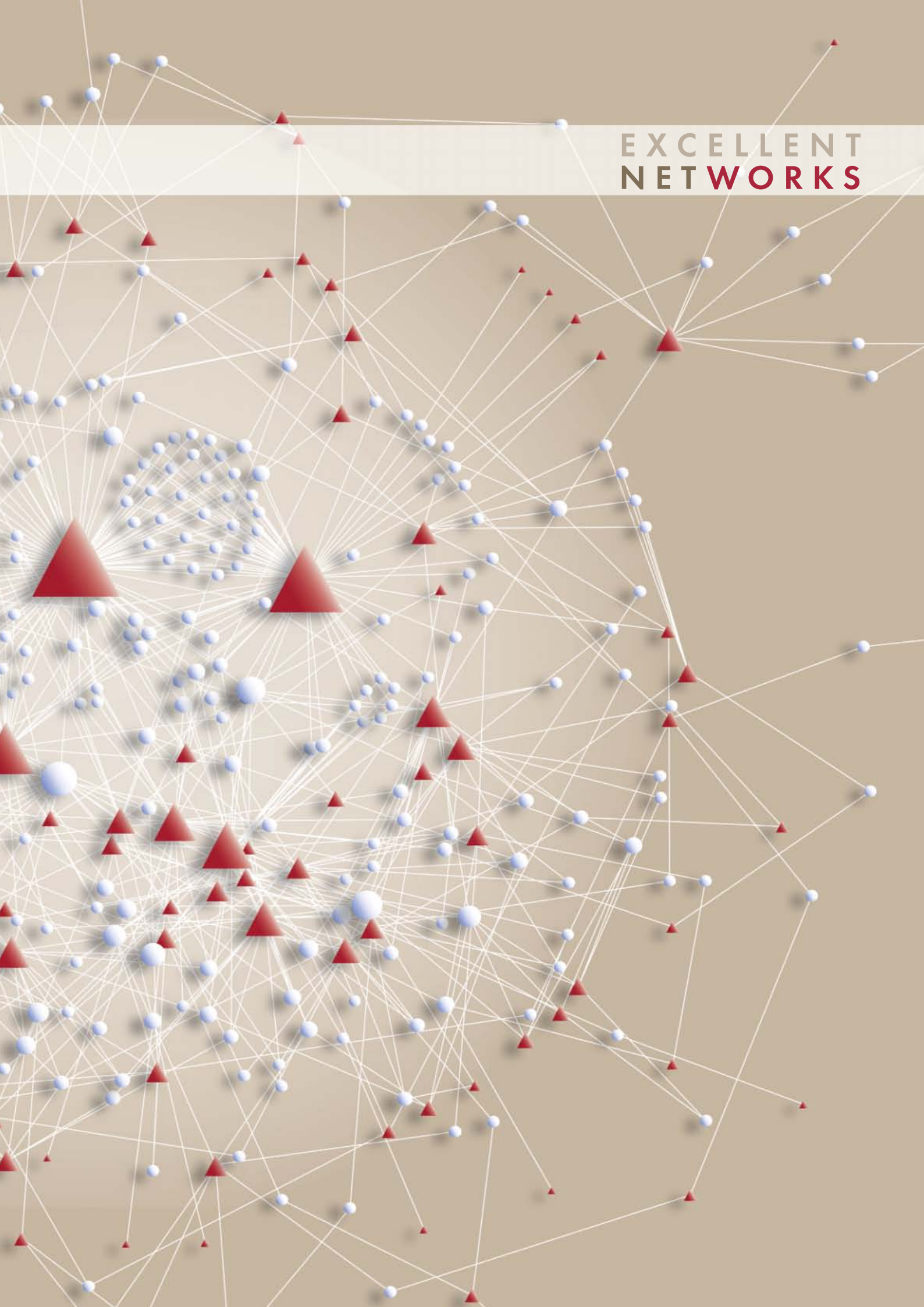
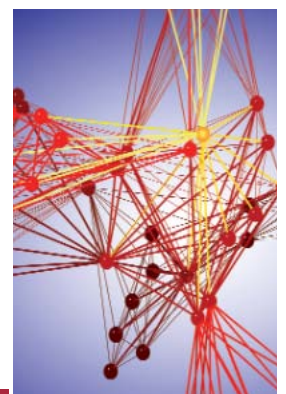
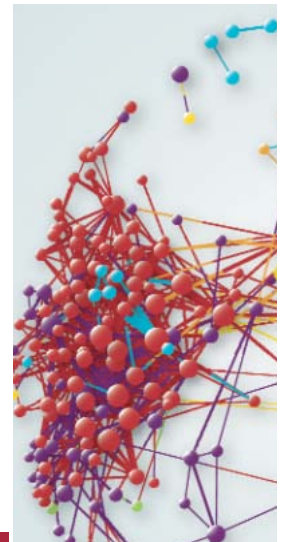


EXCELLENT NETWORKS



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Preface



**Dipl.-Ing. Dr.
Knut Consemüller**

The Austrian Council for Research and Technology Development is at the beginning of its second consultation period. Under the terms of the federal law for promotion of research and for development of technology, the Austrian Council acts as a strategic consulting body of the Austrian Federal Government in all issues related to research, technology and innovation (RTI). In close dialogue with the leading players in FTI-politics it develops recommendations for the mid- and long-term orientation of this field and issues statements on decisions regarding the investment of public funds.

At present the "Strategy 2010" which the Council published in the summer of 2005, is the subject of intensive debate. On the one hand, the Council wishes to make the Austrian system of innovation more efficient by optimizing the funding system, and on the other hand, the Council seeks to facilitate more quality in general research as well as more excellence at the top. The AIST (Austrian Institute for Science and Technology) can be seen as the first initiative of the federal government in this development.

To reach these goals new strategies and methods have to be assessed and applied. Here the Council is recommending decision makers and experts from business, science and administration to support new initiatives that make the Austrian RTI landscape and its profile of strengths more visible. What does the RTI landscape look like, what are its strengths, weaknesses and particular niches, and how can we optimize its utilization of resources? What are the criteria for measuring excellence? How can we learn from the strategies of other European countries? – We directed these questions at the study authors and experts. We would like to continue discussing them over the next years. Excellent players need excellent networks to really be able to do successful research but also to trigger off value added processes in industry.

With this brochure we would like to show the potential of network analysis and complexity theory for RTI analysis and its value for consultation and communication with the public. At the same time we would like to offer an impulse in the debate on excellence. ■

A handwritten signature in blue ink, reading "K. Consemüller".

**Dipl.-Ing. Dr. Knut Consemüller
Chairman of the Austrian Council**

“Excellence is Something you Recognize When you Encounter it”

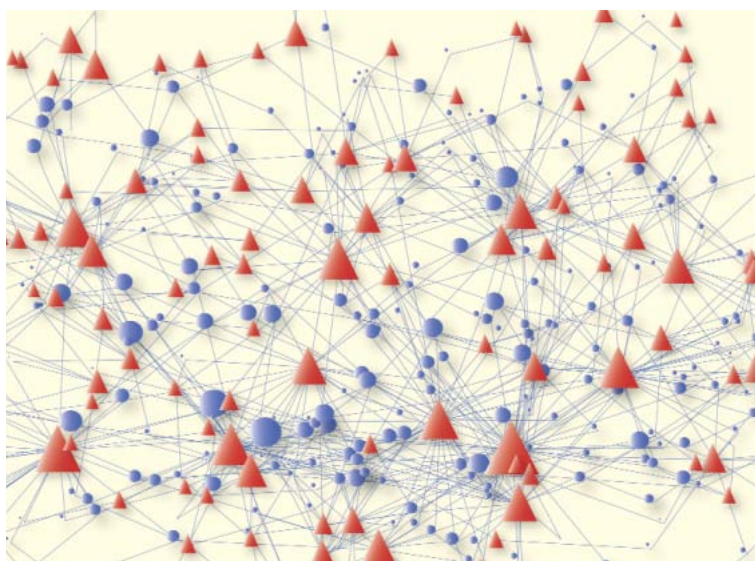
Discussion on Austria’s catching-up strategy, elites and some examples of excellence.

Has the discussion on excellence in connection with research policy taken an interesting turn in recent years?

Consemüller: Up until now Austria has pursued a catching-up strategy. We have oriented ourselves after the successful concepts of other countries. Austria has now moved very rapidly from the political debate to the implementation. In my view it was good to begin so quickly with the implementation.

Nowotny: There has been a seemingly contradictory development in the debate on excellence. On the one hand, the number of institutions, individuals, projects and research findings labelled “excellent” has shown an exponential growth. On the other hand, there is something behind this turn that has actually taken place, namely the aspiration for higher quality. This can also be detected in the fact that is largely accepted today that research achievements and institutions are compared and measured. Even in Austria people know that we have to let ourselves be compared with others in Europe and all over the world and are also measured in terms of this.

Pohoryles-Drexel: In Austria the great importance played by RTI in the total economy has only been broadly discussed in recent years. Accordingly, the public funding for RTI was also increased. In the discussion on how research funding can be best used – but also in the global competition for the best minds – the theme of “excellence” in research and development policy has become dominant and quickly part of the mainstream. It is essential to formulate the notion of “excellence” in a more concrete way and to examine it especially from the perspective of business and for Austria as a business site.



Interconnectedness of Austrian research institutions (institutes, boards, juries, faculties) through their members.
Analysis & visualization: © FAS.research 2003



Univ.-Prof. Dr. Helga Nowotny,
Chair of EURAB
 European Research Advisory
 Board of the European Union,
Nominated member of ERC
 European Research Council,
**Emeritus Professor of Social
 Studies of Science at ETH
 Zurich**

Is the debate on “excellence” or “elites” assessed differently here in Austria than in other countries?

Consemüller: The debate on excellence is very similar internationally. In Austria, too, the goal is to create several top research institutes and technology leaders – whether this is a cluster, network, or as an individual institute is irrelevant from my perspective. It seems more important to me to guarantee an opportunity for excellence in all sectors of realization and this in both the university and the co-operative sector as in industrial research.

Nowotny: In Austria, but also to a certain extent in Germany it was for a long time taboo to talk about elites. This has to do with the fact that it was not until the end of the 1960s and the early 1970s that the university system was opened to groups of the population that did not have access to higher education before that. Until then there was an unearned privilege to education which was seen as being “elitist”. This – in comparison to other European countries – relatively late opening of the universities resulted in equal opportunities becoming an ideal of education. These equal opportunities, which are to be fully affirmed in the political context of democracy, were, however, often confused with a demand for democracy which cannot be fulfilled in science. Science does not function according to democratic rules since its system of incentive and reward is completely geared to achievements.

What are the prerequisites for excellent research?

Consemüller: In addition to the necessary means you also need adequate infrastructure, top researchers as well as a culture that is open for research. The researchers should feel good in every sense and be able to find adequate career opportunities. International recognition is also crucial.

Nowotny: Those factors that are a part of research culture are at least just as important as infrastructure, and material and equipment. This includes a certain

“density” of individuals and ideas that stimulate each other and succeed in breaking out of the “mainstream” and following unconventional paths. It is also important to grant young scientists autonomy as early as possible and to give them a chance to prove themselves. In short: conditions that characterize the best universities and research institutes in the United States – and which we must create here in Austria as well.

What is in your opinion an excellent research institution?

Consemüller: The Max Planck Institute, for instance, is excellent. In Austria, existing top university institutes, institutes of the Academy of Science, co-operative labs and centers should have the chance to be able to reach international top positions faster.

Nowotny: The example I’m most familiar with is the ETH in Zurich. In addition to a basic solid financial foundation, this institution has structures that make it lead over other institutions. Two examples on this: First, the procedure for recruiting. The achievements of the ETH and its reputation depend largely on the quality of the professors that are appointed. Thus great care is taken in carrying out this procedure. The president of ETH spends half his time seeking out the best. The second example is the space given to promoting the young generation of scientists.

Which options existed and still exist for assessing excellence?

Consemüller: In addition to peer reviews we have had recourse to citation and publication analyses, international benchmarks as well as impact analyses and patent analyses.

Pohoryles-Drexel: I think that beside these traditional, well-established procedures there should also be other ones. From diverse studies we know, for instance, that peer reviews are more structure-conserving – both in terms of the assessment of new research issues and in terms of new research groups. With the impulse initiative “Laura Bassi – centres of

expertise" we wanted to blaze new trails. The selection jury includes individuals who have broad access to research themes and methods. What is extraordinary about the selection criteria is also the assessment of excellence in leading researchers and their teams. They are not only assessed on the basis of their past. The future potential one sees in the researcher and her team will also be important. A further important point in connection with the assessment of excellence is that today many assessment procedures focus on individual actors. The capability of networks and systems is just as important as the capability of individual actors.

Are the present methods of measuring excellence satisfactory?

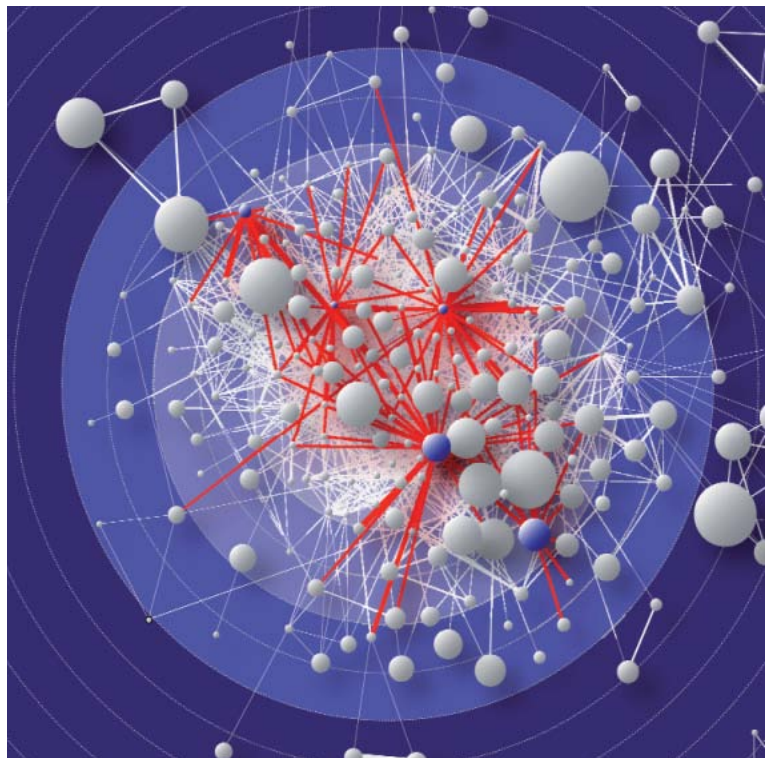
Nowotny: I don't believe that you can define excellence abstractly and without a context. It is still crucial that one is able to recognize excellence when one encounters it. This requires a certain competence on the part of those who have to assess it. Genuine excellence must be more than the best "mainstream". Thus it is also always a bit of a risk. Yet if we rely too much on parameters we are no longer willing to accept this additional risk. In addition, excellence manifests itself differently in various areas of science, but fortunately there are international comparisons.

What should a strategy for promoting excellent research look like?

Pohoryles-Drexel: In the future the impact on the network level and on the level of the entire system should be taken more into account. Furthermore, the promotion of human resources, the internationalization as well as the secure availability of public funds and funding from businesses are essential parts of a strategy for promoting excellent research.

Can excellence actually be stimulated?

Consemüller: Yes, by improving the conditions for >



The most important Austrian enterprises. The size of the circles shows the number of employees in the company. The lines represent connecting managers between these enterprises. The thicker a line, the more common managers these enterprises have. Blue circles represent Key Player enterprises. Key players are those five companies from which information spreads most efficient through the whole network.

Analysis & visualization: © FAS.research 2003



**Mag. Sabine
Pohoryles-Drexel,**
*Federal Ministry of
Economics and Labour,
Department for Research
and Technology*

top research in every sense. And, above all, one must have the courage to break with the principle of giving everybody an equal share.

Nowotny: The strategy for promoting excellent research has a name: selection, selection, selection. This is easier said than done, because in each step of the selection procedure the “right” criteria have to be applied. Yet what is “correct” can only be seen later, when you have the final result or the winner. We have very little founded knowledge or scientific studies on these processes – a deficit that should be tackled.

How do you see the planned „Austrian Institute of Advanced Science and Technology” (AIST), the new excellence university in Austria?

Consemüller: I welcome the founding of the AIST and also welcome the initiative of the science ministry. However, the “new” university must be able to compete with existing institutions of excellence. Moreover, excellent research groups must also have the chance to work together with AIST. While new paradigms are evolving, research is generally very diverse and highly productive.

Pohoryles-Drexel: It can be expected, and is also very likely, that AIST will bring forth excellent research. If it succeeds in drawing excellent research teams to Vienna, they will also produce the expected research with the proper resources.

