied

selection criteria – that they do not fit into existing structures of the organization and/or the environment/market.

The interesting challenge we want to address in this article is to solve a paradox in (radical) innovation: it seems to be relatively easy to create 'wild' ideas and radically new knowledge by applying creativity techniques, such as brainstorming (Paulus et al., 2012; Reiter-Palmon et al., 2012). Apart from the problems mentioned above, the results of such processes might be radically new; however, they neither fit into the market/environment nor into the organization and thus are not successful. In other words, neither users/customers nor people from the organization have the appropriate cognitive and perceptual structures, capabilities, or patterns to connect to this novelty. Hence, the challenge is to bring forth innovations that are (a) radically new and (b) nevertheless (organically) fit into or can be (cognitively) appropriated and connected to the environment/market ('anschlussfähig'), leading to sustainable and thriving dynamics in the interaction between the object of innovation, its environmental context, and its user.

Whenever we are dealing with innovation, we are confronted with various forms of *uncertainty* about the future and future possibilities. That is why the second part of this article explores the notion of uncertainty and gives rise to an understanding of uncertainty in which the future is not only unknown, but also unknowable. In such a perspective both search space and solution spaces are unknown, and even 'worse', they change permanently as they are continuously co-created in a process of interaction between environmental structures, potentials, and cognitive systems (and their evolving needs). Comparing this situation with evolutionary dynamics, '[...] we do not know what all the possibilities are for such preadaptation, so we do not know the unprestatable and ever changing phase space of evolution. Not only do we not know what 'will' happen, we do not even know what 'can' happen.' (Longo et al., 2012, 1.384)

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For such a tricky situation, we propose an approach to innovation, which we refer to as *Emergent Innovation* in the third part of this article: In order to resolve the above mentioned paradox and avoid the above-mentioned shortcomings of classical innovation processes, it is necessary to create niches or spaces for potentials (in Kauffman's (2014) terms 'adjacent possibles') in which innovations may emerge. The idea is to investigate the core of these niches of the object(s) of innovation (and its environment/context) in order to explore and identify the potentials in that space so that we can 'learn from the future as it emerges' (Scharmer, 2001, 2007). The implications for such an innovation- and future-based organization will be sketched.

1.1 What is innovation?

In order to understand innovation processes properly one has to put them in a larger context and investigate the systems they are embedded in. First of all, it is important to make a *distinction* between *creativity* and *innovation* (Amabile, 1996; Dodgson/Gann, 2010; Drucker, 1985; Kaufman/Sternberg, 2010; Sternberg, 2005). Whereas creativity is composed of (domain-)specific traits – according to Amabile (1996) they are (a) expertise, (b) creative thinking skills, (c) motivation –, innovation is a more general concept emphasizing not only the processes of creation, but also of *successful application* and *implementation* in the market (Schumpeter, 1934, 1947).

From such a perspective it becomes clear that innovation is not a one-dimensional phenomenon, but that it always emerges as a result of a highly complex network of interacting actors, dynamics, and constraints. Reframing these issues one could summarize them in the question: what are the (interacting) *sources* leading to new knowledge and innovations (Dönitz et al., 2010; Fagerberg et al., 2006; Hippel, 1988)? Innovation is not only about products. Innovation is intrinsically *social* and *epistemological*. The notion of innovation also comprises new services, business mo-

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dels, organizational changes, new production methods, etc. (Dodgson/Gann, 2010; Fagerberg et al., 2006; Schumpeter, 1934, 1947). Most importantly, innovation is not primarily a static concept or about a result; rather, what is of interest are the *processes* leading to an innovation. When we talk about processes in the context of innovation, the focus is on the *epistemological/knowledge* as well as *social* processes taking place in the course of creating and implementing an innovation.

a. Knowledge/epistemological processes: Epistemology is the study of knowledge, its justification, its dynamics, as well as of its relationship to the real world and cognition (Churchland, 1988; Steup, 2012). Whenever we are talking about knowledge work, knowledge management, or the 'knowledge creating company' (Krogh et al., 2000; Nonaka/Takeuchi, 1995) it is clear that knowledge has become a key asset in any organization. For instance, Tsoukas (2005) emphasizes the importance of epistemological processes in organizations and shows how they implicitly or explicitly influence an organization's dynamics. Innovation goes far beyond knowledge management as it focuses on the creation of new knowledge (Krogh et al., 2000).

b. Social processes: apart from epistemological issues, innovation is primarily a social process. This concerns several levels and social domains ranging from national innovation strategies to innovation work in organizations down to teams. Innovation is more than the sum of innovative activities of individuals: as is shown by many researchers and practitioners in the field of innovation (Fagerberg et al., 2006; Fagerberg/Verspagen, 2009; Kelley, 2004; Weisberg, 1993) innovation is rooted in a social context and a complex network of interactions in most cases. Although it is always the individual cognitive system and its creativity which brings forth new knowledge at a particular moment in time, it is the (history of) interaction(s) between these systems that enables stimulation, inspiration, and a kind of bootstrapping co-creation and co-fertilization process leading to the emergence (Corning, 2002; Stephan, 2006) of new knowledge.

Hence, if we talk about innovation in this article, we are primarily interested in the *processes* leading to this innovation and how these processes ought to be organized in order to bring forth high quality and sustainable innovations. Innovation is a *socio-epistemological technology* in the sense of 'tool-mediated social practices' (Cole/Derry, 2005, 211).

Innovation is about *change* (see section below) and, normally, change does not occur automatically or spontaneously. Rather, we are confronted with resistance when we are facing the challenge or need for change. One of the main reasons for the resistance against such changes lies in the fact that one faces *loss of control* in such a situation; an experience that is unpleasant for most humans. So, the question of change can be reformulated: How can one produce positive, in the sense of *sustainable*, change that is *fundamentally new* and *organically fits* into existing structures in the sense that it is by some means in continuity with the already existing categories of our cognition (compare Maturana and Varela's (1980) concept of structural coupling), our behavioral patterns, etc.?

1.2 Innovation as optimizing and projecting from the past to the future

Recent developments in cognitive science suggest that the human mind/brain can be interpreted as a 'machine' anticipating and predicting the future; this approach is referred to as the *predictive mind/coding hypothesis* of cognition (Clark, 2013; Hohwy, 2013; Poli, 2010a, 2010b). Taking a closer look reveals, however, that we are dealing in fact with an *optimization* mechanism continuously aiming at minimizing the prediction error by comparing the predicted sensory input with the actual input; this error updates the cognitive system's 'hypothesis about the world' accordingly in order to generate new predictions (in a new cycle). This mode of looking into the future is very close to what is known as T. Kuhn's mode of puzzle solving in the process of normal science (Kuhn, 1962). Its primary goal is to reduce (prediction) error and *uncertainty*;

as a consequence, this leads to an endless stream of rather uninspired research projects or innovations that will have almost no impact in the sense of a radical and sustainable change for the future of either the respective discipline or for society. One of the main reasons for this seems to be that this strategy is based on projecting past experiences into the future.

A similar phenomenon can be observed in the context of organizations. If innovation is primarily about a process, it is important for every organization to have such processes in place that support and bring forth a stable flow of innovations. One of these classical approaches is the so-called *stage-gate process* (Cooper, 1990; Dodgson/Gann, 2010, pp. 99ff): it operates as a well-structured sequence of stop/go decision points throughout the knowledge creation and implementation process. Starting with an idea, this new knowledge has to go through several screening procedures ('gates') moving the potential innovation from one stage to another. These stages comprise, for instance, a preliminary assessment, detailed investigation in the form of a business case preparation/development, development of the concrete innovation, testing and validating the innovation, and, finally production and market launch of the innovation (Cooper, 1990). The steps between these stages act as breakpoints and testing points for deciding whether the innovation is allowed to move one stage further or not. It has turned out that this approach is quite powerful for creating *incremental* innovation. However, 'these tools have limitations: they might be very helpful in managing the process of developing products, but they do not tell you whether they are the right products in the first place. They can also become very procedural and kill initiative' (Dodgson/Gann, 2010, 99).

Besides its focus on incremental innovation, the stage-gate approach is based on a rather erratic and unstructured process of ideation and creation of new knowledge. It is not clear where new ideas or knowledge come from and there is no structured process for this crucial phase of knowledge creation, which is the foundation for any

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high-quality innovation. Furthermore, this process is based on the concept of creating high diversity (i.e. a large number of ideas of questionable quality) and then filtering out the most appropriate and most promising innovation in an evolution-like trial-and-error process. It is neither clear which criteria should be applied in this approach (apart from business and number-driven benchmarks), nor do these criteria allow for completely new ideas to pass through these gates, because they would not fit into any of these classical categories. They simply would be blocked at the gates in the very first phases of this process. Apart from that, the stage-gate approach can be characterized as a process of 'learning from the past' by adapting already existing structures to (changes in) the environment or market. For these reasons, only in very rare cases, will such a process bring forth novelty leading to radically new innovations, which do not only react to the environment/market, but shape and change it in a fundamental manner. If we are interested in these kinds of profound changes and innovations, it seems that we have to follow different strategies that go beyond adapting to existing structures. We have to enter into the field of how to deal with uncertainty in an unknown future and how to develop (fundamentally) new *opportunities* for such a context.

2 ON UNCERTAINTY AND OPPORTUNITIES

If we are interested in radical change and sustainable innovations, we have to direct our attention towards as yet untapped and to be anticipated opportunities that lie in the future. This implies that we are dealing with the problem of *uncertainty*. Sarasvathy et al. (2003, 144) have developed three definitions of uncertainty about the future that give rise to three different kinds of opportunity:

(i) Uncertainty about a future whose distribution exists and is known

By analyzing the field of (possible) innovation(s), one recognizes a gap between a known demand and an already existing (pool of) solutions/supply and exploits this

solution. Both the problem space and the solution space are known in advance (Dorst, 2003, 2006; Gedenryd, 1998; Simon, 1996). The challenge is to identify this gap and to fill it as quickly and inexpensively as possible. Formally, this can be realized as a search and optimization process, as is well known from classical approaches in cognitive science and artificial intelligence (Newell/Simon, 1976). This leads to a *recognition* and *allocation* view of opportunity. 'The opportunity is any possibility of putting resources to better use... The core idea is that all products and ideas that can potentially exist are all known to be feasible but costly to produce' (Sarasvathy et al., 2003, 147).

(ii) Uncertainty about a future whose distribution exists but is not known

If demand exists but supply does not (or vice versa), the side that does not exist (yet) has to be *discovered*. As is shown clearly by Kauffman et al. (Felin et al., 2014; Kauffman, 2011, 2014; Koppl et al., 2014), these discoveries cannot be known ahead of time as they might give rise to completely new and unexpected usages for particular artifacts, solutions, or resources (compare Kauffman's (2014) example of unexpected usages of a screwdriver). Being epistemologically open and alert are key skills for discovering these unexpected solutions/opportunities ('discovery view' of opportunities). This means that the entrepreneurial agent has to explore the search space (i.e. latent markets) by repeated trials. It can be compared to an experimental setting in which he/she learns about and uncovers the possibilities/distribution of his/her new knowledge and potential innovations in a trial-and-error process over time. This is closely related to the approach suggested in the Predictive Mind Hypothesis (Clark, 2013; Hohwy, 2013) in which one tries to reduce the prediction error (= uncertainty) by exploring/probing reality and adapting one's knowledge. In most cases this leads to an optimization process as it is known from incremental innovation (Ettlie et al., 1984; Fagerberg et al., 2006; Peschl/Fundneider, 2014b; Tidd, 2006). As is shown by Felin (2012), this approach is primarily driven by the external environment: the

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cognitive system adapts to the environmental structures and constraints; by doing so, it tries to come up with new solutions or innovations. This implies that 'they focus on what can be absorbed from the environment, on the basis of what has been experienced in the past. The structure of the environment – and not the structure of the mind itself, or the nature of the organism under study – is central to these models' (Felin, 2012, 285). Hence, the (creative) activity of the cognitive system/entrepreneur plays only a minor role in this approach, whereas the environment acts as a primary driver of the process of finding a new solution.

(iii) Uncertainty about a future that is not only unknown, but also unknowable

This notion of uncertainty has to do with the *creation of new possibilities*, markets, or even whole environments and is the most challenging task in the field of innovation, namely the creation of novelty and new knowledge. Economically speaking, neither (knowledge about) demand nor supply exists ahead of time. Generally speaking, possible (sensible) future needs or functions are not known at the present point in time; they have to be brought into existence as a (completely) new opportunity. This requires a process of creativity (Amabile, 1996; Boden, 2004; Bohm, 1998; Kaufman/Sternberg, 2010; Koppl et al., 2014) that creates these new opportunities in an abductive manner. In terms of the classical approaches to cognition (Dorst, 2003, 2006; Friedenberg/Silverman, 2006; Newell/Simon, 1976; Simon, 1996) or economics (Alvarez/Barney, 2007; Felin et al., 2014), this case implies that both the search and the solution-space are unknown; rather, they permanently change and have to be brought into being in a process of mutual co-creation and interaction with the environment and stakeholders, as the telos is not known. 'Telos is neither ignored nor imposed on the phenomena concerned. Instead, ends emerge endogenously within a process of interactive human action (based on heterogeneous preferences and expectations) striving to imagine and create a better world [...] the crux of the creative process view is the need to build non-teleological theories of

human action, wherein values and meaning emerge endogenously' (Sarasvathy et al., 2003, 155f).

In this context the notion of *emergence* plays a central role (Corning, 2002; Kauffman, 2011; Peschl/Fundneider, 2008; Stephan, 1999, 2006). (Radically) New knowledge cannot be brought forth in a mechanistic or algorithmic manner (Koppl et al., 2014, 15; Peschl/Fundneider, 2013). Rather, telos or the final cause emerges in a process of co-creation and interaction between the cognitive system(s) and its/their environment (Mittleton-Kelly, 2007). This process can be compared to evolutionary dynamics in which the concept of so-called *adjacent possibles* (Kauffman, 2000, 142ff.; Kauffman, 1993, 2014; Longo et al., 2012) play a central role: 'The emergence of new, unprestatable functions and new, unprestatable opportunities is constant and continual. The phase space of the evolution of organisms and phenotypes [...] is never fixed. It is radically emergent. There are adjacent possibilities and niches for each trait, function, or capability of an organism and new organisms may be [...] 'enabled.' It is not possible to map all of these possible adjacencies, just as all the uses of a screwdriver are not algorithmically listable, nor are all the opportunities that arise listable or prestatable [...] One way to think about the emergence of novelty is that there is a constant 'empty' set of possibilities that are adjacent to the existing phase space' (Felin et al., 2014, 276). Hence, it is necessary to provide *enabling conditions* that foster the creation of novelty (Kauffman, 2011, 2014; Zia et al., 2014), such as suggested in the Enabling Space Approach by Peschl and Fundneider (2012, 2014a).

From an ontological perspective, this means that a phenomenon or object is not completely determined in the sense that it is unfolding over time according to its own dynamics, its possibilities, and its interactions/influences with/from the environment. This perspective has its roots in, for instance, Aristotle's *Metaphysics* (Aristotle, 2007) and draws on the concepts of *potentia/potency* and *actus/actuality* or, as Kauffman (2014, p. 4ff) calls them, [adjacent] *possibles/res potentia* and *actuals/res extensa*;

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contrary to actuals, possibles are open to develop in various ways and directions that are partially intrinsic to this phenomenon/object and partially dependent on environmental stimuli, influences, or changes. R. Poli (2006) introduces the concept of *latents* in this context: "‘Categorical openness’ means that the entity is only partially determined, some of its aspects are still hidden. Better: some of its determination may be latent. The difference between being hidden and being latent can be clarified as follows: hidden components are there, waiting for proper triggers to activate them. On the other hand, latent components do not exist at all in the entity’s actual state’ (Poli, 2006, 77f.). The interesting and challenging point is (a) to identify these latent possibilities and (b) to cultivate them in a non-imposing manner so that they can develop into ‘interesting’ and sensible innovations. This can be achieved by following a dynamic that has its foundation in the concept of adjacent possibles: ‘New Actuals create adjacent possible opportunities in which new Actuals arise in a continuous unprestable co-creation’ (Kauffman, 2014, 6).

It is clear that these three cases cannot be seen separately from each other, as they mutually depend on each other; compare also the distinction and interaction between discovery and creation in entrepreneurial activity as suggested by Alvarez and Barney, 2007). However, it is the third case that is the focus of our attention, as it is not only the most interesting, challenging, and promising (in the sense of creating novelty and entrepreneurial opportunity), but also the most general case and a prerequisite for (i) and (ii) (Sarasvathy et al., 2003, 157).