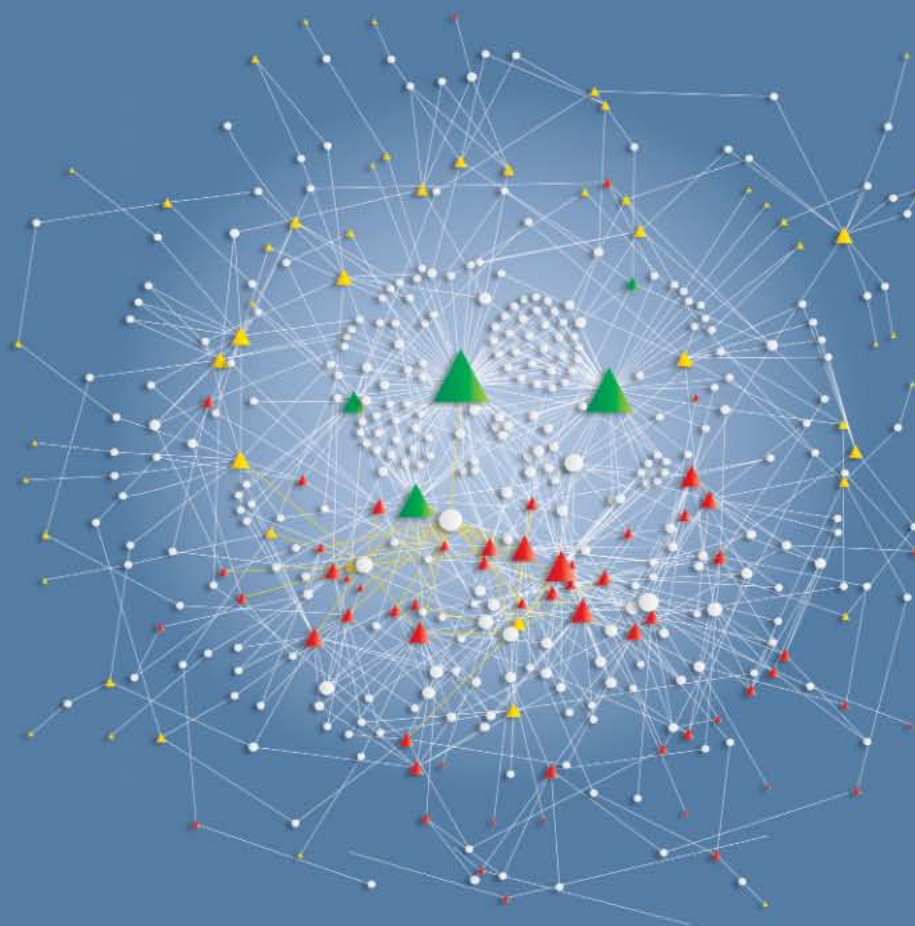
Are there comparable countries that could serve Austria as an example – or does Austria have to find its very own “incomparable” path?

Pohoryles-Drexel: In Austria some new initiatives are being developed and implemented at the moment: AIST, the new version of competence center programs, or Laura Bassi with fFORTE. It makes sense to not have a direct “role model”. It is better to identify different approaches and mechanisms from other countries, to adapt them to the given

Austrian system of science and to develop them further. This needs to be accompanied by proper monitoring systems and system evaluation.

Consemüller: I think that some good elements in connection with this theme have been developed in Switzerland and the USA. We are studying these developments very closely. But, of course, in the final analysis we are interested in finding the best solution for Austria.

Nowotny: It is interesting that in spite of the existing differences the comparable countries such as Israel, the northern countries and Switzerland are all small countries whose research performance is above average. We should try to play in this league. ■



Search of Excellence

About: FAS.research and COSY

Search of Excellence

The connection between research politics and social network analysis.



DI Dr. Ludovit Garzik,
*Managing Director of
the Austrian Council*

Developments in the realm of research, technology and innovation (RTI) are very favourable. In recent years, Austria has caught up considerably in the RTI performance. The rate of research in Austria has risen in the past five years from 1.9 to 2.35 percent and now lies clearly above the EU average. Important structural reforms have been carried out. Thanks to these developments Austria has the prospect of joining the top European performers in research, technology and innovation. To make use of this potential all actors must fully commit themselves in the innovation system to continue increasing their involvement and to invest in research and development. A strategic line of RTI policy can be characterized by the following three principles:

- Pursuing an Austrian strategy of excellence: promoting the scope of quality and excellence at the top.
- Putting the main focus on promoting the co-operative sector, thereby reinforcing the networking and cooperation between science and industry.
- Increasing efficiency and effectiveness of the support system.

Visualization of RTI landscapes

In the coming years we will produce further information on the Austrian, but also European research and innovation system in its international contexts. We need visualizations which enable political decision makers, boards, experts, communicators and also the interested public to call up information on Austrian research in a new way, for instance, in the form of visualizations of infor-

mation and intelligent charts. With this project we want to test scientifically founded methods of visualizing information. These methods should help us to effectively check the flood of information that we are confronted with every day.

How does excellence "work"?

Up until now we have mainly used indicators as orientation in assessing science. These indicators hardly take note of the social infrastructure of top research. As a result, (excellent) research has been seen as the achievement of individuals or groups of persons. However, with the creation of co-operative research institutions in which university institutes, large and small businesses, educational and testing institutions, individual experts and non-university research institutes are involved, it has become clear that we need additional information to help us assess the quality of these research structures.

In most fields of research, institutions are largely networked, receiving funding from various donors and various programs. It is of course interesting for decision makers from the area of RTI policy, for instance, to observe the effect of funding on the co-operation between various research institutions. Joint projects offer an opportunity to make the best use of financial resources.

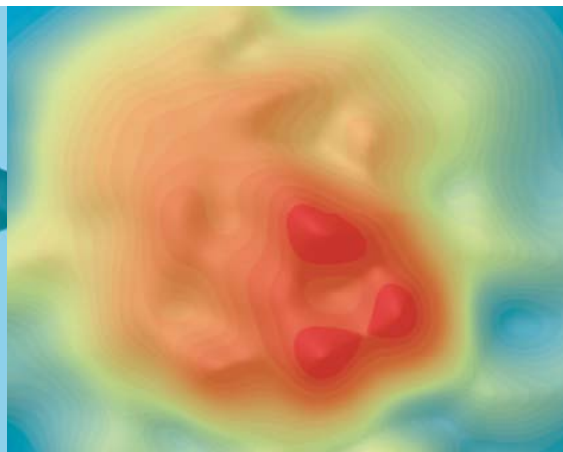
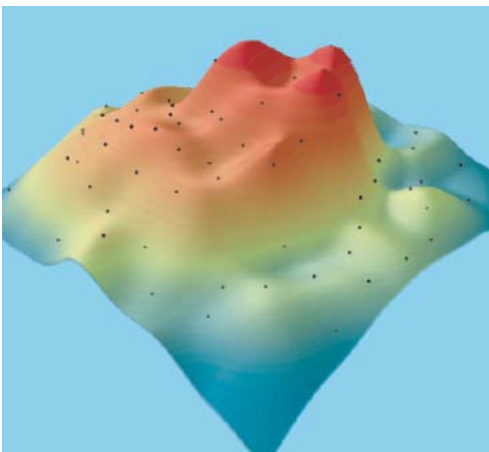
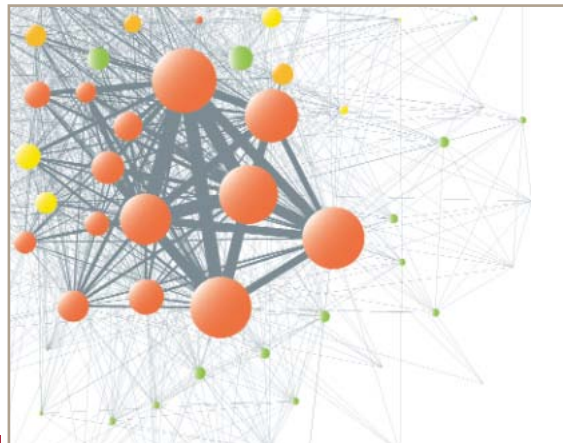
Network analysis is an excellent means for monitoring resource exploitation and the culture of cooperation in research. Further interesting questions for the council include: Is the centrality in RTI networks essentially advantageous and which Austrian actors have the greatest centrality

internationally? Which strategic options do the actors in various positions have – and how can they “experiment” with their possibilities for action by means of the simulation methods of network analysis? In this regard the council is intensively discussing evaluation and quality assurance. The council expects input from the areas of network

analysis and complexity theory for measuring and assessing the performance of networked systems. The present evaluation of research networks from the Sixth Framework Program provides valuable examples and impulses for optimizing research policy strategies that can contribute to furthering excellence in Austria. ■

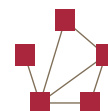
Overview and orientation with social network analysis. Complex structures become visible, comprehensible, and controllable. This picture shows the relations of cooperating actors. The thickness of lines indicates the intensity of co-operations, the size of the circles depends on the activity of the actors within the network (degree centrality).

Analysis & visualization: © FAS.research 2004



Geographic information modeling translates classical network visualizations into three-dimensional landscapes whereby decisive intensities become more tangible.

Analysis & visualization:
© FAS.research 2004



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FAS.research Ltd. (founded in 1997) is a social science-oriented company for applied structural analysis based in Vienna. The main focus of this internationally active research and consulting firm is social network analysis and complexity theory along with all of its broad applications in technology and innovation policy as well as market research, marketing, advertising and PR, key account management and sales, organizational development and risk management.

The managing director and scientific head of FAS.research is the social scientist and philosopher Dr. Harald Katzmaier. He works together with a team of eight. As an active member of the scientific community, FAS.research strives to close the gap between basic research and the business and market-oriented application of network analysis and complexity theory.

FAS.research draws its clients from a diversity of different sectors including telecommunications, pharmaceutical industry, software industry, automobile industry, advertisement and PR, consulting and organizational development, NPOs and NGOs. In the field of research and technology, FAS.research has been commissioned by the Austrian Council, the Federal Ministry of Economics and Labor as well as by the Federal Ministry of Transport and Technology to analyze a number of networks in the area of cooperative research between science and industry, clusters and organizations, as well as national and international scientific networks.

In November 2005, FAS.research opened a second office in San Francisco, USA on the edge of Silicon Valley.

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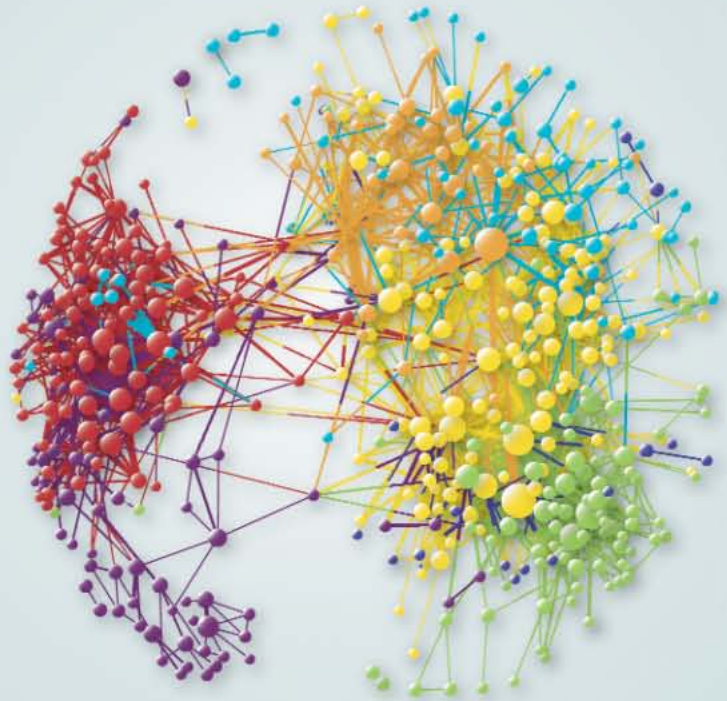
wien.ac.at



"COSY", based at the Medical University of Vienna, is a work group offering scientists and doctors a platform for exchanging ideas on issues related to the "science of the complex". The group has a team of ten and is directed by Univ.-Prof. DDr. Stefan Thurner. Research is conducted on a project-oriented, quantitative and transdisciplinary basis and is strongly networked internationally. In its orientation, this research initiative is modelled after top institutions such as the Santa Fe Institute and the Collegium Budapest.

Most projects are based on a "systemic" approach, i.e., the collective functioning of a system is reduced to the characteristics of individual components. A number of the projects aim

at applicability, e.g., design of intelligent medication in the field of genomics, strategies for regulating developments in the financial sector, optimizing medical imaging techniques (fMRI, MEG, EEG) and therapies. At present patents for two inventions by COSY collaborators have been submitted by the Medical University. In pure basic research COSY is closely linked to the international network of top scientists and devotes its efforts to analyzing the theoretical foundations of network research, econo-physics, statistical mechanics and evolutionary theory. COSY-team members have been sought out for consultancy services in risk management and economic issues.



Networks: The Social Infrastructure of Innovation

What Ants, Brains, Stock Markets and
Innovation Management Have in Common

When Images Speak to the Viewer

Measurement – a Close-up Look at Social Relations

Studying Complex Systems

Networks: The Social Infrastructure of Innovation

The analysis of social networks in the area of technology and innovation policy.

By Harald Katzmaier



Harald Katzmaier, Ph.D.,
FAS.research
Vienna / San Francisco

Networks are the social infrastructure of success. Irrespective of whether the successful actors are individuals, teams, companies, organizations or institutions, networks are nothing more than the channels by way of which actors gain access – formally or informally – to capital, knowledge, information or social relationships. Thus networks form a basis for innovation, added value and ultimately also for the research- and innovation-political position of an individual player. Those who are better connected have more success, are more innovative in a lasting way and can adapt much quicker to new conditions. The critical issue is: “What does it mean to be better connected?” and “What distinguishes good from not so good networks?”. The scientific discipline that is presently best able to analyze networks in both a comprehensive and differentiated way is social network analysis,

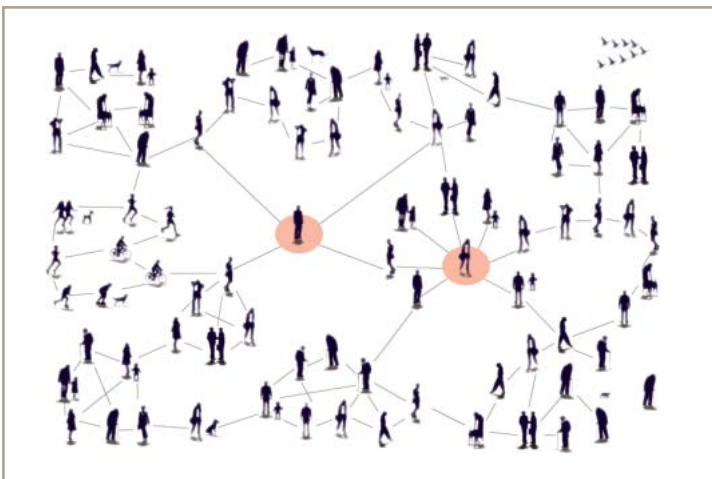
known as SNA. With its methods the individual “participants” of a network are described and the way these participants relate to each other is studied. In recent years the number of people using social network analysis for strategic planning in the various branches and institutions has risen dramatically. Not only the growing computing power of computers is responsible for this development, but the further development and dissemination of SNA has been driven to a large extent by inputs from complexity theory as well as new techniques of visualization and simulation. Researchers who have a growing stake making SNA a main instrument for entrepreneurs, politicians and strategists build a highly diverse network themselves. They come from physics, sociology, chemistry, biology, chaos theory and computer studies.

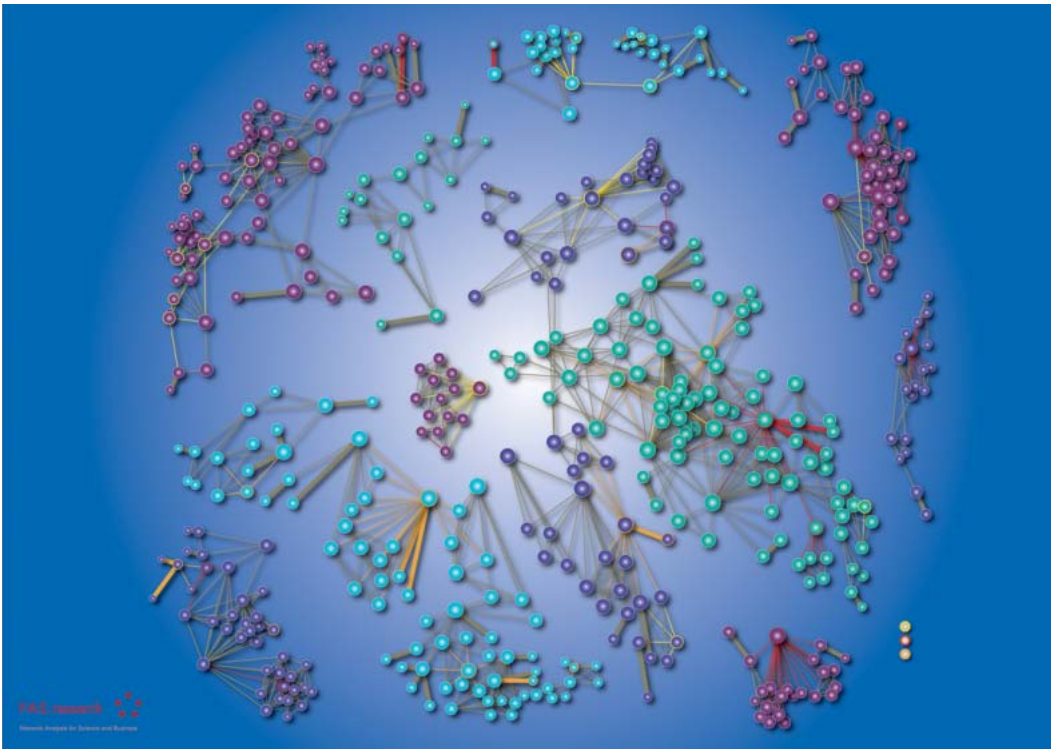
An instrument for analyzing relations

The methods of SNA can be employed to document, visualize and assess the diverse universe of social, economic and political relationships. Knowing how a network is structured and what connections keep together the actors can enable one to also control the network of relationships. Social network analysis shows who is an opinion leader, who controls the availability of information, who gains new customers, how flexibly the network reacts in emergency situations, how a cartel is consolidated or who brings new ideas into the system. Social network analysis also allows one to study the effectiveness of measures in politics, internet structures, food chains in ecology, interactions of genetic products or relationships in world trade. SNA reveals the infrastructure of winners, followers and losers.

Networks consist of actors (e.g. individuals, organizations, enterprises, teams) and a predefined relation (e.g. friendship, shareholding, membership) which connects the actors.

Graphic: © FAS.research 2004





Network analysts study a wide range of relational aspects of a system:

Co-operation-based ties

- Who does research together with whom?
- Who publishes together with whom?
- Who cites whom?

Formal ties

- Who is accountable to whom?
- Who is a shareholder in what research enterprise?
- To whom do which patent rights belong?