3 TOWARDS AN INNOVATION-BASED ORGANIZATION

The challenge we are facing is to create new knowledge and novelty that does not only reduce uncertainty, but that is both radically new and sustainable in the sense of bringing forth desired and thriving futures. Our claim is that innovation and knowledge creation have to be put to the core of an organization, of science, or even of

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society. What does such an *innovation-based organization* look like? What are the theoretical foundations for such an organization? What are the necessary (cultural) values, attitudes, and social and epistemic practices? What are the implications for a new understanding of management of such an organization?

3.1 Theoretical Foundations

We propose that the theoretical foundation of such an approach is based on the combination of three conceptual frameworks:

- **Autopoiesis:** Organizations have to be understood as autopoietic systems (Goldspink/Kay, 2003; Kay, 2001; Maturana, 1970; Maturana/Varela, 1975). In this context organizations can be characterized as autonomous, self-(re)-producing, structurally determined systems that are operationally closed and structurally coupled to other systems and their environmental context.
- **Evolutionary and anticipatory systems:** ‘Generally speaking, anticipation concerns the capacity exhibited by some systems to tune their behaviour according to a model of the future evolution of the environment in which they are embedded’ (Poli, 2010a, 770). The capacity to predict or anticipate the future in one way or the other is central for any kind of innovation. Cognitive systems as well as organizations can be seen as anticipatory systems (Clark, 2013; Hohwy, 2013; Poli, 2010a, 2010b) that are capable of predicting the future in order: (i) to deal with the permanent changes they are encountering, (ii) to find adequate solutions for these changes, and/or (iii) to create new artifacts, environmental structures, or niches for ensuring their survival either by creating new innovations and/or by changing their environment/market. As shown above – as far as issues concerning bringing forth novelty or innovations goes –, we find similarities between evolutionary dynamics and organizational/social dynamics on a structural and systemic level, e.g. concepts of adjacent possibles, pre-adaptation, niches (Felin et al., 2014; Kauffman, 2014; Koppl et al., 2014; Longo et al., 2012).

► **'Learning from the future as it emerges' | Theory U:** The most interesting challenge is to not only react to changes, but, in addition to that, to actively shape the future in a sustainable and thriving manner. This involves highly sophisticated skills and capacities on an individual/cognitive, managerial, as well as organizational level: e.g. being able to identify latent or hidden potentials (Poli, 2011), being able to redirect and re-frame one's patterns of perception and cognition (Depraz et al., 2003; Scharmer, 2001, 2007), or dealing with self-transcending knowledge (Feldhusen, 2014; Kaiser/Fordinal, 2010; Scharmer, 2001) – being able to bring forth sustainable radical innovations that are not based on the projections from the past into the future, but that are grounded in a process of 'learning from the future as it emerges' (Scharmer, 2007, p. 52). We refer to this process as *Emergent Innovation* (Peschl/Fundneider, 2008, 2013).

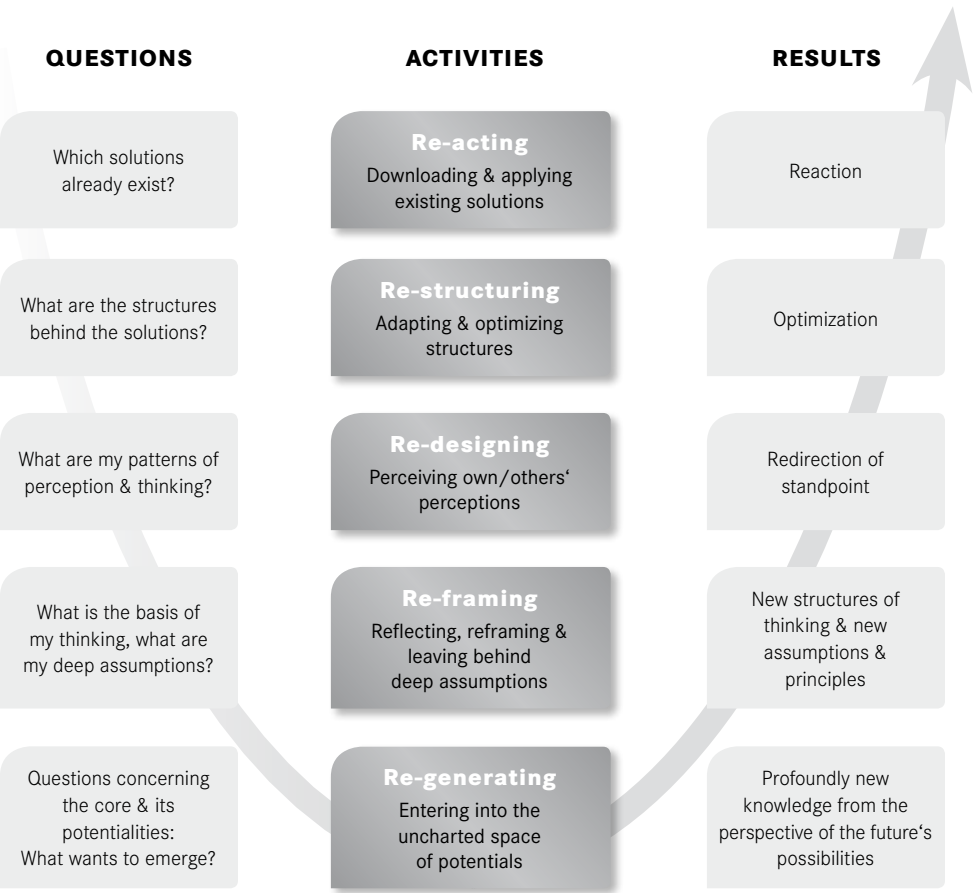
3.2 Strategies of Change

Our proposition is to develop a typology of innovation and knowledge creation that has its roots in cognitive science, epistemology, innovation studies and organization science (Fagerberg et al., 2006; Fagerberg/Verspagen, 2009), as well as second order cybernetics (of semantics) (Krippendorff, 2006). We propose the following conceptual and epistemological framework differentiating various strategies of change for bringing forth innovation (see also Figure 1):

- a. Downloading and reacting:** Existing and successful behavioral patterns from the past are downloaded and applied – no change occurs.
- b. Single-loop strategy of change/learning (adapting and restructuring):** this circular process is closely related to the evolutionary dynamics or to Kuhn's (1962) concept of 'puzzle solving' i.e. adapting to the environment through generating variation and testing it by externalizing knowledge through behavioral action. Such a strategy leads to optimizing existing structures; oftentimes it is referred to as incremental innovation (Ettlie et al., 1984).

- c. Double-loop strategy of change/learning (redesigning & reframing):** humans are not only capable of simply adapting to the environment, but also of reframing their symbolic/symotype system by reflecting on their assumptions or values and changing them (e.g. a change in premises in our cognitive framework, paradigmatic shift in the realm of science (Kuhn, 1962), radical innovation (Corso et al., 2009; Ettlie et al., 1984) or double-loop learning in the context of organizational theory (Argyris/Schön, 1996; Peschl, 2007)). This creates a new space of knowledge opening up an unexplored scope of potential knowledge structures, meanings, and behaviors. Both the single- and double-loop strategies understand change as adaptation and as 'learning from the past'.
- d. 'Learning from the future as it emerges' (regenerating):** Going one step further, our cognition and symbolic capabilities enable us to intellectually deeply penetrate the environment in order to achieve a profound understanding of the potentials that are not yet realized in a particular part of the (internal or external) environment; i.e. potentials or latents (Poli, 2006, 2011) that are already there, however hidden, that need to be discovered, developed, and cultivated in order to emerge in the future. This is a rather different strategy which we refer to as *Emergent Innovation* (Peschl/Fundneider, 2008, 2013; Peschl et al., 2010). It is partially based on Scharmer's (2007) Theory U and does not primarily follow the classical strategy of trial-and-error, variation, selection, and adaptation in order to bring forth change and innovation, but uses deep knowledge about the core of the object of innovation (OOI) and its potentials in order to 'learn from the future as it emerges' (Scharmer, 2007, 55). In other words, these potentials offer a (hidden) pointer towards the future possibilities that might emerge. This approach is coherent with the concept of adjacent possibles (Felin et al., 2014; Kauffman, 2014; Koppl et al., 2014), in which actuals create a niche for new opportunities that might emerge, if the context(s) of these niches change(s). Our approach goes one step further insofar as we propose to identify the core of these potentials

Figure 1 Strategies and levels for dealing with (open-ended) change (they do not exclude each other)



and cultivate them further in an enabling environment. This leads to changes that fill the classical gap and challenge of radical innovations: they fit into the environment in a sustainable manner (because they have their basis in the core of the OOI) and they are at the same time fundamentally new (because they tap yet unrealized potentials of the core of the OOI).

4 CONCLUDING REMARKS

Besides having to employ a whole new set of cognitive and epistemological skills, as well as attitudes (e.g. openness, patience, letting go, coping with loss of control, deep understanding of the core potentials, etc.) complementing the classical variation-and-selection processes, such an approach has far-reaching implications for innovation and creating new knowledge.

Among the key features leading to rethinking innovation and knowledge creation, the following points have turned out to be crucial:

- A new understanding of innovation as *learning from the future as it emerges* (as opposed to extrapolating from the past).
- Innovation is not primarily the result of a 'creative process' that is based on relatively unstructured and unfocused creativity techniques (such as brainstorming) that are based mainly on past experiences.
- Furthermore, innovations are not primarily a result of a trial-and-error process as we know it from evolutionary processes or the stage-gate innovation strategy (Cooper, 1990): i.e. the production of a high quantity of (more or less) low quality ideas and selecting and filtering these ideas according to classical economic decision criteria. Here, again, criteria that have proven to be appropriate in the past are applied to a potentially unknown future.
- Rather, the Emergent Innovation Approach (Peschl/Fundneider, 2008, 2013) suggests turning the process on its head: (i) instead of developing a high diversity of

low quality ideas, we suggest starting with a deep and systemic understanding of the (core of the) object of innovation (OOI) and its environment; (ii) this is the foundation for understanding and developing its potentials for future development(s); (iii) creation of enabling conditions and an environment that supports the emergence of innovations that are (radically) new while nevertheless fitting into the core of the OOI.

- This implies that we have to be able to develop a profound, reflected, and *deep understanding* of our own thinking, of the frameworks and assumptions of our cognition and knowledge as well as of our patterns of perception.
- This should lead to the capacity of understanding the core of the OOI: what is its most profound meaning? On which (implicit) assumptions is it based? What are the 'real' issues at stake concerning the OOI and its environment?
- Finally, it is necessary to be able to deal with and explore *potentials* and *latents* (Poli, 2011) in a sovereign manner so that one can develop *new (emerging) semantic fields* around this core.
- Shifting from managing and controlling to *enabling* innovation and knowledge creation.

This list was just to name the most important issues. In any case, the notion of enabling plays a central role (Kauffman, 2011, 2014): innovations cannot be brought about in a mechanistic or algorithmic manner. Entailing laws or purely rational approaches cannot be applied in the creation of novelty or in the context of innovations (Felin, 2012; Felin et al., 2014; Longo et al., 2012). They have to be replaced by a logic and strategy of enablement or enabling. It can be shown that this does not only concern processes, practices, values, or abstract structures, but also extends to and has implications for the important domain of *how to design environments enabling innovation and knowledge creation* (e.g. office design, organizational design, etc.), known as *Enabling Spaces* (Peschl/Fundneider, 2014a, 2014c).

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THE FUTURE OF RESEARCH AND INNOVATION

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1 INTRODUCTION

1.1 THE DOUBLE DILEMMA OF RESEARCH AND INNOVATION POLICY

Research and innovation policy is faced with a double dilemma. First of all, while the practices of research and innovation are changing fast, the necessary adjustments of institutional and organisational settings to keep pace with these changes can take many years to become effective. This governance challenge of permanently adjusting to, and lagging behind, a fast-changing, sometimes even disruptive reality while being expected to provide guidance and stability has become more pressing in recent years (Rousselet, 2014). It is also one of the reasons why the EC has again put foresight on the agenda (Burgelman et al., 2014).

Second, the expectations and demands with regard to innovation policy are rising. This development is closely tied to the 'strategic turn' in research and innovation policy (Weber, 2012), which can be observed since the turn of the millennium. Not only is R&I expected to be the remedy to economic recession and downturn but also to contribute to tackling major societal challenges in a much more targeted way than in the past. At the same time, while being faced with increasingly complex problems, the steering capabilities of government remain limited in a world of distributed and inter-dependent competencies, resources and strategies. This is particularly challenging for small countries that need to concentrate their resources on a limited range of domains while at the same time seeking to benefit from European and international R&I developments to the largest extent possible; developments that are usually well beyond their influence.

¹ Disclaimer: this article does not reflect an official EC position.

1.2 SHAPING THE FUTURE

IN THE FACE OF COMPLEXITY AND UNCERTAINTY

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The traditional way of devising policy relies on a thorough analysis of the past and the present. On that basis, generalised lessons and insights for policy are derived, guided by political goals and ambitions. This approach is quite suitable in times of incremental change, when the structural and institutional conditions for economic and social behaviour remain largely stable and can thus be captured in corresponding models. However, in times of radical and qualitative, maybe even disruptive and paradigmatic change (Freeman/Perez, 1988) this mode of operation is not sufficient any more. A first challenge of shaping the future thus consists of better understanding what futures might arise.

In the face of complexity, uncertainty and ambiguity (Renn et al., 2011), i.e. the typical features of the wicked problems of our times, a second major challenge of shaping the future consists of translating insight into action. Wicked problems tend to require collective solutions involving a multitude of actors in a coordinated manner, be they global in nature (climate change, feeding the world) or concentrated on the specific localities (e.g. in cities).

The third major challenge concerns the question what future we, as society, actually want. Of course, due to the veil of uncertainty, our ability to specify such normative orientations is limited. However, overarching visions and guiding principles are key to assessing alternative scenarios of the future and making choices that cohere with these principles. Foresight processes have been devised since the early 1990s to help dealing with such wicked problems by combining the long-term view on qualitatively different scenarios with an early engagement of stakeholders in order to enable coordinated action for tackling shared problems in line with shared goals. In a way, foresight can be regarded as a means to gain time and get prepared for dealing reflexively with future (rather than present) challenges.

1.3 EXPLORING FUTURE RESEARCH AND INNOVATION

In recent years, a number of emerging trends and developments have been identified that have the potential of changing prevailing R&I practices in quite fundamental ways, with corresponding impacts on the institutional and organisational structures in which R&I is embedded. For instance, some of the proponents of the notion of Science 2.0 see an era of data-driven science emerging, which may put into question the need for deductive, theory-led research. While we can currently observe only first weak signals of the potential of these developments to shape our R&I practices and systems, some authors assign a transformative potential to them (Burgelman et al., 2010; EFFLA, 2014; RDA Europe, 2014). Interesting enough, this emerging picture of a new way of doing research in an open and bottom-up way runs in parallel with change in innovation practices towards more bottom-up and 'open' models (Enkel et al., 2009).

At this point, two words of caution are needed: first, we need to be cautious not to let ourselves be carried away by hypes and overwhelming expectations associated with some emerging trends. It is a recurrent pattern that emerging developments are assigned a path-changing potential while ignoring that counter-acting effects may well arise that prevent the paradigm shift to happen.² From a foresight perspective, we need to acknowledge that we cannot know how the future will unfold.

A second word of caution relates to our limited ability to shape the future, in particular when seen from the perspective of a small country. If we take the claim to shape the future seriously, we need to acknowledge the limits to shaping in a context that is shaped by developments beyond our influence as well as the balance of these developments with what we can influence from a national or organisational perspective.

² Freeman and Perez (1988) already highlighted in their work on techno-economic paradigm shifts that several complementary self-reinforcing mechanisms need to be at play to turn a promising technology into a new paradigm.

In a similar though somewhat less radical vein, we argue in this article that it is not enough to look at emerging trends if we want to get a handle on the longer-term perspectives for R&I in Europe. Instead, the interactions, tensions and synergies between these trends need to be analysed, as a first step towards the exploration of qualitatively different transformative futures of R&I.

In a set of EU-funded projects, longer-term perspectives on science, research, innovation, together with the institutional and organisational setting in which these activities are embedded, have been explored for time horizons around 2030 and beyond.³ What these projects share is the conviction that it is not enough to look at emerging trends only but that we need to explore transformative changes ahead by analysing the interplay of such trends. This is associated with the fear that if we miss the 'next big thing', as Europe did with the internet revolution, there is a risk that the gap between Europe and the US will further widen and gaps between Europe and other countries may open up. We have to get it right this time.

It is therefore necessary to get prepared for qualitatively different futures, even if we do not yet know with certainty how they will look like. Rather than predict and control approaches, robust and adaptive strategies are needed for dealing with uncertain, complex and ambiguous future developments ahead, while being sensitive to the potentials they may entail.