Communication-based ties

- Who gets advice and tips from whom?
- Who talks to whom in a research operation?
- Who is connected to whom via virtual communication infrastructure?

Co-publishing analysis. The analysis of a scientific publication data base shows the network of authors (circles) who frequently publish scientific findings together. This allows the identification of Key Opinion Leaders or Key Decision Makers between and within scientific fields. It also produces clusters of authors with oppositional traits. Analysis & visualization: © FAS.research 2005

Business ties

- Who is the sponsor of what scientific conference?
- Who is the client of what research operation?
- Who supplies what research operation?

Affiliations, memberships

- Who is a member of a board, a jury?
- Who is an expert advisor or publisher of which journal?
- Who lives, works and researches where? >

TRADITION OF NETWORK ANALYSIS

The roots of modern network analysis reach back to mathematics in the last third of the 19th century. The modern theory of numbers, relational logic, Boolean algebra and group theory which all emerged at the time were the starting point for the formulation of

graph theory – the central point of reference for SNA today. At the beginning of the 20th century the Viennese scientists Jacob Levy Moreno, Fritz Heider and Paul Lazarsfeld figured significantly in the development of the network-analytic method.

INSTITUTIONS AND COMPANIES

that do strategic planning by means of SNA

- Amazon
- IBM
- HP
- Google
- Pfizer
- Allianz Insurance
- German Research Foundation



Shareholder Network of Austrian Companies

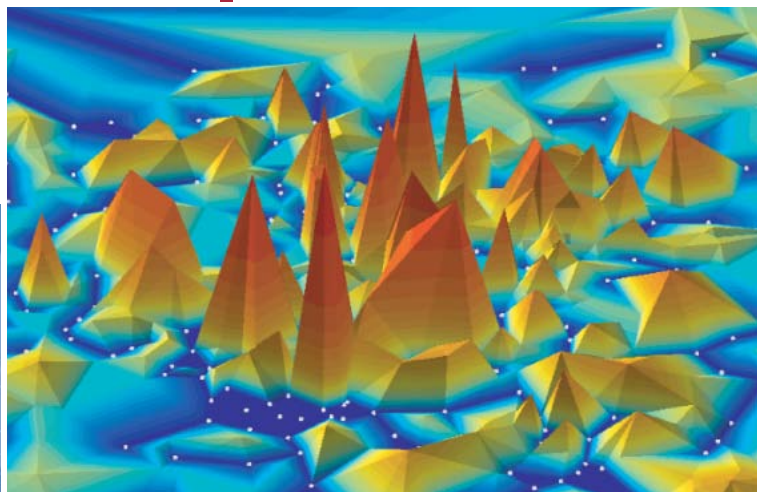
The visualization is based on the shareholder network of Austrian companies. It displays capital sources and capital sinks. The visualization by means of GIS (Geographical Information Systems) transforms network measures into geographical measures. The result is an impressive "landscape": "Mountains" depict enterprises, which are positioned at the origin of a shareholder chain, "valleys" symbolize "capital sinks".

Source: Commercial Register, Austria
Population: 2.150 most important Austrian companies
Sample: Main component of the shareholder network (844 Companies)
Analysis & visualization: © FAS.research 2004



The scientific field of Austria. The network shows the relationship of classification codes assigned by the submitter of a proposal to 5.217 projects funded by the Austrian Science Fund (FWF) from 1994 to 2004.
Number of Projects: 5.217 (1994–2004)

Source: FWF Austrian Science Fund
Analysis & visualization: © FAS.research 2005



Excellent research requires excellent networks

How do research networks look when they are capable of producing innovations on a permanent basis? What laws and regularities are they subject to? What is the pattern by which they can be recognized? For decision makers in research, innovation and technology policy the measurement, assessment and simulation of “good” and “bad” networks is interesting. It is also interesting to note the conditions in which networks flourish or atrophy. Research culture is strongly dependent on the number and quality of relations maintained by re-

search institutions. Knowledge only emerges in exchange with other actors and institutions. Well-networked research institutions have quicker access to important information. They have better chances of obtaining funding and implementing innovations. Through co-operation with members of “other” disciplines scholars get information that is not tied to the methods and thinking traditions of their own research culture and plays a crucial role in dealing with unsolved problems.

Social network analysis in research and technology innovation policy has already proven to be extremely useful in various fields of application:

Analysis, support for strategic decisions	
1) Field analysis	In which contexts and structures is an actor, a field of technology or a scientific discipline embedded?
2) Identification of strategic actors	Which actors, technology fields or scientific disciplines are the most central, influential and “most conspicuous”?
3) Partner search and logging into networks	Which structural characteristics do (potential) partners have?
Evaluation, controlling, monitoring	
4) Dynamic network analysis	How do networks change over the course of time?
5) Innovation potential measurement	Which network structures have more potential than others? How must excellent structures capable of lasting innovation look like?
6) Market and competition analysis in technology policy fields	What classes or groups of actors have similar structural qualities?

Innovation is the product of new “links”

SNA reveals what promotes creativity and which design innovation networks (should) have. Innovation is the result of the transformation and recombination of already existing elements (e.g., technologies, behavioural modes, codes). Actors who bring together unrelated elements and build a bridge are the driving forces of innovation. These driving forces are often located on the periphery of networks and profit from certain prerequisites and structural conditions. For political decision makers SNA is a valuable tool for analyzing and supporting strategic decisions. By changing the “connectivity” of innovation systems it is possible to dramatically increase the innovation potential of a region, a sector or an area of technology. Someone who is able to create new links between to date unrelated areas and thus make

the network landscape more diverse but also more robust is clearly ahead of the game. ■

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What Ants, Brains, Stock Markets and Innovation Management Have in Common

On the study of complex systems. *By Stefan Thurner*



Prof. Stefan Thurner, Ph.D.,
Complex Systems Research
Group; HNO, Medical
University of Vienna

In nature there essentially exist three types of systems. For one there are the precisely predictable regular systems (like most systems in physics, e.g. gravity). Then there are the probabilistic systems driven by chance (e.g. decay of atoms, roulette, weather). The third type of systems is literally in the middle. They are neither predictable nor entirely chaotic. Among those one finds the complex systems. The tools of classical science, as perfectly as they might describe regular or probabilistic systems, are often completely inadequate for explaining complex systems (such as for example research networks) in a satisfactory way. Yet precisely the understanding of these systems is important, since many of them are biologically or socially relevant (KAUFFMAN, 1993). One might think of early recognition of earthquakes, the spread of epidemics, consequences of regulating the financial market, or optimizing strategic management in large companies. A fundamental understanding of complex systems also forms the basis to answer the question: How is it possible to optimally control innovation?

More than the sum of its parts

The concept of “emergence” is essential for complex systems. Broadly speaking, emergence is the reverse process of reductionism which was enormously successful over the past three hundred years and still continues to be so. Reductionism explains systems as the “sum” of their individual components. Among the milestones of reductionism (which dominate our present view of the world) we understand matter through molecules, molecules through atoms, atoms through elementary particles and elementary particles through quarks.

One ant behaves chaotic – 10,000 constitute a state

Emergence takes something like the opposite path of reductionism. One proceeds from the familiar char-

acteristics of building blocks and asks what characteristics systems have when they are constructed from these building blocks. The interplay and reciprocal influence of building blocks often allows for characteristics of the total system that are not immediately obvious and certainly more than the sum of the elements. As an example take a living cell built from familiar proteins. It can never be understood on the basis of these proteins. However, it can be understood with the knowledge of the interrelations of proteins, that is, their huge and even today still unfathomable “network of relationships”. The characteristics of these complex systems are often not based on the detailed characteristics of the building blocks but to a large – often huge – extent on the network of relationships. The behaviour of ants is a popular example for describing a typical complex system. A single ant moves about in a chaotic way. Even two ants move in a random manner. Ten ants begin to march in a row. 10,000 genetically identical ants create a state. In addition to the “sum of ants” the individual components (10,000 individual identical ants) influence each other in such a way that they constitute a new system characteristic, the ant state. From here it is only a small step to understand that these systems contain social relevance, just think of collective behaviour of societies, markets, firms and almost all forms of socio-economical life.

Mathematical rules have to describe the system

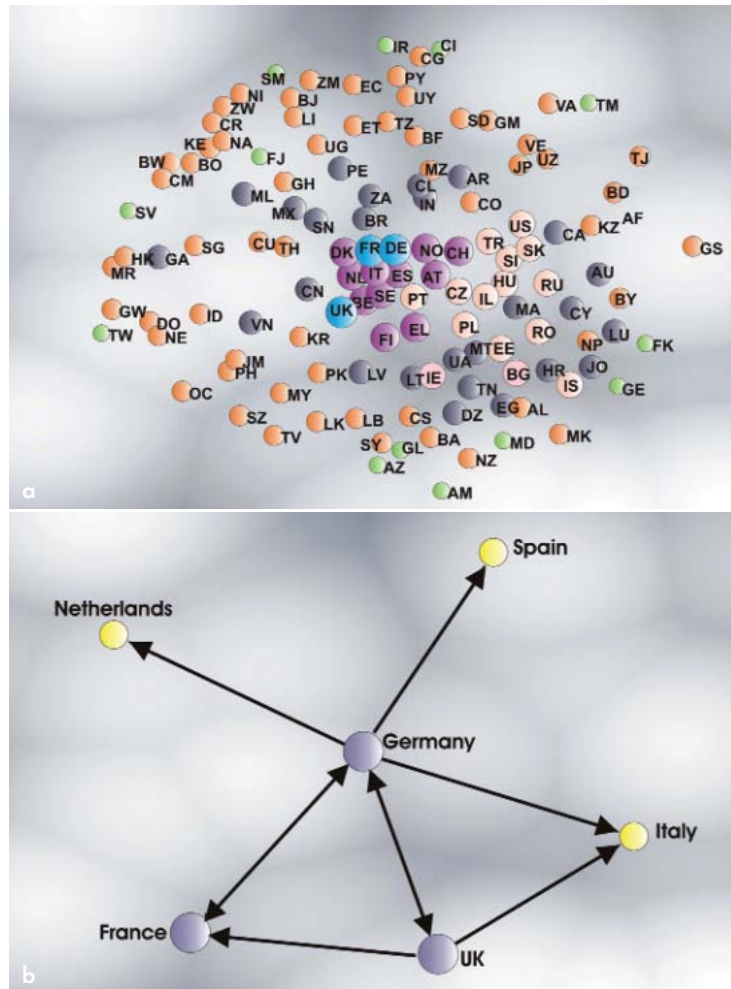
The theory of complex systems has the goal of embedding insights regarding these systems into modern occidental knowledge. That is to say, system descriptions must ultimately exist in the form of natural laws and mathematical rules which can be verified at any time. This is a challenge experienced by many experts working in “complex systems research” which represents a new and creative, but above all, a promising approach to a large variety of systemic and scientific

disciplines. A large variety of mathematical methods are used to translate system characteristics into many languages, amongst them being differential equations, game theory, network theory, information theory, non-linear systems or chaos theory as well as genetic and evolutionary algorithms. Even though the complex systems are often “actually” too complicated to completely understand within the exact sciences, small successes in their understanding are big steps forward. The increase in knowledge per invested working hour is much larger than in the “mature” sciences.

Quantitative knowledge about innovation processes sets new standards to strategic management

Economic systems or processes of information-processing often resemble evolutionary processes. Individuals within an existing system have ideas: They invent or discover something new, e.g. a product, a material, a production process, or a distribution channel. This corresponds to a biological mutation which introduces a genetically novel organism. The more ideas are produced, the more likely it is that one will be “useful” and “prevail”. It is now the surrounding “value system” (e.g. stock market, entrepreneurial culture, educational system, scientific culture) which is decisive for whether and which ideas become accepted or which die out. This can be linked to the process of selection in biology. Only the fittest survive. However, one should not forget that upon the existence of a new idea the environment itself changes and reconfigures itself, setting a new stage for existing and yet to come ideas.

If it is possible to describe the concept of innovation in quantitative terms it will also be possible to control and manipulate this process in a very efficient way. Thus it is important to find and analyze the most important foundations of innovation. One of these foundations is network theory which seeks to focus on the most relevant relationships between components in quanti-



(a) Autocatalytic view on the interconnectedness of the 6th Framework Programme. The nodes in the centre have a strong dynamic influence. (b) Represents the autocatalytic core which is the “driving force” of the whole network.

Analysis & visualization: © COSY, HNO, Medical University of Vienna
Data: European Commission. Source: PROVISO, a project by BMBWK, BMVIT, BMLFUW and BMWA [www.bmbwk.gv.at/proviso]

tative terms. By means of targeted manipulation of the network structure it is possible to optimize the output of a system that is capable of innovation.

Critical mass as a prerequisite of progress

Flashes of genius, the generation of new ideas or creativity itself cannot be significantly controlled – at least according to our present knowledge. They are governed by chance. The relationships between network relevant individuals (e.g. “folks with ideas”) in contrast, are much easier to “control”. If there is a relation of one idea influencing or stimulating others it is thus possible to control the “rate” of ideas by network topology. Innovation is more than a set of new >

AUTOCATALYTIC CYCLES

The notion of autocatalytic cycles, which stems from biology, has recently been applied to economic systems. The best-known example is the coal-iron-machine cycle. The more coal is mined the more iron is won. The more iron, the more machines constructed, part of which are used to mine more coal and iron. This cycle is one of the driving forces of western economies. Successful businesses generally have several autocatalytic cycles. Finding and optimizing these cycles requires high standards on data quality, management and consulting agencies. The individual formula for closing an autocatalytic cycle is certainly – not cheap.

a) Example for an Autocatalytic Cycle (ACC) within a network in which every node (company) provides output which is the input for another node. Red nodes indicate the ACC. The cycle enables the “productivity” of all other nodes (yellow). Removing the ACC would lead to the collapse of the network (b).
Analysis & visualization: © COSY, HNO, Medical University of Vienna

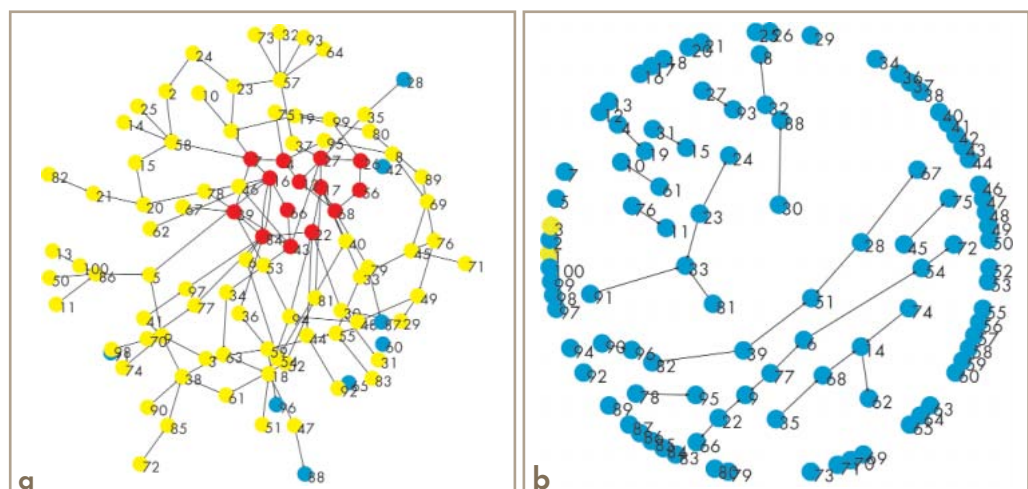
ideas, it is the production of something new, which is able to withstand the pressure of selection and which is able to influence the environment in a sustained way. Innovation only emerges when there is a critical mass of new ideas in tight combination with the possibility of creating further ideas from the interplay of ideas within a network. Thus the good news: The quota of “innovation” can be controlled by controlling the structure of networks, keeping in mind the necessity of a critical amount of ideas. It is important for the “innovation manager” to know that networks themselves (generally) cannot be rigidly imposed and controlled. However, it is possible to implement rules in which adaptive, robust and optimally productive networks will actually emerge.

Systems with innovative potential are adaptive, robust and efficient

Forms of life capable of successfully surviving the evolutionary selection pressure are generally adaptive, robust and efficient (KAUFFMAN, 1993). Social systems and processes with these characteristics have a “selection advantage” (e.g. market economy vs. a communist system). When new forms (e.g. new products, new research methods, new cultures and fashions) keep appearing, the conditions for the existing system can become “undermined”. The existence of something new allows for a feedback which can trig-

ger a lasting gradual change of the entire system (mobile phone, iPod). Change only occurs when there are enough possibilities for feedback, that is, when the network is sufficiently structured and dense (HANEL/KAUFFMAN/TURNER, 2005). In such a situation, system theorists often talk about that an “autocatalytic cycle” has been closed (HANEL/KAUFFMAN/TURNER, 2005; JAIN/KRISHNA, 2002). If one wants to create a favourable climate for innovations, one way is to “close” such cycles. Successful managers know this, and large international companies have applied this approach strategically for several years. The prerequisite for controlling innovation is a concrete idea of what type of innovation is actually intended, a “vision”. Innovation management assumes the role of selection pressure by virtue of the control over resources. “Good” and “bad” new ideas and cycles emerge spontaneously and everywhere at all times. Without a vision of the direction in which networks, and as a consequence innovation, are supposed to develop to, reflections as those above are useless – even if they are highly “complex”.

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When Images Speak to the Viewer

The visualization of networks.

The interactions of football players, business bosses, proteins in a cell or party babes have already been depicted on network maps. Now it's science's turn. Where is the connection?

Krempel: Network maps can be used to depict innumerable systems, namely those where information exists on how the actors relate. First you have to convert this relationship information – that is, matrices with huge quantities of data – into mathematical graphs. These cumbersome and confusing amounts of data can, however, be assembled to form a straightforward, accessible overall image with recognizable patterns.

Why do images and network maps lend themselves better than other methods to “convey” complex connections?

Krempel: Maps are among the most straightforward means of visualization. They can also convey complex information. I focus deliberately on the ability of our visual sense to process a lot of complex information at the same time. Amateurs are able to recognize a lot at first glance. For this reason a picture is worth more than a thousand words – and a map is probably worth much more. Network maps are indispensable in discovering new worlds or in exploring existing worlds.

Even decision makers such as research politicians are already using network maps to evaluate research programs and to plan strategies. The German Research Foundation (DFG – Deutsche Forschungsgesellschaft) ordered network visualizations from you. Why?

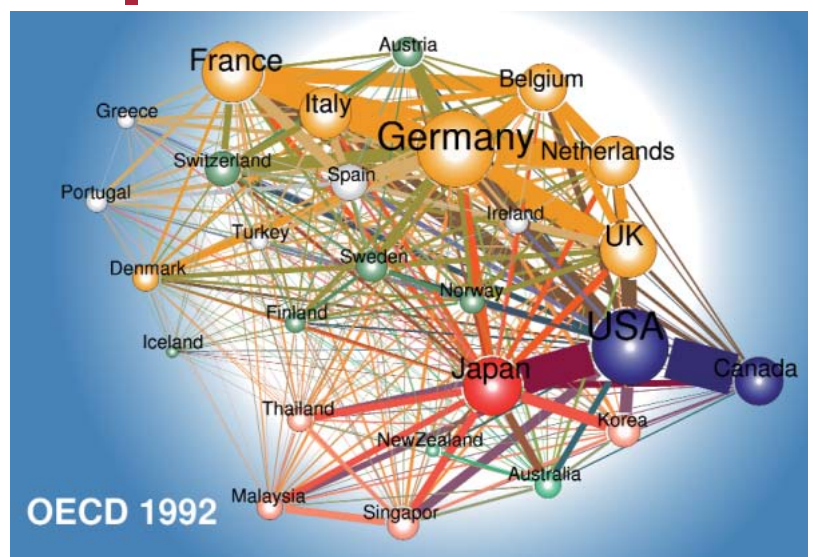
Krempel: The German Research Foundation is supporting some 20 000 research projects at universities and other institutions. This support amounts to 1.3 billion euros per year. The DFG is naturally interested in the impact of this support on the co-operation between institutions. Co-oper-

ations offer a chance to use financial resources in an optimal way. For instance, various work groups can purchase expensive machines together by means of funds. My task is to make the information on these interactions visible. This way one can discuss which synergies are available in research programs and how these synergies can be used. Until recently this was only possible to a limited extent. My network visualizations provide information on how strongly the German research landscape is networked and which universities are the central actors.

There are many ways to study the statistic connections and to depict them graphically. What makes your procedure so special?

Krempel: Purely statistic analyses reveal the global connections but neglect the local level. In network depictions, by contrast, it is possible to verify each single piece of information or to select individual themes – which is very difficult with statisti- ➤

Flows of trade between OECD-member states 1992.
Analysis & visualization: © Lothar Krempel, MPI-Cologne





Lothar Krempel, Ph.D.,
Max Planck-Institute
for the Study of
Societies, Cologne

cal results. Depictions in the form of network maps enable the viewer to also discover local patterns which can only be found with statistic procedures if one looks for them in a very targeted way. And precisely this approach is an advance. Knowledge is first organized locally, when favourable conditions come together. To what extent these can contribute to global innovations is a different question. When research funding and politics want to intervene here they need highly sensitive tools to be able to discover innovation potential – in both the humanities and natural sciences.

Your maps also enable the measuring of scientific output. This, too, is interesting for decision makers in research. Were the methods used to date insufficient?

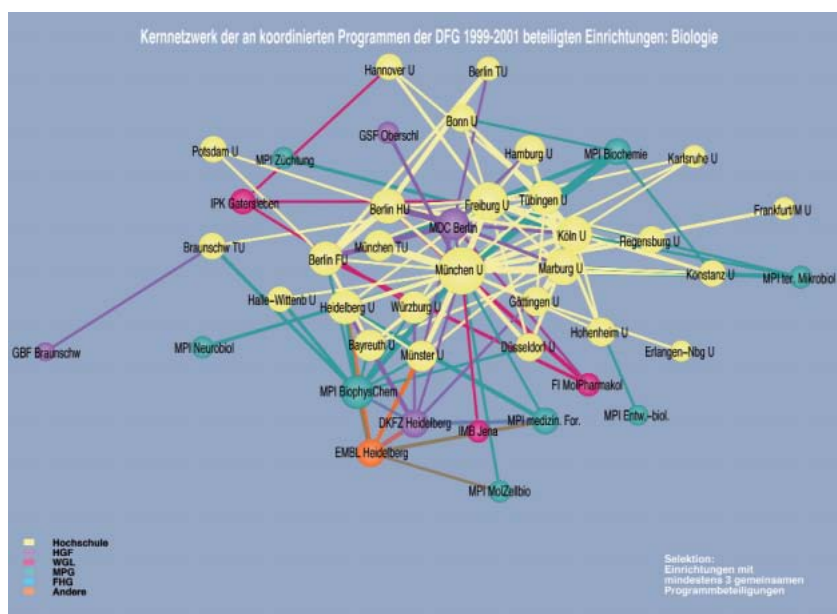
Krempel: Traditional indicators such as publication lists or patent data hardly provided

any information on where, how and when innovations emerged. It would have been very important to know who works together with whom and which co-operation partner sets or receives impulses. State funding has viewed the university system and the industrial research system more from a disciplinary perspective. To gain insights on which untapped synergy potential lies in the networking of these different activities it is first of all necessary to document the status quo. This can take place through network visualization.

For good maps you need access to sufficiently large amounts of data. Are people always ready to provide you the data – or do researchers show more scepticism towards your project?

Krempel: Of course there is still much to be desired with regard to the availability of data. Sometimes data sets are difficult to access for reasons of ignorance or apprehensive reservation. At the same time the public discussion on information landscapes is extremely exciting – for instance on the strengths and weaknesses of resource distribution and the resulting information potential. In this sense I see myself – the visualizer of information – as a service provider facilitating this discussion.

Wolfgang Neurath (Office of the Austrian Council for Research and Technology Development) conducted this interview.



The picture shows the network of research institutions (universities and non-university institutions) in the research area of biology. The graph illustrates institutions that have participated with one another in at least three (or more) programs that were coordinated by the DFG (German Research Foundation) between 1999 and 2001.

Analysis & visualization: © Lothar Krempel, MPI-Cologne

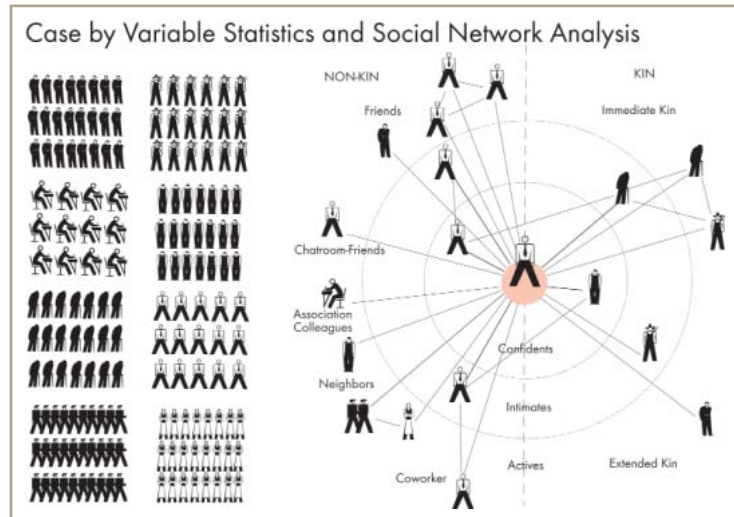
Literature ■ KREMPEL Lothar – Visualisierung komplexer Strukturen. Grundlagen der Darstellung mehrdimensionaler Netzwerke. Frankfurt am Main, 2005 ■ BERTIN Jacques – Graphische Semiologie. Diagramme, Netze, Karten. Berlin, 1974 ■ TUFTE Edward R. – Envisioning Information. Cheshire, Connecticut, 1990 ■ TUFTE Edward R. – Visual Explanations. Images and Quantities, Evidence and Narrative. Cheshire, Connecticut, 1997 ■ TUFTE Edward R. – The Visual Display of Quantitative Information. Cheshire, Connecticut, 2001 ■

Measurement – a Close-up look at Social Relations

How relations produce data. By Harald Katzmaier

It is the goal of every empirical discipline to do measurements. Since its founding in the 1930s the scientific discipline of social network analysis (SNA) has developed a comprehensive set of measuring methods to describe the structural characteristics of a network and its actors in quantitative terms. While classical social science, with its statistic methods, has concentrated on the analysis of the relationships between the **attributes of actors** (so-called variables), network analysis has focussed its measurements on the **attributes of relations** between actors. Its foundation is primarily graph theory, which, in addition to group theory and matrix algebra, represents a mathematical foundation of indicator creation. Graph theory can be used universally to model social relationships. Data on social relations are transformed into graphs and evaluated on various analytical levels.

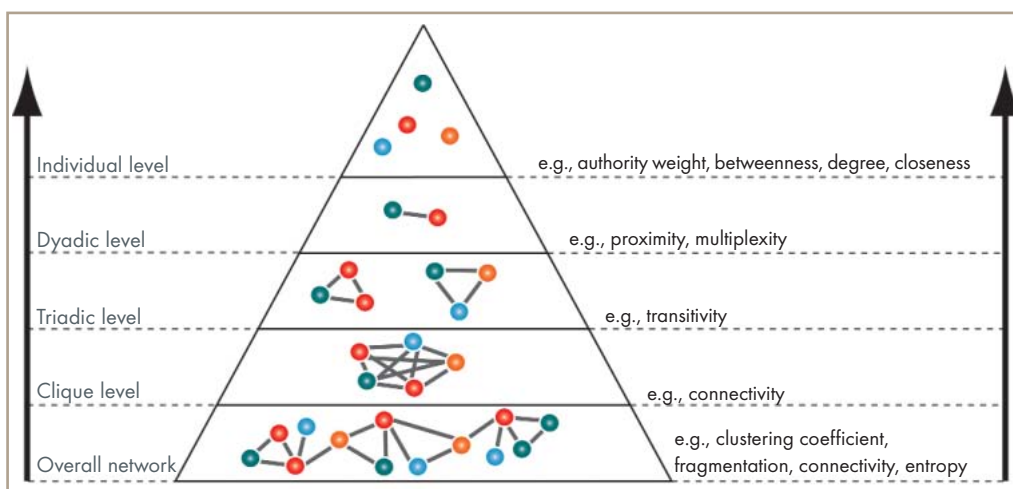
Social science, which orientates itself on the characteristics of actors, proceeds in most of its models from the assumption that its cases (= the actors that have attributes) are independent of each other. At the same time, the reciprocal interdependence is the very backbone of network analysis. The characteristics of relationships to other individuals are



Variable statistics deals with the attributes of actors, network analysis with the attributes of relations.

Graphic: based on a template by Barry Wellman

not independent of their relationship patterns. In the case of networks we are thus dealing with a complex, dynamic system in which not variables, but rather "real" actors interact with each other. The complex patterns emerging in the process can be grasped in quantitative terms (actors level, dyadic or triadic level, cluster level, level of the entire network).



The various levels of measurement in network analysis.

Graphic: © FAS.research 2005

The scientific community of network analysis is constantly developing new, and better, measuring methods. Thanks to the ever greater computing performance and ever more intricate algorithms networks with many hundreds of thousands of actors can be quantitatively examined in terms of their structural characteristics (e.g. by means of the PAJEK software package which is suited for analyzing very large networks).

On the individual actor's level various measures of centrality, in particular, are significant. Let's take a look at the data set of the EU projects of the 6th Framework Program: Projects and the partners involved in the respective projects, and/or their homeland constitute a network. Some actors assume a more significant position than others. This is called centrality in social network analysis.

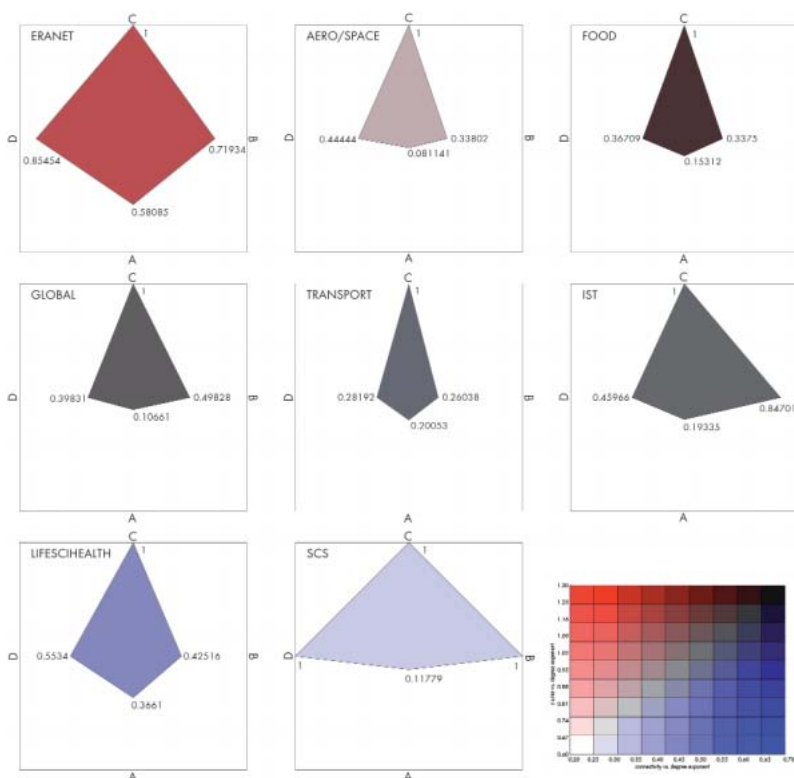
There are four ways to measure centrality.

Degree centrality: Central is whoever has the most contacts. The degree of centrality of an actor is the number of relations he/she has. An actor is central in terms of degree when he/she has a very large number of relationships and is thus very active in the network.

Closeness centrality: Central is whoever can be reached quicker. The closeness centrality measures for each node the path distance to all other actors of the network. The smaller the total distance is, the greater the closeness centrality and the easier it is for the actor in question to reach all of the other actors in the network.

Betweenness centrality: Central is whoever has the greatest control. An actor is central in the sense of betweenness when he often finds himself in a position between two other actors who do not have any direct contact with each other. An actor with high betweenness can control relations between others and stop or promote the flow of information within the network.

Authority weight: Central is whoever has influential friends. The authority weight measures



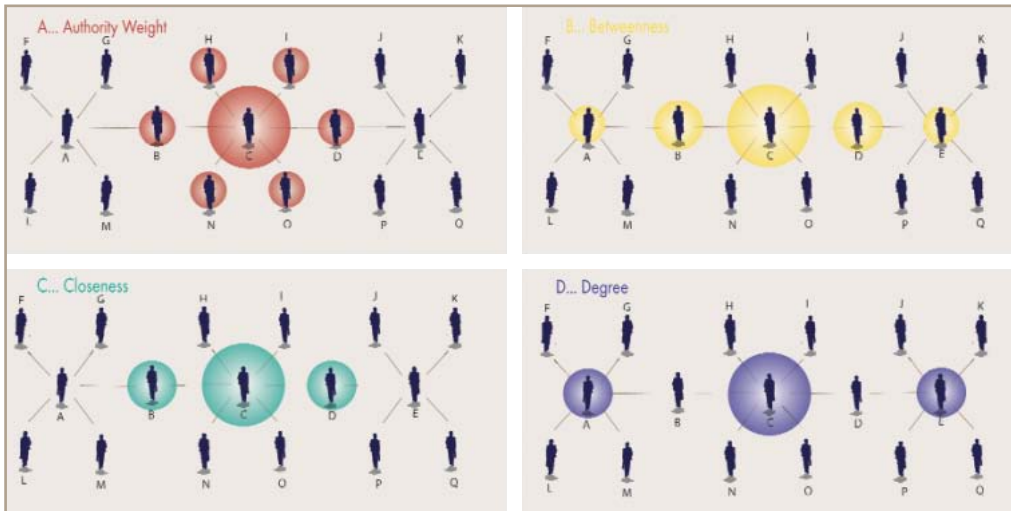
The geometric figure of the "diamond" shows Austria's position in the individual programs of the 6th Framework Program with regard to the centrality measures authority (A), betweenness (B), closeness (C) and degree (D). The closer the value is to 1, the larger Austria's centrality in this program network which was based on those projects in which Austrian institutions participated as project partners.

The degree correlation (or hub assortativity) defines the color assigned: a high percentage of red means that the corresponding network has a pronounced hierarchical structure, while a high blue percentage signals strong competition.

Analysis and Plots: © COSY, HNO, Med Uni
Data: European Commission
Source: PROVISO, a project of Austrian ministries (BMBWK, BMVIT, BMLFUW and BMLWA)
[www.bmbwk.gv.at/proviso]

The overview of projects with Austrian participation within the individual programs of the 6th Framework Program shows that Austria plays a central role (high values in the measures authority, betweenness, degree), e.g., in ERANET (support for the coordination of activities), which is strongly hierarchical and hardly competitive. Also in the LIFESCIHEALTH program, which is hardly hierarchically structured but strongly competitive, Austria has a stronger position (higher authority value). The high betweenness centrality of Austria in the program IST is also remarkable.

ERANET (Support for the co-ordination of activities), AERO/SPACE (aeronautics and space), FOOD (food safety and health risks), GLOBAL (global change and ecosystems), IST (information society technologies), LIFESCIHEALTH (genomics and biotechnology for health), SCS (science/society), TRANSPORT (sustainable surface transport).



The A, B, C, D of network analysis: centrality measures at a glance. Graphic: © FAS.research 2005

to what extent an actor is linked with other actors who, in turn, have many relationships (e.g., a high degree).