In the next sections, first some past and then some of the most prominent emerging developments in R&I are briefly revisited, pointing also to some second-order and counter-mechanisms associated with these trends. The subsequent section is going to look at some of the tensions that may arise from the interplay of these trends,

³ See the corresponding projects INFU – Innovation Futures (www.innovation-futures.org), RIF – Research and Innovation Futures. From Explorative to Transformative Scenarios (www.rif2030.eu), VERA – Forward Visions on the European Research Area (www.era-visions.eu), and Science 2.0 (EFFLA 2014).

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and the potential for qualitative changes occurring from such tensions in terms of transformative scenarios, impinging on the practices, the organisational models and the institutional settings associated with them. The final section looks into some lessons to be learned for policy strategy in the face of transformative long-term changes of R&I.

2 EMERGING DEVELOPMENTS AND EMERGING TENSIONS

2.1 PAST PATTERNS OF RESEARCH AND INNOVATION

Research and innovation are among the most noteworthy areas where practices and organisational models are changing very fast. In this context, it is instructive to take a look back at changes we have witnessed during the past century. The systematic practice of conducting research for the purpose of developing new products started in the late 19th century, more or less in parallel with the rise of Fordism, as a *modus operandi* for industry. Noteworthy examples were to be found in the chemical industries, but also in areas like energy systems, automotive engineering or electrical engineering. In these areas, research was still tightly integrated in development and engineering activities. A major change can be assigned to the large-scale scientific efforts undertaken during and after the Second World War, first to bring about breakthroughs for military technology but later on also for civil purposes (Bush, 1945). The Manhattan Project to develop the nuclear bomb may be the most well-known example in case, but big industrial and public labs (e.g. Bell Labs in the US and the major research centres in Europe) provide evidence of scientific research efforts leading to a range of innovations and successful products in the 1950s and 1960s.

Innovation was recognised as a crucial determinant of economic growth and prosperity, and as a decisive factor for enhancing the competitiveness of firms and countries in the face of globalising competition. With the need to accelerate the process of novelty creation, research and innovation activities became increasingly interactive

and distributed, involving both elements of scientific discovery and market-led impulses. Of course, universities have been centres of scientific knowledge for many decades, if not centuries, but their role as sources of scientific knowledge to fuel innovation was increasingly promoted from the 1970s onwards. Better connecting science to innovation was the imperative of the 1970s and 1980s, with demands growing to provide a political and economic framework conducive to R&I.

The practices and organisational forms of conducting R&I have evolved in line with these changing requirements. The lab as the central place where research was providing the foundations for innovation, gave way, first in the ICT sector, to a model where the linkages and synergies between science on the one hand and the realm of industrial applications on the other were in the focus, in order to speed up the process of innovation and better exploit scientific insights. This is not to say that innovation did not take place in different forms in the industrial context as well. In fact, much innovation was created in an industrial environment without major links to science. However, there is little doubt that the role of innovation that is based on systematic scientific research has been growing in importance.

In the meantime, innovation has also become pervasive, and it covers a range of phenomena well beyond the traditional notion of technological innovation: service innovation, social innovation, institutional innovation, etc. While not all of these types of innovation are necessarily research-led, the growing knowledge-intensity of innovation is widely recognised, often requiring to combine technological, organisational, institutional and social elements.

2.2 EMERGING DEVELOPMENTS IN RESEARCH AND INNOVATION

In recent years, several important emerging trends and developments in research and innovation have been identified, which are going to be summarised and discussed in the following section. Of course, this summary is a simplification of highly differen-

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tiated phenomena, but it should help understand the currently changing landscape of R&I. Each of the seven dimensions of change will be discussed in terms of both current trends and trade-offs associated with these trends:⁴

Dimension 1: Participation and coordination

Collaboration in research and innovation intensifies and tends to involve a broader spectrum of actors and stakeholders than in the past. Of course, collaboration has a long-standing tradition in traditional large-scale scientific endeavours, and it is also increasingly demanded by publicly funded research programmes. Over the past two decades, the internationalisation of collaborative links has been growing and science-industry relations have become an important focus of collaboration in relation to R&I. These well-known developments are complemented by collaborations with other than traditional R&I agents and often mediated through other than market mechanisms. As regards innovation in particular, the coordination between innovation demand and supply can also take place in self-organised user communities or web-based co-design platforms; initiatives on the city level involve public and private actors in social innovations that complement or even substitute market-based relationships. Citizens and customers are likely to play an even more significant role in innovation in the future than they do nowadays, both in deciding on innovation priorities and in contributing to the innovation activities. The latter observations also apply to research activities. Patients, for instance, are partners in medical research, and volunteers get actively involved in research on the conservation of nature.

Cooperation and coordination entail costs that are growing exponentially with the complexity of R&I endeavours. In Europe, multi-level coordination between different political and geographical levels has led to the introduction of new and demanding

⁴ The distinction into these seven dimensions draws on prior work by Leitner and Weber (2015).

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cooperation frameworks such as Joint Technology Initiatives, Joint Programming Initiatives, or European Innovation Partnerships. While all these initiatives are based on well-intended rationales to create a more efficient and effective European research and innovation area, the costs of coordination are significant and may well limit the potential for collaboration in the future. What can be observed here is that the justified need for new ways of collaborating is done in an institutional setting geared towards traditional ways of doing research and innovation, hence the heavy transaction costs. Coordination may also have ambivalent consequences for the substance of future R&I agendas. While complex endeavours may require the involvement of many different actors with their respective competencies, finding agreement on a common agenda may not necessarily lead to the pursuit of the best solution but to a sub-optimal strategy, which has as its main quality that all partners can agree to it. Ultimately, however, science is highly unpredictable and thus difficult to plan *ex ante*.

Dimension 2: Motivation

Economic incentives remain key to understanding the main motivation of firms to innovate. However, we can observe that the motivations for getting engaged in innovation activities are changing. Intrinsically motivated users, communities, citizens, and social entrepreneurs contribute to companies' innovation activities without necessarily expecting an economic return, thus complementing the traditional monetary motivation. Solving societal problems is becoming an important driving force for research as well as for innovation, in companies and research-performing organisations, as well as for individuals. There are many examples showing that individual actors are motivated to contribute to research and innovation activities, e.g. by launching crowdsourcing initiatives or idea competitions for their pleasure and outside of the boundaries of established organisations (Leitner et al., 2012). This expanded range of stakeholders and participants in research and innovation processes

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is often driven by intrinsic motivations, and their interaction relies on a broad range of novel coordination mechanisms, based for instance on participatory processes and user involvement in early phases of the innovation process. Changing values and lifestyles are at the origin of this change in behavioural patterns, entailing new forms of entrepreneurship (Wevolve, 2013).

Ultimately, these novel developments may still be embedded in activities with an economic purpose, and in fact private firms exploit the potential of intrinsically motivated innovators to their benefit. It is important to keep in mind that firms should take notice and make use of these new forms of innovation that are based on voluntary contributions. While, for the moment, the returns for the innovators are often not well defined, this is likely to become an issue once these and similar forms of innovation become more widespread.

Dimension 3: Automatisatation, digitalisation and virtualisation

The role of ICT is expected to play an ever-growing role in research and innovation. There are several facets to this development, of which only some can be highlighted. The proponents of big data applications promise a new data-driven mode of knowledge production and enhanced transparency of the research process, up to the point of claiming a fundamental change in the nature of R&I, with data-driven science increasingly complementing traditional deductive, theory-led scientific approaches.

The involvement of citizens in research and innovation activities is enabled and facilitated by ICT. From the companies' perspectives, social media offer new opportunities of tracking changes in consumer preferences and new ideas in real time on the internet by using sophisticated semantic web-mining technologies. Ultimately, this allows them to automatically spot and extract innovations with outstanding market potential. More and more innovation steps may become automated, e.g. by using a web crawler to identify ideas.

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The automatisatation and standardisation of innovation is a highly contested issue, with critics pointing to negative side-effects of rationalised and automatised forms of R&I (Francisco, 2010). Incremental and almost standardised forms of innovation may indeed be accelerated by automatisatation, but creativity and radical innovation may be hampered. Overall, there is a fear that automatisatation may lead to a loss of diversity in innovation, and to stronger path-dependencies along the lines of what has already been discovered. Attention needs to be paid to ensure that opportunities for radical innovation are not missed.