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TON Peter J., SCOTT John, WASSERMAN Stanley – Models and Methods in Social Network Analysis. Cambridge University Press, 2005 ■ de NOOY Wouter, MRVAR Andrej, BATAGELJ Vladimir – Exploratory Social Network Analysis with Pajek. New York, 2005 ■ WELLMAN Barry – <http://www.chass.utoronto.ca/~wellman/> ■

Studying Complex Systems

The simulation of networks. By Harald Katzmaier

Social network analysis (SNA) rests on three pillars: the measurement of social relationships (application of structural indicators), the visualization of relationships (application of graph drawing technology) and the simulation of relationship dynamics (application of agent-based modelling and p*-statistics). Simulation models can be used in a very broad sense as a tool for supporting decision-making processes and for developing strategy concepts in the realm of research, technology and innovation policy.

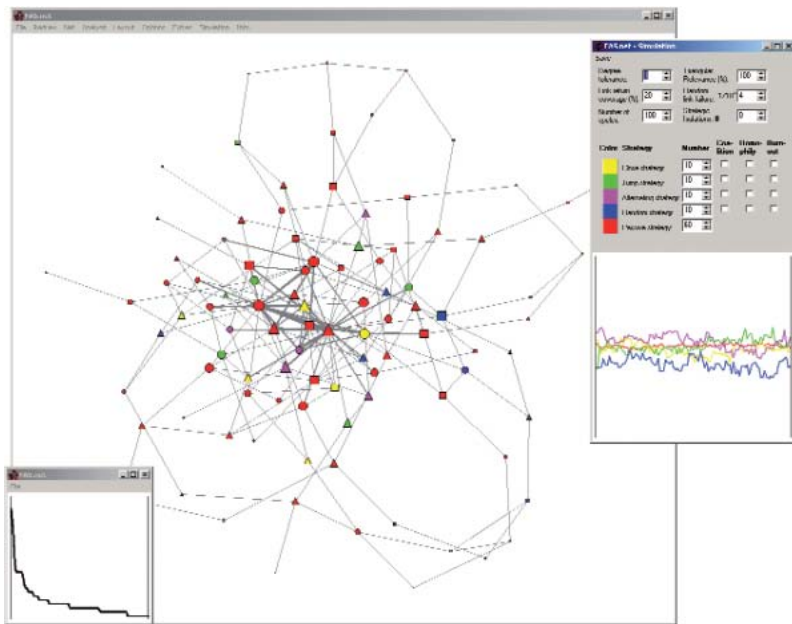
In the context of an interactive SWOT scenario analysis the following questions are explored:

- What are the best strategies for improving the innovation potential of a network?
- What effects does the addition of new actors have on the efficiency and innovation potential of a network?
- Between which actors should relationships be

established to optimize the robustness and efficiency of the network?

- Where do links have to be added or eliminated to minimize transaction costs?
- How does the change in a system of incentives (new programs, new models of support or guidelines) affect the network strategies of actors and what effects does this have on the macro-level?
- How adaptive and resistant is a network in reacting to external shocks (e.g., technological changes, market slumps) and changes in the composition at the level of actors (e.g., company start-ups, mergers, bankruptcy, appearance of new international players in local markets)?

What is special about the agent-based modeling approach is that simple rules of behaviour can be ascribed to the individual actors according to the given objective function. This means that each actor is assigned to a set of behaviour rules that enable >



The program FAS Net Strat™, developed by FAS.research, analyzes the best networking strategies for each actor of the network under pre-defined conditions.

him/her to optimize his/her position by interacting with the other actors. This interaction gives way to a network whose structure is more or less well suited to fulfilling a certain task. Thus the behaviour of the individual actors determines the entire system (bottom-up).

The effect that this interplay of actors has on the entire network is studied in simulations. It can be detected whether local changes of the game rules have a positive or negative effect on the global innovation potential of a network. Measures related to technology policy that change the system of incentives for the actors can be controlled on the basis of "what if"-simulations in terms of their effects on the entire innovation system.

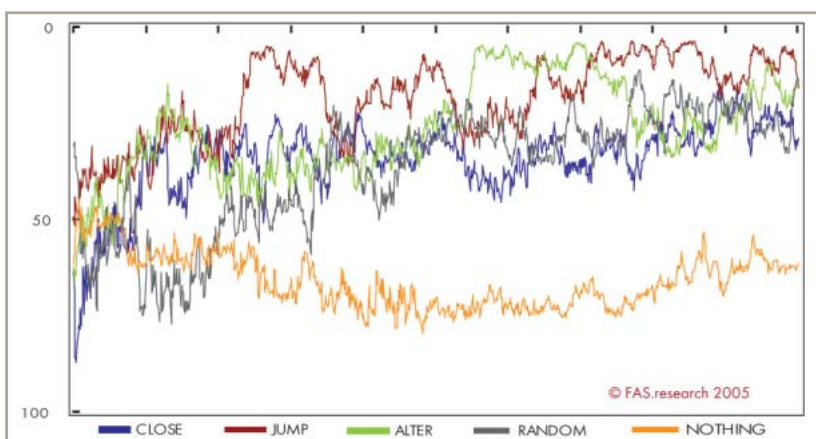
The goal of the simulations depicted in the illustrations was to find out which network strategies can

help an economic actor in the mid-term to improve his own position within the network. Improvement here means that the actor has a more efficient (in terms of the cost-benefit ratio) access to capital, knowledge and social relationships.

Each individual actor within this simulation acts according to defined and individually different strategies. Some try to close off their structures to the outside by networking closely with their environment (close strategy). Other actors, by contrast, try to gain advantages by creating connections with actors from distant network regions (jump strategy). Others, in turn, use both strategies alternately or network in a purely random way. A further group of actors acts completely passive, that is to say does not actively approach the others but is only "invited" by others to engage in relationships.

The results after 100,000 rounds show the following: The most successful strategy depends on how the global network looks. In an environment, in which the network structure is random (so-called Erdős Renyi network) it is best to build contacts that are in the immediate vicinity. In a highly centralized network (so-called scale-free network) "jumping" is the best strategy. In particular for outsiders who enter the races from the network periphery this is the only way to work their way into a self-contained center or to build a new center. And even following external shocks (e.g., bankruptcy, terror attacks, change of technology) those actors who engage in contacts with more distant network regions have the lead much faster (structural holes network). The famous "moving closer" in times of crisis is a strategy of only limited efficiency. Especially in fields with young technologies in the development stage it is advisable to prevent an excessively high local isolation and to "blend" the network clusters.

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FAS Net Strat™ shows the results of different networking strategies by comparison.

Harald Katzmair FAS.research, Vienna/San Francisco

Christian Gulas, Katharina Oberbichler, Jürgen Pfeffer, Ruth Pfosser, Max Ruhri, Doris Spielthener

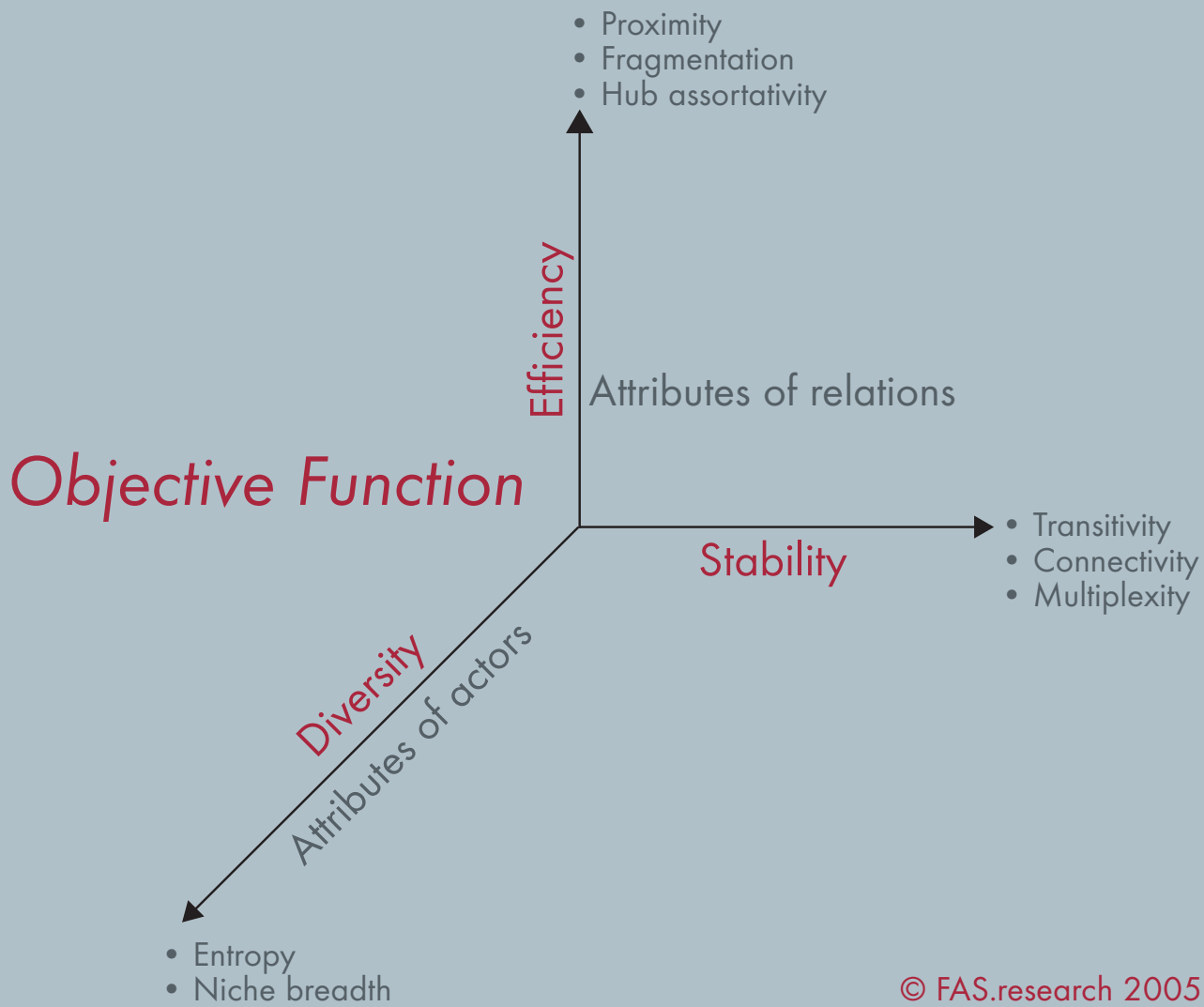
Good networks, bad networks ...

Dimensions of a SWOT analysis based on Complexity Theory
and Social Network Analysis

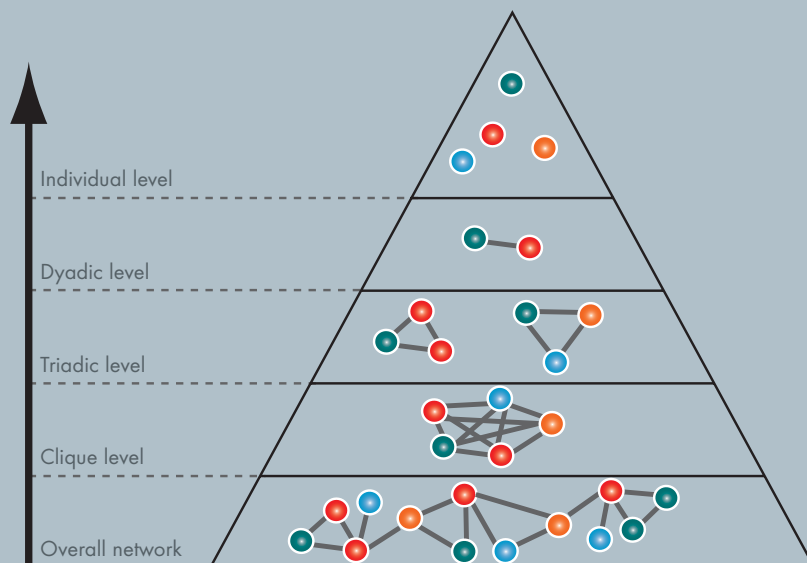
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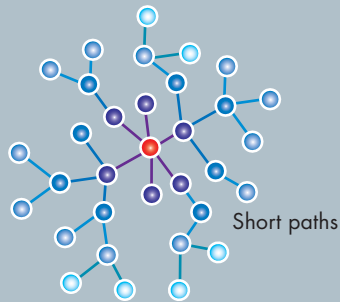
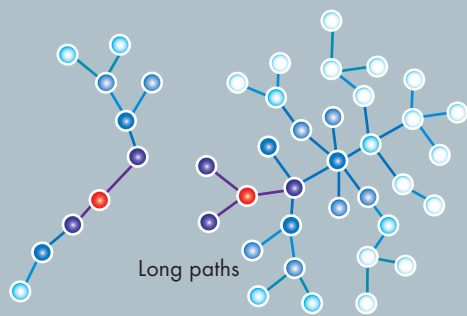
Dimensions of excellence



Multi-level dimensions



EFFICIENCY



PROXIMITY

Average distances (number of steps) in a network are dependent on network structure and the network position of the actor



FRAGMENTATION

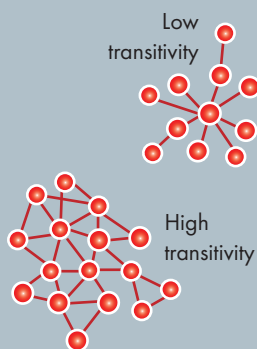
Percentage of actors who cannot be reached by means of direct and indirect contacts



HUB ASSORTATIVITY

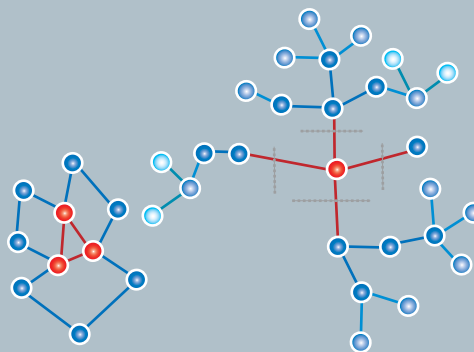
Dependence of total centrality on the centrality of the few actors who are connected

STABILITY



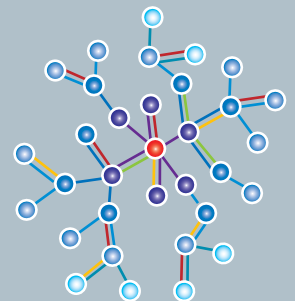
TRANSITIVITY

Number of common neighbors of 2 actors



CONNECTIVITY

Number of actors/relationships whose removal can lead to dissolution of a network



MULTIPLEXITY

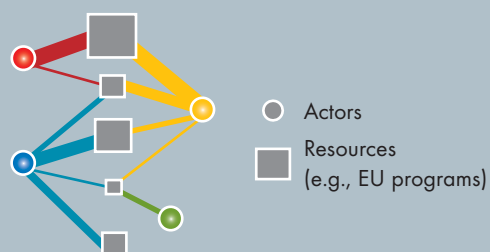
Various levels of relationships connect actors