Dimension 4: Re-contextualization of science in society

There are several indications of a changing relationship between science and society. This re-contextualization of science in society emerges as part of a wider change process of industrialised societies, as reflected in changing value patterns, social differentiation and internationalisation of personal networks. Beyond these generic developments a few recognisable strands of change can be specified. First of all, research and innovation activities appear to play a growing role in society on a number of grounds (e.g. in terms of investment, number of researchers, number of publications, etc.). At the same time, the distinctive nature of research and innovation systems is eroding and being replaced by blurring and open boundaries with society. In doing so, innovation is moving increasingly to a co-creation model. While there are frequent complaints, albeit from the scientists, about the disinterest of society at large in science and technology, citizens have more and more possibilities to get directly engaged in research and innovation activities, and they also use these possibilities. But diversity increases also within the research and innovation system where new actors with specialised roles are emerging and shaping the interfaces with society and economy. Traditional technology transfer activities are complemented by new interfaces to ensure knowledge exchange, for instance through science-based start-ups, social

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innovations, or science centres. Finally, public and policy debates about what science and innovation should deliver to society are pointing to new claims to better justify the societal relevance of R&I agendas and – as a consequence – the involvement of societal stakeholders in setting (public) research and innovation agendas.⁵

This apparent trend towards a tighter embedding of science in society, and thus higher accountability, is associated with a corresponding loss of autonomy.

It goes hand in hand with a growing rationalisation and planification of science and entails continuous monitoring and assessment of research activities. While this may help reduce risks and increase the societal relevance of science, it also constrains the possibility of surprise. In practice, the tightening of social control over science and research has imposed a heavy burden of bureaucratisation which runs counter to the most fundamental role that science should play in society, namely, to generate novelty and surprise.

Dimension 5: Spatial shifts

The spatial patterns of research and innovation are changing in several different regards. Science has been an important element and driver of internationalisation and globalisation, and innovation in several domains is driven by globalisation in science. Processes of internationalisation and globalisation occur within a scientific landscape that includes many of the political, technological, infrastructural, social, and economic drivers affecting structures, patterns and trends in research collaboration. The globalisation of science is seen as a process in terms of transnational collaboration agreements, shared resources, joint activities, migration of researchers and flows and exchanges of knowledge and skills (The Royal Society, 2011; Tijssen et al.,

⁵ At a European level, many of these developments associated with the changing relationship between science and society is summarised under the headline of Responsible Research and Innovation (RRI).

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2012]. Globalisation of science is also related to access to literature, or as the Royal Society (2011) puts it: 'The spread of access to academic journals across the world is a key factor in the globalisation of research.'

The situation is more complicated with regard to innovation. In many areas, innovation is key to the transformation of global value networks. The relationship between the different nodes of these networks is characterised by competition, with different nodes striving for control over resources, be they financial, intellectual or physical. Innovation – and for that matter also research – is crucial for determining future shifts in control over value networks. This development has important consequences for policy and strategy at the level of countries and firms because their future perspectives (e.g. in terms of employment and growth) depend on their ability to master certain key innovation assets. Regions that manage their innovation activities in a clever way may evolve into important hubs in these global innovation networks.

To this adds the observation that the local level, and cities in particular – where soon sixty per cent of the world population will live – are likely to gain relevance for the spatial patterns of research and innovation. Not only are cities important demand-side drivers of research and innovation, as potential knowledge hubs they are also the locations where research and innovation concentrate. As a consequence, both the potential benefits of innovation (e.g. in terms of employment created) and its downsides (e.g. growing inequality) are likely to get amplified.

Dimension 6: Sustainable systemic innovation

Not least reflected in the orientation towards Grand Challenges in European research and innovation policy, systemic innovations are attracting growing attention. Rather than just focusing on isolated product developments, systemic innovation calls for radical changes in the components and the architecture of large socio-technical

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systems like energy supply, mobility or health. Research and innovation activities thus need to be coordinated and framed at different levels of aggregation in order to enable systemic innovations and – in the case of existing systems – systemic transitions. Behavioural changes, motivated by changes in values and lifestyles, are as much part of systemic innovations as new technological and organisational inroads to satisfy user needs, or institutional changes to set different incentives for innovation, investment and behaviour. Systemic innovations are often associated with normative considerations regarding a desirable future state of the system in question. This requires, for example, that social and ecological criteria are considered during the entire innovation process, e.g. by designing circular resource flows following a cradle-to-cradle strategy (Braungart/McDonough, 2002). Research agendas are increasingly motivated and legitimised by making reference to the need for systemic transitions, and recent attempts to organise and institutionalise research and innovation activities geared towards such transitions have taken a prominent place in research and innovation policy.

Obviously, the level of aspiration tied to R&I agendas aiming to facilitate sustainable systemic innovations and transitions is extremely demanding. High demands on government policy are formulated to trigger, guide, or even manage systemic innovations. However, there is a risk of failing to meet the high expectations raised if the limits to what governments can do and deliver in a complex world are ignored and demands are raised that are impossible to fulfil. First of all, policies for systemic innovation are likely to succeed only on the basis of a well-functioning research and innovation system. As long as a strategy to foster sustainable systemic innovation cannot be built on a structurally and institutionally robust research and innovation system, a goal-oriented policy approach combining innovation and sectoral policy instruments will fail. Moreover, a balance needs to be struck between top-down planning and bottom-up experimentation while accepting the risk of (partial) failure of such risky

endeavours. Also the balance between short-term and long-term consequences of sustainable systemic innovations needs to be carefully considered. There will be inevitably losers of a systemic innovation, such as those actors closely tied to incumbent systems in place.

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Dimension 7: Access to research and innovation/knowledge

In spite of growing claims for openness, the access to data, funding, infrastructure, results, benefits, and careers in research and innovation is still highly contested. Initiatives that aim at enabling open access or open science get increasing support from government policy (European Commission, 2012). Both European and national level research funding bodies promote open access policies. At the same time, private enterprises (e.g. publishers) have built their business model on the commercial access to their research data and analyses. These policies will transform the traditional publication system by shifting the costs to authors and/or their home organisations ('pay to publish').⁶ Nevertheless, in the longer term completely new business models ('pay per download') could emerge.

Overall, the undeniable quest for openness is currently only slowly leaving the stage of experimentation. Practices are diverse and guided by different visions of what openness could mean. Access to knowledge is still confronted with many barriers, even if in poorer regions of the world access is organised through special arrangements with publishers or through public-private partnerships.

In relation to innovation, the notion of openness has even broader connotations. In a world where research and innovation activities are increasingly conducted outside the

⁶ The two most prominent models are the 'gold' and the 'green' standard. The gold standard builds on publication of scientific texts in open access media and journals, with fees to be paid by the researcher, his/her home organisation, or the funding body. The green standard ensures open access through self-archiving of pre- or post-prints in a community-based web infrastructure (e.g. arXiv).

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boundaries of the organisation that will use the outcomes, managing access to research and innovation knowledge becomes a critical competence. Open innovation is thus about the intelligent management of internal and external knowledge resources. It is about intelligent partnerships rather than in-sourcing all required competences, and it therefore is about new business models, too. It covers more sophisticated knowledge exchange processes with partners and competitors, as well as innovation contests involving the public (raising all kinds of concerns regarding IPR).

With these seven dimensions, the inroads triggering future changes in research and innovation practices have been defined. Taken individually, each dimension may offer opportunities for quite significant changes but, as argued in this article, it is only by way of novel combinations of these dimensions that transformative changes are likely to come about. An isolated extrapolation of individual trends without taking into account interdependencies may easily lead to simplistic hypes and conclusions. Second-order effects that may either dampen or reinforce these trends need to be taken into account in consistent scenarios.

3 FROM TENSIONS TO TRANSFORMATIVE CHANGE

3.1 BEWARE OF TENSIONS AHEAD

Emerging developments, such as the ones sketched in the previous section, are likely to give rise to tensions and potential trade-offs, in particular when they are arising as quickly as we can currently observe in research and innovation. Path-dependencies inhibit institutional and structural adjustment processes to take place until increasingly pressing deficits require a fundamental transformation to unfold. Such transformations can be triggered by success cases of novel R&I practices that may propagate quickly and erode the prevailing organisation models and practices. This is the basic logic behind the transformative scenarios that are going to be sketched later

in this section. They are triggered and driven by tensions resulting from the interplay between the different emerging developments, tensions such as the following:

Fragmentation vs. standardisation: The first example refers to the tension between the growing fragmentation, largely due to extreme disciplinary specialisation of science and research on the one hand, and the introduction of increasingly standardised rules and procedures on the other. We have witnessed an explosive growth and differentiation of knowledge production, with growing diversity in epistemic cultures and novel disciplines emerging at the intersection of established ones. At the same time, research and innovation activities are increasingly subject to processes of standardisation and rationalisation. This applies in particular to performance measurements and evaluation, often dominated by the standards and practices of natural sciences, with their wide-ranging implications for careers and funding. The tendency to standardise puts into question the specificities and thus the richness of alternative paths and paradigms in science as well as in innovation.

Efficiency vs. ambition: The second example tension focuses on the purpose of research and innovation. In essence, it is about the question whether R&I should deliver novel and sometimes even surprising impulses or rather reliable and planable results. There is growing demand and pressure to develop and implement research and innovation activities in a fast, efficient and predictable manner. The project-based approach focuses on reducing risks and ensuring delivery of results according to a work plan. This is particularly apparent in public (but also in private) research funding where risk-taking is often not rewarded, but legitimisation of public funding is rooted in the reliable delivery of the results that were promised at the outset. A massive legitimisation and reporting machinery has been established to monitor progress towards initially defined goals to justify spending. Obviously, the notion of surprise,

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which is regarded by many as essential to R&I, has a limited role to play in such a context. This stands in stark contrast with the high levels of ambition that are often tied to research and innovation. These ambitions can be of two kinds, namely either foundational breakthroughs in science or the development of path-breaking systemic innovations that are expected to have a major impact on addressing important societal needs. In both regards, long-term perspectives and maybe even novel forms of institutionalisation are needed to enable high-ambition research. A high degree of trust and willingness to accept failure is needed in high-ambition and risky R&I initiatives because of their inherently uncertain and complex nature. This is, of course, difficult to justify in an institutional setting that mainly rewards the reliable delivery of outputs according to plan.

Competition vs. cooperation: The third example refers to the tension between competition and cooperation in R&I. On the one hand, ever more complex R&I endeavours require comprehensive inter- and transdisciplinary cooperation. On the other hand, growing competition for resources, both in public sector research and in private organisations, hampers precisely the kind of cooperation needed. The competition principle tends to be further broken down to the level of the individual researcher, with corresponding consequences for the incentives to cooperate. Competition may be a very valuable principle for selection of the best ideas, but cooperation is about building ties between different epistemic communities and thus a major source of creativity. It is a precious phenomenon that comes increasingly under pressure in a world of individualised rewards, and this in spite of many public funding programmes requiring some form of cooperation. This raises the question whether the frequently uttered claim to attract creative minds to research and innovation is going to succeed in environments that reward individual achievements rather than creative collaboration.

While these have just been some examples of emerging and even current tensions, they illustrate the risks that the extrapolation and pursuit of certain 'trends' at the cost of diversity may entail, risks that may put into question the very nature and function of R&I for society. If tensions like the ones outlined above persist, they will negatively affect the performance of R&I systems. Contradictory incentives and frameworks may lead to deadlocks in our R&I systems if the dynamics of change are not addressed early on. However, it is difficult to address these dynamics in settings that are characterised by long-standing path-dependencies and thus show a great deal of resistance to change; but this is precisely the situation in R&I systems that are dominated by large organisations.

The tensions thus point to issues related to the institutional conditions for R&I and the possibilities to change these conditions. In this article, we argue that the tensions can be resolved by transformative changes in R&I systems, i.e. changes that may entail shifts in structures, institutions and behaviour.

There is a need to navigate and balance these emerging developments in novel ways in order to overcome the tensions, but there are no clear-cut models to follow. Inspiration for guidance and orientation can come from radically different scenarios of how the future of R&I might look in order to gauge our strategies to a diverse range of possible futures. However, there seems to be a lack of imagination of how alternative models might look. It is this bottleneck that the scenarios sketched out below aim to address. They draw plausible alternative pathways as thought-experiments about how the tensions might be overcome. None of them can claim to be an accurate description of the future, and some may even look radical or unrealistic at first glance, but as a result of a participatory process involving a range of different experts and stakeholders they have been validated by a relevant community.

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3.2 TRANSFORMATIVE SCENARIOS OF R&I

Devising images and pathways of transformative futures is a daunting task. You cannot prove whether they are right or wrong; only time will tell whether they were useful as mental models to guide thinking about organisational and institutional adjustments and decision-making.

Some partial answers to how transformative scenarios of our R&I systems might look have been provided by a number of European research projects conducted in recent years, which focused on exploring future developments in R&I at a time horizon of 2030 and beyond.⁷ While having a special interest in the European situation, they all looked into global developments as well as into specific R&I practices and institutional conditions for R&I. For illustrative purposes, the scenarios developed as part of the EU-funded project RIF (Research and Innovation Futures 2030) are presented in Table 1. They all follow the reasoning that current trends will lead to major tension. These tensions are overcome by a transformative change process that is triggered by specific success stories and subsequent reinforcement mechanisms.

The scenarios sketched in Table 1 are all very different from the situation we have today. None of the scenarios can claim to cover the entire spectrum of R&I activities in the future. Neither should they be regarded as mutually exclusive. They can serve as relevant models in certain areas of R&I while being less relevant in others. Each scenario thus represents a partial picture of how the future research landscape may look, and some of them may even co-exist. For instance, the scenarios ‘Open Research Platforms’ and ‘Grand Challenges for Real’ draw different pictures of how major societal challenges could be addressed by way of research and innovation. At the same time, the scenario ‘Knowledge Value Chains’ represents an industrially-

⁷ See footnote 2 for the corresponding references.

centred model of future R&I which may or may not be directed towards grand challenges. It may well co-exist with each of the two other scenarios.

The scenario ‘Researchers’ Choice’ focuses on the quality and motivation concerns of researchers from an individual perspective. It represents an important bottom-up element of the future of research and innovation which complements key features of the scenario ‘Open Research Platforms.’ Finally, the scenario ‘Knowledge Parliaments’ could also be considered complementary to ‘Open Research Platforms’ as regards the way research agendas are set. It becomes evident that the way ahead probably lies in an intelligent combination of elements from the five scenarios used as inspiration for devising future-oriented strategies beyond the ‘business-as-usual’ framework of extrapolating current trends.

Table 1 Overview of RIF Scenarios, based on Erdmann et al. (2013)

Open Research Platforms (ORPs) – self-governance in a networked decentralised research landscape	
Assumptions	R&I landscape is highly fragmented. Global cooperation and open knowledge-sharing grow rapidly in a still dominant ‘closed’ science system. R&I can be performed and accessed nearly for free by everyone. Growing demand to tackle major societal challenges but confidence in government to solve these challenges declines.
Core tension	Ongoing fragmentation of R&I and conflicting actor strategies (e.g. open versus closed R&I) prevent the necessary coordination of R&I for tackling major societal challenges.
Trigger	In the face of a newly-emerging deadly disease, scientists worldwide integrate their findings on an open wiki platform and collaboratively discover a solution.

Trigger	Major success cases of open collaborative research contribute to the global rise of Open Research Platforms (ORPs) as a means of research self-governance.
Key characteristics	The first scenario, Open Research Platforms, describes a research and innovation future of self-governance in a networked decentralised research landscape. By 2030, the research landscape with its research-performing organisations (and individuals) and funding mechanisms is fully decentralised, global and open. Virtual communities initiate research that is integrated into virtual platforms and openly accessible. Self-governance of research around 'Open Research Platforms' (ORPs), fully open to universities, RTOs, industry, individuals, foundations and civil society at large, is the norm. Into the vast knowledge flows passing through these ORPs, governments of open societies worldwide embed their soft coordination activities such as monitoring of research, assistance in connection of research activities and targeted provision of incentives for researchers to contribute to certain ORPs of public interest.
Knowledge Parliaments (KPs) – the free negotiation of knowledge claims world-wide	
Assumptions	A variety of knowledge domains (beyond science) provide inspiration for possible research and innovation directions. Epistemological diversity strengthens principles of social responsibility in R&I. Growing importance of non-European sources/agencies for funding research in Europe.
Core tension	There is a struggle for distribution of resources between conventional scientific and non-conventional (e.g. indigenous, experience-based, responsible) forms of knowledge. There is a struggle for distribution of resources between conventional scientific and non-conventional (e.g. indigenous, experience-based, responsible) forms of knowledge.