DIVERSITY



ENTROPY

Number and distribution of actors with various characteristics



NICHE BREADTH

Type and amount of resource utilization by actors

Prototype cycle

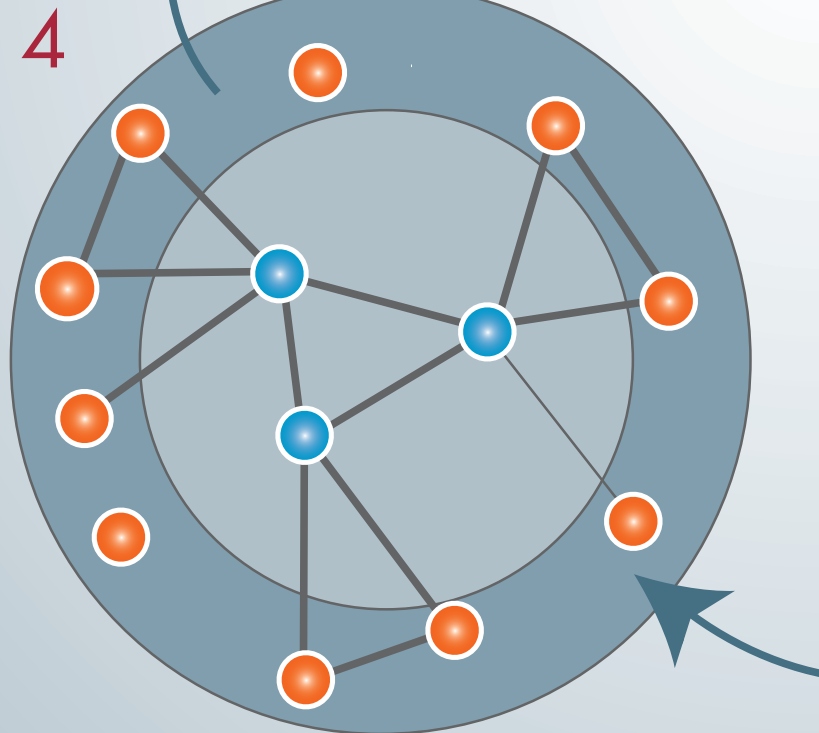
Profile of excellence Research



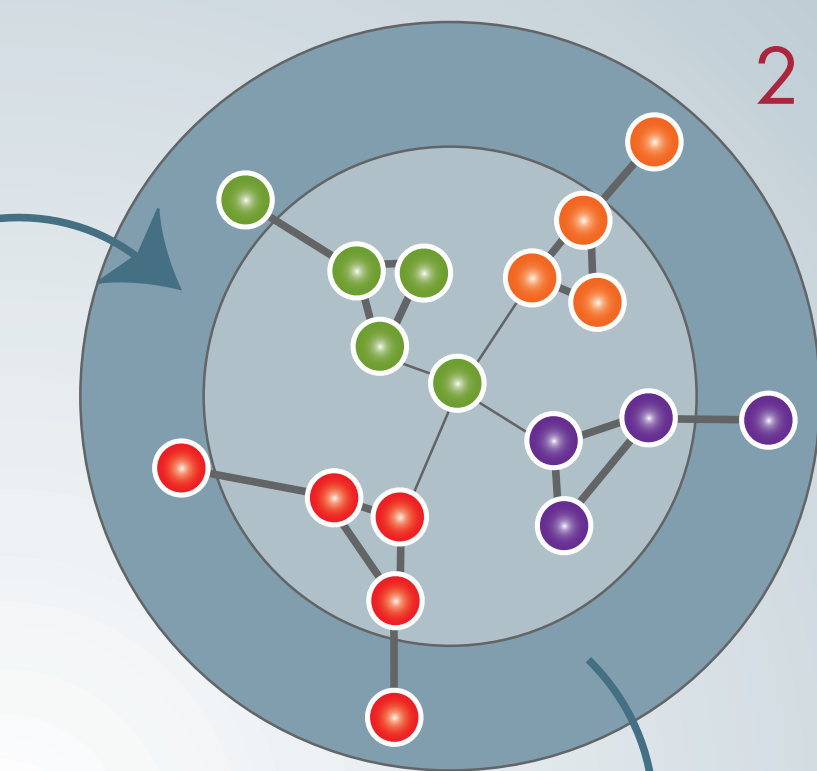
Profile of excellence Diffusion



SCALA



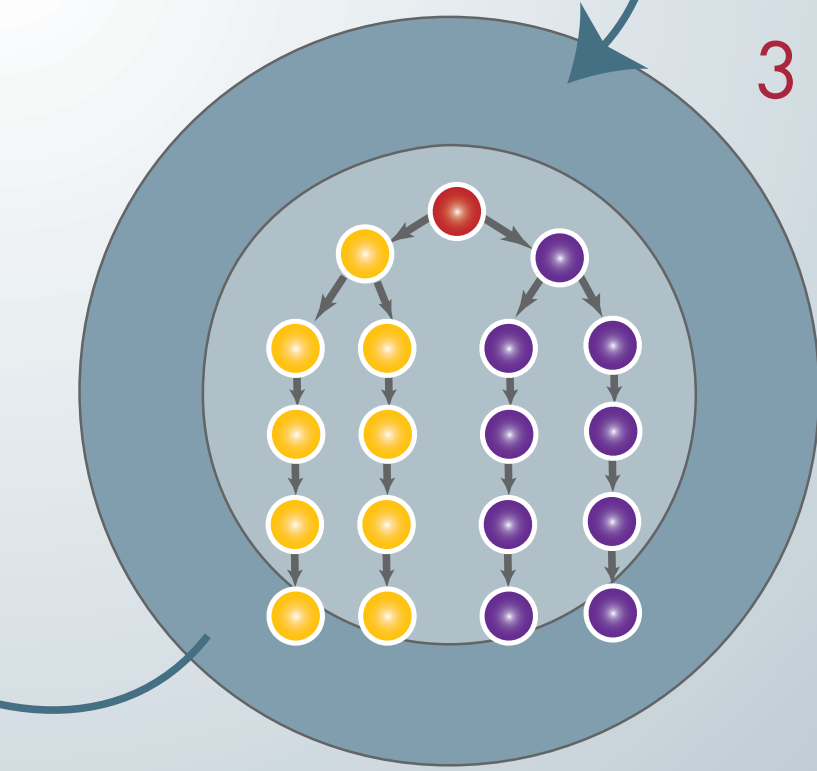
of excellence



Profile of excellence
Development



BILITY



Profile of excellence
Production



1 Profile of excellence I: development of new ideas and research institutions, brainstorming, formation of skunk works, definition of project goals and project delineations, general team formation and measures for promoting trust

STRENGTHS	WEAKNESSES
■ Strong cohesion enables trust to be established and common goals to be defined, common horizons and interpretations to be developed ■ High inner diversity (representatives of various fields of expertise) allows for new ideas and innovations	■ Low efficiency, high structural redundancy ■ Low impact with regard to monitoring market developments and diffusion of information
OPPORTUNITIES	THREATS
■ Outside experts and future users can be consulted for examining project goals ■ Feedback from focus groups can help improve the research process	■ False assessment of external wishes and needs as a result of lacking outside contacts and too much internal orientation ■ The output of research has no input in value added cycles as a result of relative isolation ■ Danger of double strategies being pursued as a result of lacking knowledge of comparable projects

4 Profile of excellence IV: diffusion, distribution, adoption, sales, marketing, and customer feedback

STRENGTHS	WEAKNESSES
■ High efficiency as a result of short paths to customers ■ Highly specialized knowledge of customer needs and situation	■ High orientation to the outside ■ Low internal-organizational diversity ■ Lacking integration of other departments
OPPORTUNITIES	THREATS
■ Improving the balance between internal and outside contacts according to the concept of a "learning organization" ■ Building triangles stabilizes customers and users and promotes trust	■ No learning organization, because knowledge on customers and users can hardly, or insufficiently, be transferred to research, development and production department ■ Danger of lacking knowledge of technology and production and thus lacking support of customers

2 Profile of excellence II: development, prototyping, acquiring expertise, complex processes

STRENGTHS	WEAKNESSES
■ Specialist teams with critical mass of expertise work on modularized tasks ■ Efficient division of labor with high local structural stability guarantees team creation and promotes expertise	■ Weak connection between the modules, thus low efficiency due to long paths ■ Specialist teams with high global diversity with low local diversity cause interdisciplinary communication problems
OPPORTUNITIES	THREATS
■ Stronger interface management between modules (cross teams, dual roles...) improves efficiency and communication ■ Enhancing inner diversity through stronger integration of future users (examining project goals)	■ Serious crisis in the event of a breakdown of a module as a result of low functional stability ■ Danger of overburdening the coordinator in the center of the modules ■ General danger of "production at cross purposes" within the specialist modules

3 Profile of excellence III: production, standardized manufacturing, general standardized processes

STRENGTHS	WEAKNESSES
■ Linear, hierarchical top-down structure guarantees efficient realization of processes according to given production plans ■ Clearly formulated criteria of success and failure ■ Clearly defined competences, clear distribution of tasks and roles	■ Low stability as a result of lacking alternative paths ■ Slow response to changes as a result of long feedback loops
OPPORTUNITIES	THREATS
■ Networking and reduction of production lines through coupled production and introduction of cross-connections	■ Danger of individual actors being overburdened, especially in the top level of the hierarchy ■ Lack of cross-connections makes "self-organization" of the lower levels impossible in the event of a breakdown of the top level

Efficiency

Proximity: measure for the average distances (=number of handshakes) between actors in the network. The greater the distances, the higher the fragmentation of the network, extending the dissolution of the network in unconnected components. The higher the average proximity value in the entire network, the lower the transaction costs in the network. On the level of actors, this means that a single actor can have an efficient network at his disposal when he has a very close proximity to all the other actors; i.e., when he can reach a maximum number of actors within a few steps.

Hub Assortativity: degree to which central actors (so-called hubs) are also interconnected (also referred to as "degree correlation"). The greater the assortativity of the hubs, the more efficient the network, since the direct contacts created among the hubs create "short cuts" throughout the network which make it possible to very quickly reach various areas of the network. For the hub in particular, this guarantees that its direct contacts (to other hubs) ensure a high secondary reach (indirect relationships), i.e., a maximum number of indirect contacts can be reached with a small number of direct contacts.

Fragmentation: measures on the level of the entire network the percentage of actors who cannot be reached by means of direct and indirect relationships. The smaller the fragmentation in the network, the more efficient it is, since all areas of the network (so-called components or subgraphs) can be reached.

Stability

Transitivity: degree to which actors in a network have common "neighbors", which is synonymous with them being embedded in stable triangular relationships (so-called triangles). The more common partners two actors have, the more stable the relationship is, since the actors are forced to establish positive relationships among each other (transitivity rule). Generally it is assumed that the stability of a relationship between two actors can be depicted as the direct function of the number of their common "friends" and "foes".

Connectivity: Number of actors who have to be removed from the network so that the network is fragmented or existing components dissolve into further subcomponents. The more actors have to be removed from the network (so-called "minimum cutset") the more stable the network is. On the level of actors/link

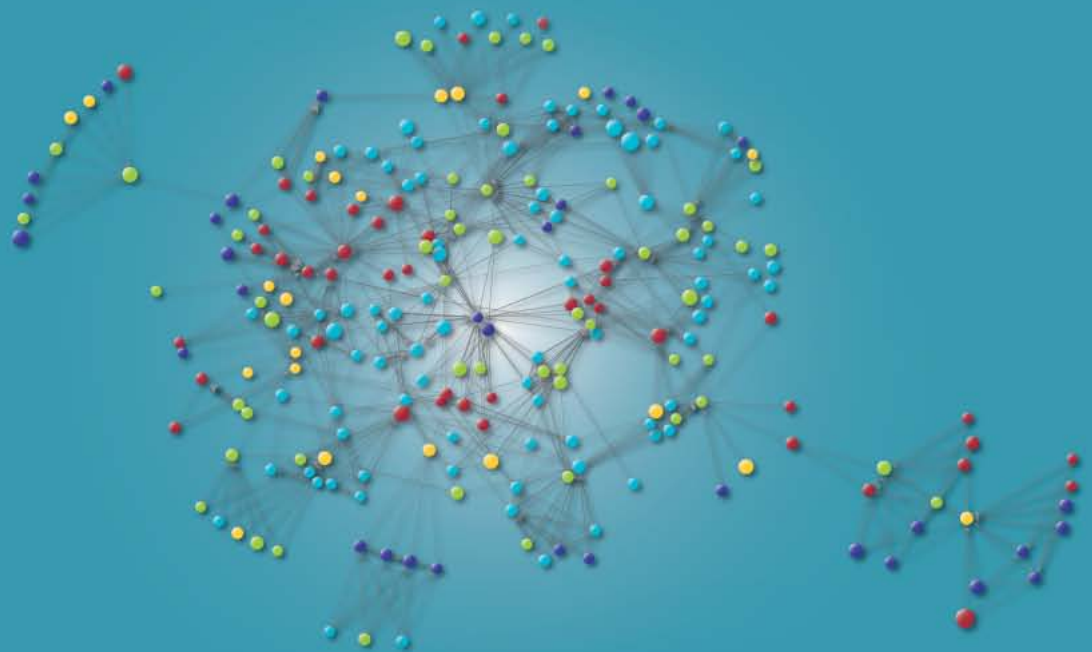
this means that each actor contributes to a different degree to the "cohesion"/"adhesion" of a network.

Multiplexity: measure for the number of different levels of relationships the actors are interconnected on. This is given, for instance, when two actors involved in the same research project are not just exchanging knowledge but also perhaps exchanging personnel and/or are entertaining relationships on the ownership level (shares, etc.). The more diverse and multiplex these relationship levels are, the richer the possibilities for an exchange for each actor. The more forms of relationships, the higher also the stability, since the relationship dimensions consolidate each other and are "interlocked". Typically, multiplexity grows with an increase in transitivity.

Diversity

Entropy: The criterion for entropy refers to the differences and heterogeneity of actors (professional groups, scholars, age groups, genders, etc.) Entropy is a measure of security (order) and insecurity (disorder) in the network. It measures the probability when someone is "drawn" from a network this person will have a certain characteristic (company size, gender, profession, scientific discipline, task, etc.) and the next actor "drawn" has the same characteristic. If all actors of a network are the same (e.g., they are all physicists), then entropy amounts to 0, since there is no insecurity. If all are different (and represented to the same extent) then there is maximum entropy. The more diverse the characteristics of the actors, the more different the experiences and problem solution strategies that can be generated and also the greater the likelihood of radical innovations (breakthroughs). The more diverse a network, the higher the control and implementation costs and the greater the danger of a Babylonian jumble of languages.

Niche breadth: The same applies for niche breadth as a characteristic of an individual actor. The niche breadth is a concept from ecology closely related to diversity. It provides information on the type and quantity of various resources used by actors (in a certain sense it is weighted diversity.) The greater the niche breadth, the more different areas of a value added chain an actor is involved in, the greater share he has in the consumption of resources. The narrower the niche breadth of an actor is, the higher his specialization and the lower his share in the entire resource turnover.

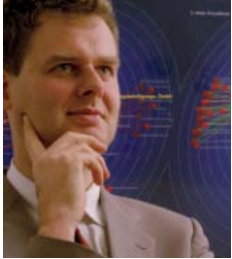


Excellent Networks

Prototypical Cycle of Excellence

Excellent Networks

Dimensions and criteria from the perspective of complexity research and social network analysis. By Harald Katzmaier



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Summary: Excellent networks are capable of remaining coherent in spite of changes in the composition of their actors, their actors relations and of a change in the objective function. They are able to tackle the complex demands of their context-related objective functions in a sustainable way. Even in the event of technological changes, disruptions, accidents or new market situations, they are capable of carrying out search processes, bringing forth innovations and integrating them, creating a cultural identity that makes sense to the actors, and co-ordinating the individual objective functions of the individual actors with the objective functions of the entire network. The parameters of efficiency, stability and diversity of a network are scaled so that they can be optimally adapted to the given production conditions and objective functions (the feature of multi-scalability).

A network is thus excellent when the variables of efficiency, stability and of diversity can be "tuned" depending on the demand (objective function). Thus the network is adaptive and stable enough to assume various states and patterns of networking. The ideal form of a network differs from case to case – it must be assessed according to the objective function of the network. As opposed to a network that is only "ideal", an "excellent" network can process a number of different objective functions. Given its structural efficiency, stability and diversity an excellent network is capable of reacting to disturbances from the outside in a robust and flexible way without losing any of its mid- and longer-term capacity to develop (global network characteristics of robustness, adaptability, evolvability).

1. The network paradigm

In recent years the term "network" has become one of the keywords of the still young 21st century. This has to do with the general diffusion and use of the Internet. The awareness of "links", for establishing contacts (networking), procuring information and resources has long become a part of everyday culture. In science, network theory has long become one of the most important transdisciplinary paradigms of the 21st century. Network theory as a paradigm has most successfully bridged disciplines ranging from mathematics, biology, physics and computer science to sociology and economic theory (KATZMAIER, 2004). The scientific fields of complexity theory (KAUFFMAN, 2000; SOLE/GOODWIN, 2000; NEWMAN, 2003; BOCCA-RA 2004) as well as of social network analysis (WASSERMAN/FAUST, 1994; CARRINGTON/SCOTT/WASSERMAN, 2005; de NOOY / MRVAR

/ BATAGELJ, 2005) deserve special mention. Both have experienced a real upswing over the past thirty years. Physicists analyze the network structures of the World Wide Web, while biologists study the widely branched maps of the genetic networks. Marketing experts research the pattern according to which opinions, fashions and new products disseminate in consumer networks, while epidemiologists study the contamination and propagation networks of dangerous viruses. Ecologists examine the stability of food chains in ecosystems, while lobbyists identify key players in social networks of relationships. Genealogists and anthropologists analyze the network structures of relatives and marriages. Researchers in the fields of innovation, technology and science policy search for basic patterns and regular structures in innovation and adaptable networks.

Criteria for network evaluation

For all the attention that the network paradigm attracts, it is surprising that to date no effort has been carried out to assemble the, in many cases, sophisticated insights from the various scientific fields in terms of feasibility, potential for learning and development, the strength and robustness of networks and to use them as evaluation criteria for a systematic SWOT analysis.

The goal of this article is thus to show the conceptual dimensions according to which the **strengths, weaknesses, opportunities** and

threats of social networks can be evaluated both quantitatively and qualitatively (SWOT analysis). The criteria are kept as general as possible so that they can be applied to various types of networks. The focus will be mainly on the following types of networks:

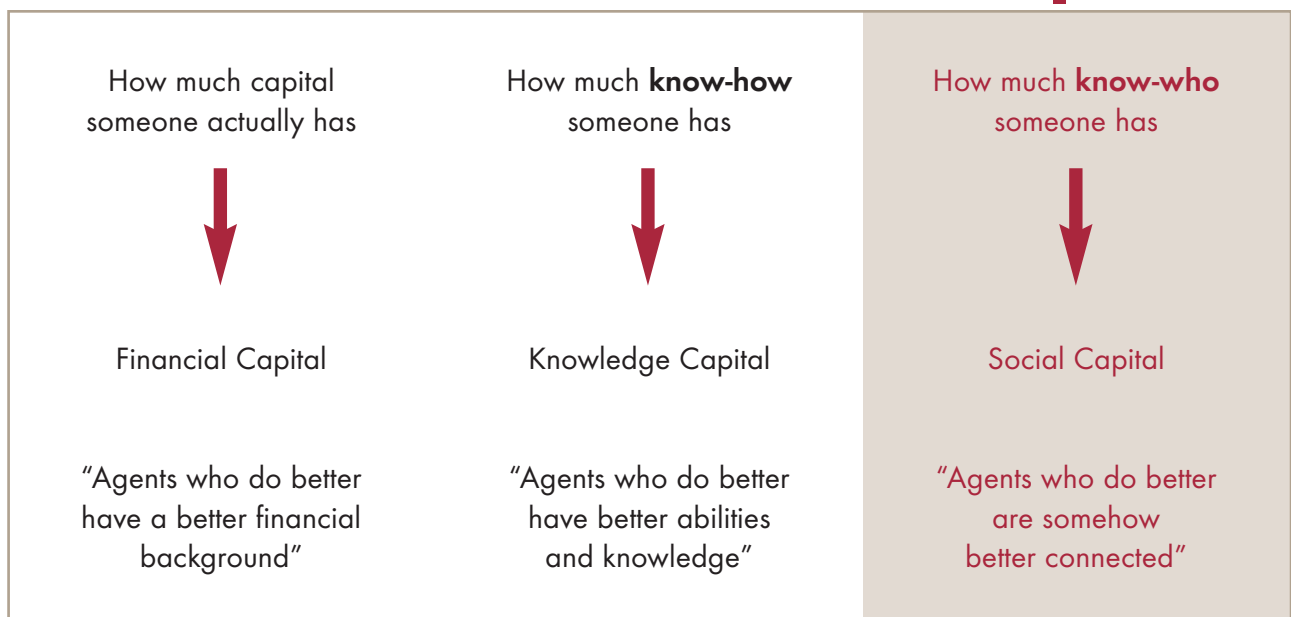
- research and innovation networks
- networks of knowledge
- value added and production networks
- distribution, sales and marketing networks
- inter-organizational networks
- intra-organizational networks
- virtual organizations

2. Networks in the context of organization and innovation

Not only those organizations that have more economic capital and/or more knowledge (human capital) are more successful, but also those that are better connected both on the inside and to the outside. That is, those that have more social capital and have better networks (GRANOVETTER, 1973, BURT, 1992; BORGATTI/JONES/EVERETT, 1998; LIN, 2001). Social capital is thus

the economic value which results from the existing social relations; it is the economic value of being connected. Or to put it differently, social capital is necessary for economic capital and human capital to be used economically. Without the right connections one remains literally "stuck" with one's knowledge and skills (GRANOVETTER, 2005).

Three forms of capital.
In addition to financial capital and human capital ("know-how") social capital ("know-who") also represents a crucial factor for success.



Typical examples for actors in social networks are:

- Individuals
- Teams
- Departments
- Sites
- Organizations
- Companies
- Institutions

Typical examples in the realm of science and technology:

- Publications
- Patents
- Scientific disciplines and areas of expertise
- Fields of technology
- Competence centers
- Clusters and networks
- Sectors and industrial districts

The CASOS Metamatrix Model (based on CARLEY/KRACKHARDT, 1999)

Generally speaking, social networks constitute the immaterial infrastructure that enables actors to produce, carry out search processes, bring forth innovation, to learn as well as to develop a social and

cultural identity. In formal terms, a network is a number of actors who are connected or not connected through the same kind of relations. Networks are thus defined by existing and non-existing relations.

	People	Knowledge / Resources	Tasks / Events	Organizations / Affiliations
People	Social network Who is in contact with whom ?	Knowledge and resource network Who knows what? Who has what?	Task and Event Network Who does what? What happens at a certain point in time?	Membership and attendance network Who is member of which affiliation? Who attends which event?
Knowledge/ Resources		Information network What Information leads to what knowledge? What knowledge is needed to use a resource?	Needs network Which resource is needed to fulfill a task? What knowledge is needed to fulfill a task?	Capability network Which organization has what knowledge? Which organization has which resources?
Tasks			Temporal and workflow networks Which tasks must be done before which? What happened before what?	Organizational support network Which organization supports which event or task?
Organizations / Affiliations				Interorganizational network Which organization is in contact with which? Which organizations are linked through common people?

Social relations are just one type of relations among many others. Also the relations between individuals and their tasks, the relationship of an individual to a certain type of knowledge and know-how or to resources could be mapped as a network. The so-called "meta-matrix model" has proven to be especially coherent. It was developed at the end of the 1990s at the CASOS

Institute of Carnegie Mellon University (Pittsburgh, USA; CARLEY/KRACKHARDT, 1998, 1999). In this model five dimensions (individual, knowledge, resources, tasks and affiliations, e.g., to a company, organization, association) are related in a matrix. In this way the complex reality of an organization can be modeled in a surprisingly effective way.

3. Networks as social infrastructure of possibilities

As social capital, building and maintaining social relationships incurs expenses: in the form of time and social "energy" for communication, for processing and making available valuable resources (e.g., money, knowledge, products, services, contacts) to be "attractive" for the others. The costs are compensated by rewards that are generally described as economically significant opportunities and advantages (BURT, 1992, 2000; GRANOVETTER, 2005). Examples of such advantages are:

■ **Search cost advantages:** higher competence in problem solution because one has contact to the "right" people who know who the best experts are.

■ **Transaction cost advantages:** Through use of the right channels one is able to convey one's own products or information to the desired target individuals.

■ **Tactic information advantages:** to have certain information earlier than others.

■ **Strategic advantages:** to have a better overview of what is happening in the markets, because one has contacts to very different areas.

■ **Contact advantages:** to establish contact with important persons, because one is introduced by someone else.

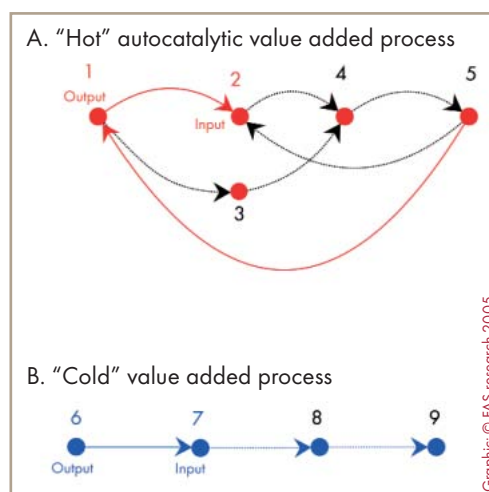
■ **Advantages in partner search:** to be attractive for other partners because one has good contacts.

■ **Control advantages:** to have control over information streams because of a good network position.

■ **Bargaining advantages:** to have a better bargaining position because of alternative contact channels.

With his/her social capital, each actor has contacts with other actors in the network, which offer him/her access to resources, a sort of investment budget. This budget serves to "finance" contacts. The structural position in the network is used to promote projects and processes but also to increase one's own social capital or to establish new contacts and to give up others.

>



Value added processes. Output of an actor becomes the input for a second actor who, in turn, individually or together with another actor, produces input for a third actor. The more feed-back loops in such a process, the "hotter" and thus more autocatalytic the process of added value is. The more one-dimensional, the "colder", the more standardized and less innovative the process is.

Networks can be compared to a system of conduits via which material as well as immaterial resources are transported in connection with exchange and added value processes. Networks, after all, constitute the “space of opportunities” whose structure determines whether and to what extent an actor has the production factors that are necessary for value added processes: money (economic capital), knowledge (human capital) and social contacts (social capital). Networks determine whether and to what extent an actor can “play along” and whether he is attractive enough to potential partners so that they engage in an exchange with him.

It depends on the position

The availability of resources (money, knowledge, relationships) is determined by where one stands, which position one assumes. For the costs of access to these resources (= the costs of a “link”) as well as the yields to be expected are also

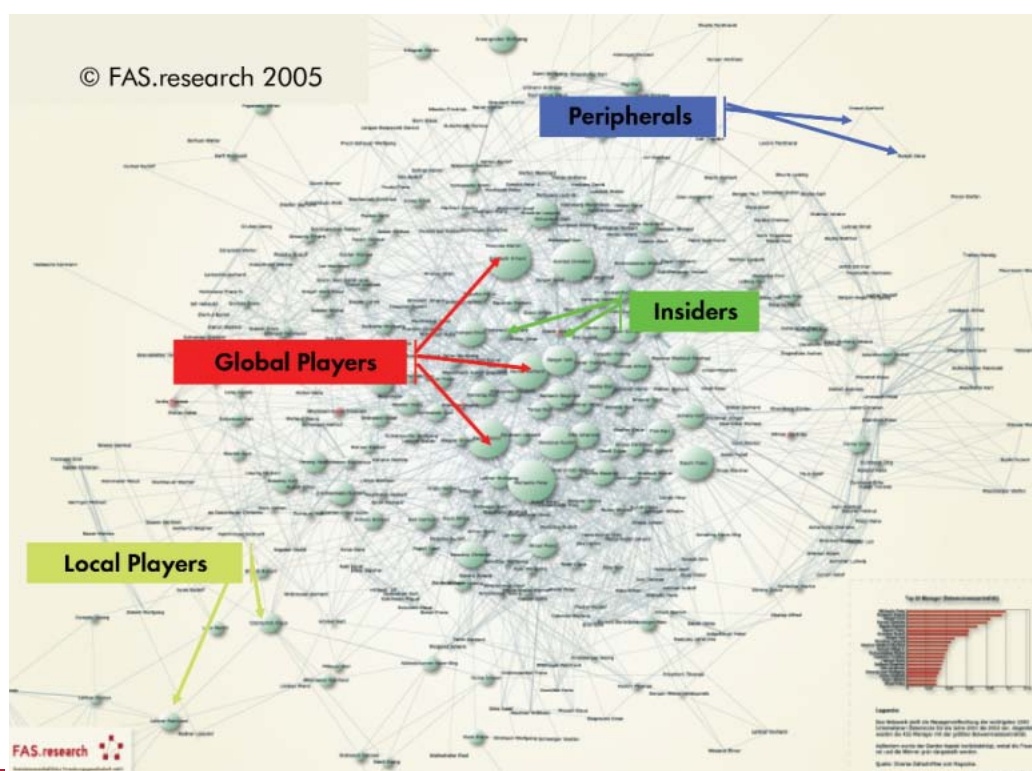
defined by the position in the network and by the general structure of the network. This is the central economic and business-related message of network analysis. The second message in this context is that the methods of network analysis can be used to measure and depict both dimensions (position and structure) in quantitative terms. Social capital also reveals both of these dimensions which must also be taken into account in a SWOT analysis based on the methods of social network analysis:

a.) Positional dimension of a network: Where does an actor stand?

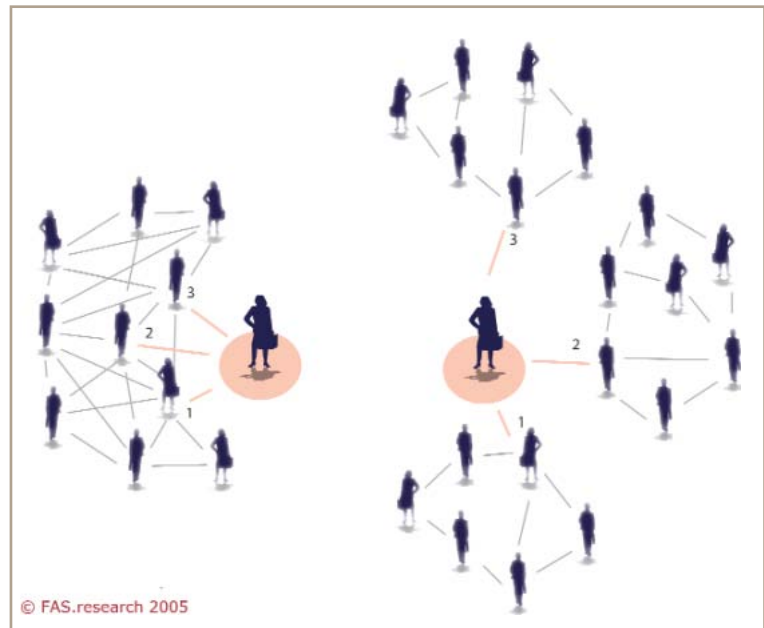
b.) Structural dimension of network: What does the environment in which the actor is embedded in look like?

The possibilities of added value, of innovation, chances for successful search processes for better solutions as well as the costs of adaptation to changes are distributed differently for each actor within one and the same network. This is not just because each actor assumes a different position and

Positions in the network:
Global players have the highest global centrality in the network.
Local players are situated on the periphery of the network where, however, they enjoy a high degree of local centrality.
Insiders are located at the center of the network and have contact with the global players but do not have any global “power” themselves (they are high in closeness and authority weight, but low in betweenness and degree centrality).
Peripherals are actors on the periphery of the network.



thus the costs of access to the limited resources vary, but also because with each position the immediate environment changes. Thus the character of the network (the “network profile”) is a different one from the local perspective of the actor. Each actor in the network finds a different space of possibilities and has better or worse access to the existing resources by virtue of his relationships to the other actors. The network thus creates the social infrastructure of the opportunities offered to an actor.



Role distribution in the network

Regarding position in the network, the following analytic terms have become established. They also serve as a sort of role description of the person assuming this position. The network analysts of FAS.research distinguish the following roles of network actors derived from network positions (KATZMAIR, 2005): **Global players** have the highest global centrality in the network. **Local players** are situated on the periphery of the network where, however, they enjoy a high degree of local centrality. **Insiders** are located at the center of the network and have contact with the global players but do not have any global “power” themselves (they are high in closeness and authority weight, but low in betweenness and degree centrality). **Peripherals** are actors on the periphery of the network.

The two poles of social capital

We can distinguish between two basic forms of network typology. In literature they are also often described as the “two poles” of social capital (BURT, 2000):

a) Closure networks: These networks are characterized by the fact that the actors maintain

contacts to the other actors who are also connected among each other. The advantage of networks with such a high density: As a result of the large number of “common acquaintances” there is trust, stable expectations, a tendency to create common values, world views, interpretations and norms (important for team-building processes), a tendency to develop group, organization and network identity (relevant for the implementation of strategies). The disadvantage: What is gained in network stability, is lost in efficiency. No new regions are reached through the portal of existing relationships. And since everyone is connected to everyone, there are high co-ordination costs, limitations and constraints, since everything has to be co-ordinated among the individual actors (BURT, 1992, 2000).

b) Structural holes networks: These are networks in which actors have contacts to other actors who are not connected among each other. This is the opposite of closure networks. The lack of contacts between the actors are the so-called structural holes which, given the control advantages, make the network particularly interesting from the per-

Network types:

closure network (left) and structural holes network (right). The structure of a network determines how and which processes might take place: in a dense network, where everybody knows everybody else, this social intensity is an evidence for mutual trust, stability but also dependency; vice versa this means: within a loosely knit network information can easily travel into the center und messages can easily be diffused throughout the whole network, however these relations are not stable and such a network is fairly vulnerable.

Chart: © FAS.research 2005

Closure network – stable but limited	Structural holes network – efficient but unstable
Ideal for building trust and consolidating co-operation relationships	Ideal for distribution, diffusion and monitoring

A network is excellent when it remains structurally and culturally coherent in spite of the constant change of its elements, their relationships, as well as objective functions (tasks). Even though it is constantly changing it still retains its internal cohesion – it continues to be able to fulfill the demands, i.e., it is still capable of producing, learning, carrying out search processes, developing and/or integrating innovations, giving their members a meaningful cultural (corporate) identity.

spective of the “broker” between the unconnected actors. Since the co-ordination costs are low and the indirect reaches (that is, the contacts of contacts = the friends of friends) are markedly larger, these networks are especially interesting for diffusion processes (distribution, marketing) but also for monitoring and procurement tasks. There is the advantage of low redundancy but also the disadvantage of lacking stability. Since there are no “common acquaintances” to stabilize the relationship, it can bear much less strain and is less stable

than those with a number of triangular relationships, which is typical for closure networks (BURT, 1992, 2000).

The blend is what counts: The description of these two types of networks already indicates the characteristics required for a network to be “excellent”. It must be a combination of the two network types, and depending on the situation it must be able to be transformed from a closure network into a structural holes network (and vice versa.)

4. Dimensions of excellence

Before a network can be labeled “excellent” two questions must be answered:

- Which objective function (task, product, benefit, value) does the network have to fulfill and how good is this function carried out?
- Which standard and which evaluation system (system of valorization) is best suited?

The actor who performs an objective function can be an individual, a team or even the entire network. In the case of an organization the objective function can be included in a hierarchical network of objective functions, that is, as part of a value added chain (e.g., research, development, marketing along the chain). Each of these goals (products) requires other network structures. “Excellent” processing of tasks requires that various relationships to resources are available (optimal link allocations).

Here, too, the principle is: “Form follows function”. To be excellent each network requires a different form of relationship among the actors, depending on the function (CROSS/PARKER, 2004; GARGIULO/RUS, 2001). In one case, a closure network is better, while in a different case, a structural holes network is better suited. In yet

another case, a hybrid form of both types may be called for. There is no point in pinning down network excellence to one single ideal type. Excellence is a dynamic notion which requires different manifestations and rules of recombining relationships within a network. It can also appear in various forms (“polymorphism” of network types).

Scalability as a criterion of excellence

For instance, very different forms of networks are needed in a project for brainstorming and producing new ideas than for creating a prototype, for doing routine processes and for marketing a product (VALENTE, 1995; HARGADON, 2003). In all of these cases, the standard for an excellent network is the same: Excellence refers to the ability of actors to adapt their network structures to different objective functions (scalability of networks) and to thus carry out complex demands and tasks on a long-term basis.

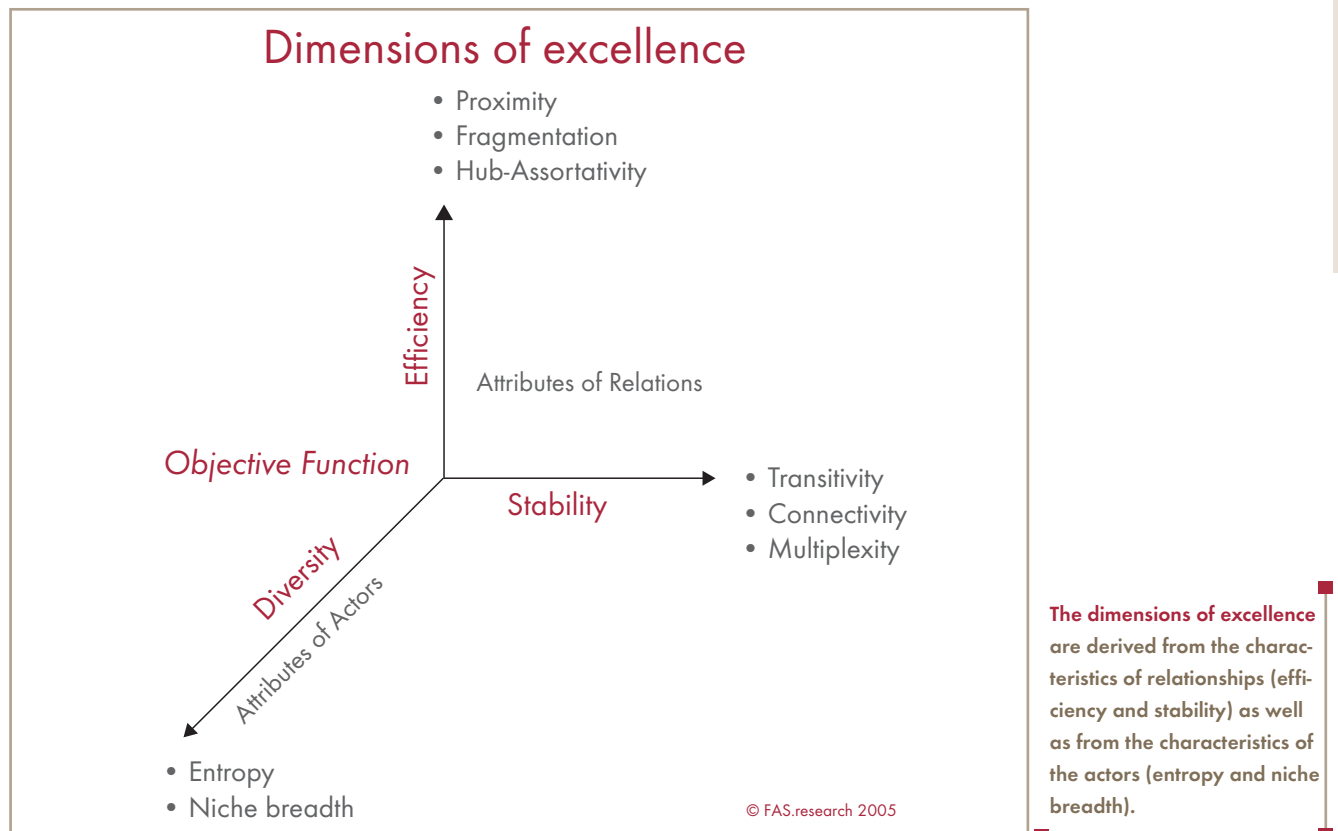
Specifically, this means that an actor does not just have to be efficient and effective to carry out specific objective functions but also withstand external shocks. It must show a high degree of

adaptability and capacity to learn and be capable in the long run of developing new objective functions (innovations) and/or integrating them. This is also what distinguishes this network approach from the standard business-oriented view of organizational efficiency and effectiveness.