Core tension	In Europe, large public and private players dominate the definition of R&I agendas, with rigid and inflexible participation procedures preventing many other players from applying.
Trigger	The struggle between conventional science and alternatives leads to split communities with movements of responsible alternative knowledge linking up worldwide, thus creating an influential global community.
Key characteristics	New types of fora are created to negotiate knowledge claims in society. Civil society acquires a stronger role in setting public R&I agendas. By 2030, all kinds of knowledge claims are raised by new knowledge actors and negotiated in so-called 'knowledge parliaments'. These knowledge parliaments evolve into a new governance model for science in society. They prioritise research topics and provide 'trading zones' in which actors with particular research interests, topics and epistemologies compete for acceptance. This form of forum also facilitates the building of research consortia. Citizens and a variety of other local stakeholders and epistemic cultures (e.g. lay and indigenous knowledge) are incorporated. Neglected research topics and unconventional knowledge domains are brought to the fore. A global research landscape emerges, accepting the plurality of knowledge types, IPRs and research practices.
Grand Challenges for Real (GC-KICs) – collective experimentation in socio-technical labs	
Assumptions	Grand challenges evolve into the main concern of publicly funded R&D, seen also as a major economic opportunity. Knowledge and Innovation Centres (KICs) represent the dominant organisational model for research, innovation and education on Grand Challenges.

Core tension	European research on Grand Challenges fails to deliver; at a global level, R&I on Grand Challenges is dominated by new players from China and other emerging countries, thus also questioning the economic potential expected from research on Grand Challenges.
Trigger	Growing claims to take Grand Challenges seriously and devise a new model for R&I, replacing the established KICs. Success cases of organised collective learning processes delivering smart technological and social solutions to Grand Challenge issues pave the way for a switch towards a new generation of KICs relying on collective experimentation.
Characteristics	This scenario describes a future that revolves around a new research practice of collective experimentation in socio-technical labs. In 2030, the research landscape in Europe is characterised by making extensive use of collective experimentation. Research on Grand Challenges in Europe is organised around twelve large Knowledge and Innovation Communities (GC-KICs), each one overseeing several regional and local socio-technical laboratories in which a large number of different solutions responding to Grand Challenges are developed and tested. These socio-technical labs are key instruments for learning about effective solutions. Diverse actors such as citizens, companies, universities, and social entrepreneurs engage in collective experimentation. Experimentation, measurement of practices and impacts, and co-creation go hand in hand so that real progress towards Grand Challenges becomes evident.
Knowledge Value Chains (KVCs) – research for innovation in a specialised and stratified research landscape	
Assumptions	The global race for leadership in technological innovation is accelerating. Public research funding relies increasingly on outsourcing and monitoring research activities to large platforms and consortia. These platforms connect an increasingly fragmented R&I landscape of public and private R&I performers.

Core tension	Fierce competition for limited resources leads to a boost in efforts and streamlining of research planning; this puts increasing pressure on the few remaining large research-performing organisations.
Trigger	Large consultancies, some universities and research organisations specialise in running efficient large-scale research endeavours. They prove their success in some selected cases (e.g. e-mobility) and thus favour a generalised shift towards this new organisational model.
Key characteristics	In this scenario, research and innovation are intimately intertwined in a specialised and stratified research landscape. By 2030, the public research landscape is closely connected with the private research landscape globally. Research in Europe proceeds at various national and regional speeds aiming to improve their competitiveness in global markets through innovation. Research is carried out in ‘Knowledge Value Chains’ (KVCs) organising the cooperation between three types of highly specialised and stratified organisations: Research-Integrating Organisations (RIOs) that control the KVCs, Research Service Organisations (RSOs) and Specialised Research Suppliers (SRS). Using business-planning methods, research is increasingly rationalised and tied directly into industrial innovation agendas. National governments nurture their RSOs to position them as key players supporting the very few global RIOs.
Researchers’ Choice (RCs) – autonomous researchers go for creativity and well-being	
Assumptions	Fierce competition in academia for funding and tenured positions. Declining societal esteem for scientists. Creativity, autonomy and a good work-life balance are increasingly valued by the younger generation, but academia cannot satisfy these expectations anymore.

Core tension	Young researchers do not strive for academic positions any more and look for job opportunities outside the science system.
Trigger	New opportunities for young scientists are offered outside established institutions. Small-scale and individual research activities, interconnected through open science/open data social networks, create a new culture of scientific collaboration. Scientific entrepreneurship as well as slow science emerge as role models within this new type of scientific environment.
Key characteristics	Autonomous and networked researchers are the drivers of this scenario. Creativity, autonomy and a decent quality of life are central values and replace the strive for traditional career paths. Society is characterised by highly individualistic values and a strong emphasis on individual well-being, autonomy and creativity. Autonomous researchers are at the heart of scientific research. They offer their scientific skills and knowledge on virtual research markets, with new business models emerging. To realise their ambitions researchers choose options within a broad spectrum of models, ranging from new forms of science entrepreneurship to more collective forms under the umbrella of 'slow science', with a strong orientation towards local societal needs. Apart from global research ventures, autonomous researchers can equally engage in local alliances for tackling problems and gain high reputation for their work.

4 LESSONS TO BE LEARNED

In this contribution, we have started with highlighting certain emerging dynamics in R&I, which are currently under discussion in Europe and globally, while stressing that we should avoid extrapolating from them. Some of the developments observed will inevitably influence our R&I systems, but the more radical consequences are to be expected from the interactions between them, their dampening and reinforcing second-order effects, and in particular from the radical changes needed to overcome tensions between them.

Lesson 1: Don't follow the hype of extrapolating single trends and watch out for alternative models to overcome tensions between them!

A second key argument relates to the need to prepare for the unexpected. The transformative scenarios have shown that quite radical changes are indeed possible and plausible given the tensions that otherwise might arise. However, as we cannot predict the unpredictable, we need to prepare a range of alternative pathways and options and continue to monitor how the future unfolds. In particular, we should avoid optimising with regard to a single dimension of interest. Optimisation strategies have been pursued for several years in many societal domains, in particular with a view to improving economic efficiency, but with negative consequences for the adaptability and resilience of these systems. This may be a suitable strategy under stable conditions, but not in the fast-changing world of R&I, where it is more important to keep options open and ensure adaptability to new developments. As a consequence, the frequently raised arguments in favour of strengthening industrial and scientific specialisation must be put in perspective as it can be detrimental to adaptability.

Lesson 2: Always be prepared for the unexpected! Move from optimisation strategies to strategies for enhancing resilience and adaptability of R&I systems!

What we should, however, cater for are the more transformative changes ahead of us because they may both raise major opportunities but also major threats to prevailing R&I organisations. While we may not know precisely what these changes will look like, they are likely to require substantial adjustments at the level of individuals (i.e. in terms of their skills and capabilities), organisations (i.e. in terms of openness of and incentives at universities, research organisations and firms) and systems (i.e. in terms of institutional structures and conditions), and transformative scenarios may

help get a better idea of the changes that may come about. As changes in R&I need to be addressed collectively, matters of cooperation and conflict between different entities may come into play, pointing to a need for governance settings to enable handling them.

Lesson 3: Explore and cater for potentially transformative changes in R&I systems in order to be prepared to respond!

These lessons also point to a need for re-positioning R&I policy. In line with the arguments espoused by Edler and Nowotny (2015, in this volume), we argue that it is necessary to rethink the possibilities but in particular also the limitations of R&I policy when it comes to shaping the future of R&I.

Given the uncertainty and complexity of future developments in R&I, R&I policy should not be over-burdened with expectations that it cannot deliver. The future developments and tensions outlined in this chapter point to a challenging agenda for horizontal R&I policy already. Enhancing the adaptability to, and at the same time the ability to shape, new emerging patterns of R&I will require reconsidering a range of institutional frameworks for public and private R&I.

Preparing the research and innovation systems for these upcoming developments is a precondition for addressing more specific thematic and technological agendas, tied to the ambition to tackle major societal challenges. In this regard, horizontal R&I policy can provide only certain impulses from the supply side, where better coordination with sectoral or thematic policies is needed to handle the corresponding levers of innovation and diffusion on the demand side. Ensuring the coherence between R&I policy and sectoral policies is a major requirement for policy coordination and priority-setting, aiming to take into account both scientific opportunities and societal challenges.

Lesson 4: Don't be over-ambitious with regard to what R&I policy can deliver. Better coordination with sectoral policies is key to trigger transformative change on both the supply and demand sides of innovation.

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