The basic formula derived from complexity theory is: a network is excellent when it remains structurally and culturally coherent in spite of the constant change of its elements, their relationships, as well as objective functions (tasks). Even though it is constantly changing it still retains its internal cohesion – it continues to be able to fulfill the demands, i.e., it is still capable of producing, learning, carrying out search processes, developing and/or integrating innovations, giving their members a meaningful cultural (corporate) identity (LANGTON, 1989; KAUFFMAN, 1995, 2000; MEYER/DAVIS, 2003).

For this reason “excellence” cannot be exclusively viewed in terms of the criteria of economic efficiency (greatest possible yields with the least expenses) and effectiveness (best attainment of goals with the lowest use of means). An evaluation of excellence must also take into account structural and cultural robustness, resilience, sustainability, adaptability and potential for development (evolvability) (BONACICH/BIENENSTOCK, 2003; BORGATTI, 2003; JEN, 2005; WASSERMAN/STEINLEY, 2003).

Resilience, evolvability and adaptability give a network the ability to respond more quickly to sudden external developments (crises, new technologies, general changes in the market) and to be able to reconfigure itself. This adaptive potential also includes the ability to merge with other actors to create a new actor (mergers and acquisitions) or, in the opposite case, to split off >



Networks that are only efficient are also highly unstable. They are too fragile and vulnerable to be able to adapt to new conditions; they have too little disparity and redundancy to be armed for new, future, surprising developments and to keep the symbolic, cultural forms of the network (its "corporate identity") coherent under change. From the perspective of a network that has been optimized exclusively in terms of efficiency considerations, diversity is a disturbing "noise" that can only result in skyrocketing transaction costs; and redundancy is a waste of infrastructure costs. But in times of permanent change both – diversity and redundancy – are needed for the cultural and structural robustness of the network.

from existing organizations (e.g., buy-outs, spin-offs). The idea is to not only configure the relationship structure of the network in a variable way but also to allow for the possibility of a transformation of the identity of the actors (evolvability).

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If, by contrast, one demands potential for development and innovation, other structural characteristics of the network apart from efficiency must be taken into account so that the network also features adaptability, evolvability and robustness.

On the edge of chaos: complex networks

Researchers in complexity theory have reached a consensus that networks with the best characteristics in terms of robustness, adaptability and evolvability are those that have neither a too high nor a too low network density (degree of connections between actors). Excellent networks in this sense of the word are situated at the interface between pure interdependence (everyone is linked with everyone else, i.e., the state of one actor is dependent on the state of all other actors in the network) and complete independence (the state of one actor is completely independent of the state of another actor).

Excellent networks are complex networks "on the edges of chaos" (LANGTON, 1989; KAUFFMAN, 1995, 2000). They are mobile and flexible enough to be capable of learning and innovating, to produce sense and meaning in terms of cultural identity, to adapt and/or are influential enough to adapt the environment to their own needs. They are also sufficiently robust, i.e., able to withstand the adversities of an internal and external world often subject to radical changes (e.g. accidents, errors, new technologies, market changes, illness or job change of organizational members, new fads, cultural codes).

The structural characteristics of such networks reveal various scalable parameters, i.e., parameters that can be easily set to respond to new demands, which is why they are also called **multi-scale networks** (WATTS, 2003; WATTS/SABEL/DODDS, 2003). Depending on how these parameters are "tuned", the robustness, adaptability and evolvability of a network change in relation to the objective function of a network.

Crucial parameters: efficiency, stability and diversity

We can distinguish three parameters which, in the following, will serve as the starting point for describing in operational terms the dimensions of a SWOT analysis. These three parameters must be present in a certain combination and manifestation, if the network is to be excellent with respect to a certain objective function. A network must show the following parameters: efficiency, stability and diversity. Recent research on the subject of complex networks (KAUFFMAN, 1995, 2000; BORGATTI, 2003, MITCHELL/NEWMAN, 2002) has cited these characteristics as the crucial parameters for assessing "excellent networks". The dimensions of **efficiency** (y-axis) and **stability** (x-axis) refer to the characteristics of relationships, whereas **diversity** (z-axis) captures the characteristics of the actors.

5. Excellence indicators

In recent decades the scientific community has developed a number of structural indices to measure the different aspects of stability, efficiency and diversity in networks. FAS.research has selected indicators that are listed in the following. Its own experience has demonstrated that these indicators show the highest validity in the context of application in the fields of technology and innovation policy.

EFFICIENCY

Proximity: measure for the average distances (= number of handshakes) between actors in the network. The greater the distances (also referred to as characteristic path lengths), the higher the fragmentation of the network, extending the dissolution of the network in unconnected components. The higher the average proximity value in the entire network, the lower the transaction costs in the network. On the level of actors, this means that a single actor can have an efficient network at his/her disposal when he has a very close proximity to all

the other actors; i.e., when he/she can reach a maximum number of actors within a few steps. Typically, the structural holes network is highly efficient in terms of transaction costs. In such networks, the relationships to actors that have no relationship to each other dominate. Thus each contact opens up access to different network clusters. While an actor can quickly reach each point in the network the following principle still applies: the more efficient a network is, the lower the stability, since maximizing the indirect reach requires that there are only dyadic relationships that have no backing from transitive relationships (= common friends or foes). If an individual partnership is disrupted, all contacts to this region of the network are lost. High indirect reach can thus only be "bought" at a high price that must be paid as soon as a link is lost. Beyond this, it is extremely difficult for trust to develop in such a network that is optimized only on the basis of efficiency considerations, since

PROXIMITY

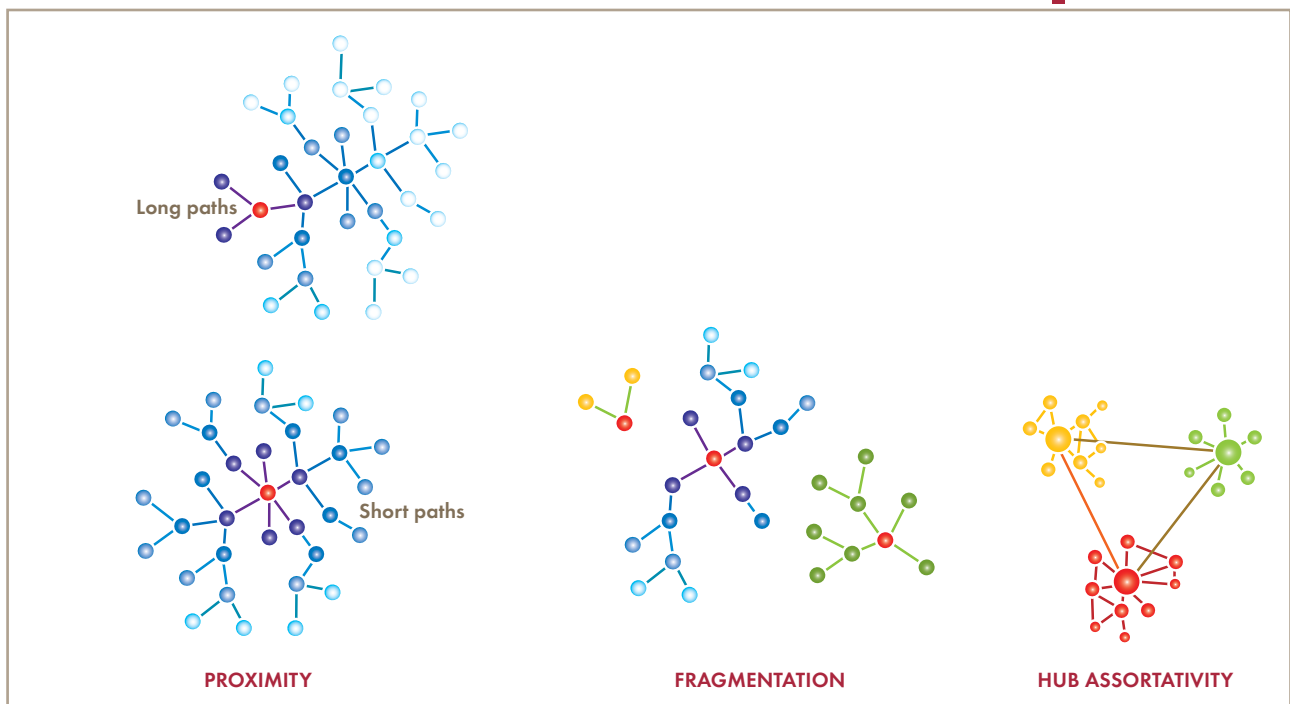
Average distances (number of steps) in a network are dependent on network structure and the network position of the actor.

FRAGMENTATION

Percentage of actors who cannot be reached by means of direct and indirect contacts.

HUB ASSORTATIVITY

Dependence of total centrality on the centrality of the few actors who are connected.



trust only thrives under certain structural conditions (e.g., in a high redundancy of friends, foes, goals, interests, benefits). In this sense a theoretically high indirect network rank is often unrealistic in social terms, since the trust within dyadic relationships is lacking. This trust is, however, the prerequisite for resources actually being exchanged and/or someone actually offering another person his contacts (BORGATTI, 2003).

Fragmentation: measure for the percentage of actors who cannot be reached on the level of the entire network – neither through direct nor through indirect contacts. The smaller the fragmentation in the network, the more efficient it is, since all partial areas of the network (so-called components or subgraphs) can be reached.

Hub assortativity: indicates whether central actors (so-called hubs) are connected with each other (also referred to as “degree correlation”). The greater the assortativity of the hubs, the more efficient the network, since the direct contacts among the hubs create “shortcuts” throughout the network which enable one to very quickly reach different parts of the network. This mainly guarantees that a hub’s direct contacts (to other hubs) have a high secondary reach (indirect contacts) (Burt criterion of efficiency), i.e., that it can reach

a maximum number of indirect contacts with a small number of direct contacts (BURT, 1992; NEWMAN, 2002).

STABILITY

Transitivity: degree to which actors in a network have common “neighbors” which also means that they are embedded in stable triangular relationships (so-called triangles) (BATAGELJ/ZAVERSENIK, 2003). The more common partners two actors have, the more stable their relationship is, since the actors are forced to establish positive relationships among themselves (rule of transitivity). Generally the following holds: The stability of a relationship between two actors can be depicted as the direct function of the number of their common “friends” and “foes”.

Connectivity: indicates how many actors must be removed from a network for it to be fragmented (= disintegrates into individual parts) or for existing components to disintegrate into further sub-components. The more actors that have to be eliminated from the network until the network disintegrates (so-called “minimum cutset”), the more stable the network is. On the level of the actor, this means that each actor/link contributes to a different degree to the cohesion/adhesion of

TRANSITIVITY

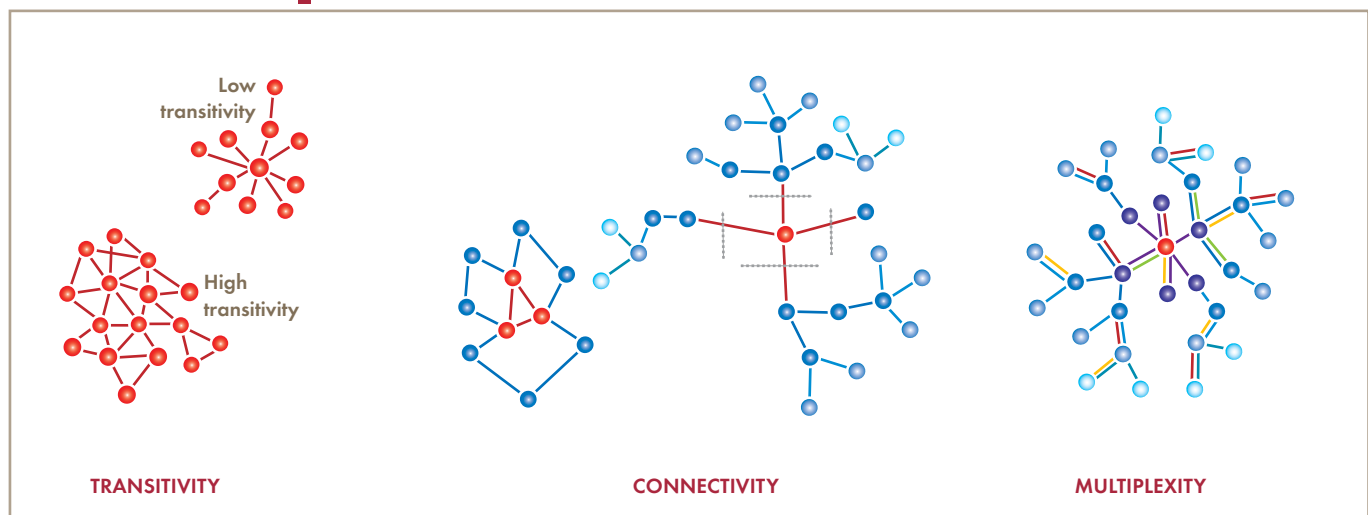
Number of common neighbors of two actors. The number of triangles a relation is embedded in.

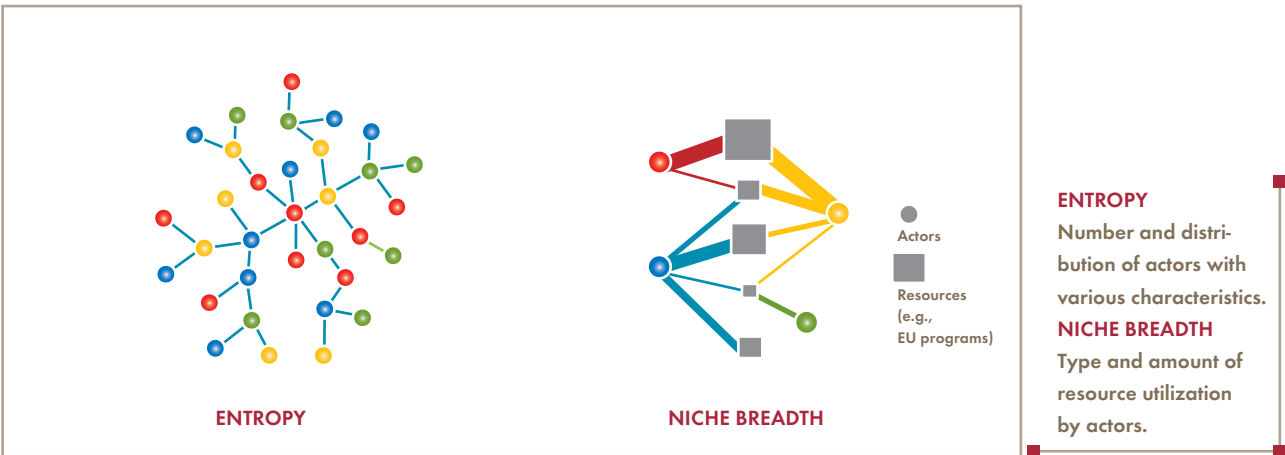
CONNECTIVITY

Number of actors/relationships whose removal can lead to dissolution of a network.

MULTIPLEXITY

Various levels of relationships connect actors.





the network (WHITE/POWELL/OWEN-SMITH, 2003).

Multiplexity: indicates the number of relationship levels the actors have with each other. This is the case, for instance, when there is not just an exchange of knowledge between two actors who are working on the same research project but also possibly an exchange of personnel and/or contacts on the ownership level (shares, etc.). The more diverse and multiplex these levels of contacts are, the richer the possibilities of exchange for an individual actor. The more types of relationships, the higher the stability, since the dimensions of different relationships reinforce each other and become “interlocked”. Typically, multiplexity rises with an increase in transitivity.

DIVERSITY

Entropy: indicates the difference of actors, e.g. professional groups, scientific disciplines, age groups, genders. Entropy is a measure for security (order) and insecurity (disorder) in the network (MAGURRAN, 2004).

Entropy stands for the likelihood of two randomly selected actors from a network having the same characteristic (e.g. company size, gender, profession, scientific discipline, task). If all actors in a network are the same (e.g., they are all physi-

cists), entropy amounts to zero, because there is nothing unsure. If all are different (and represented just as often), then there is maximum entropy (SHANNON/WEAVER, 1963).

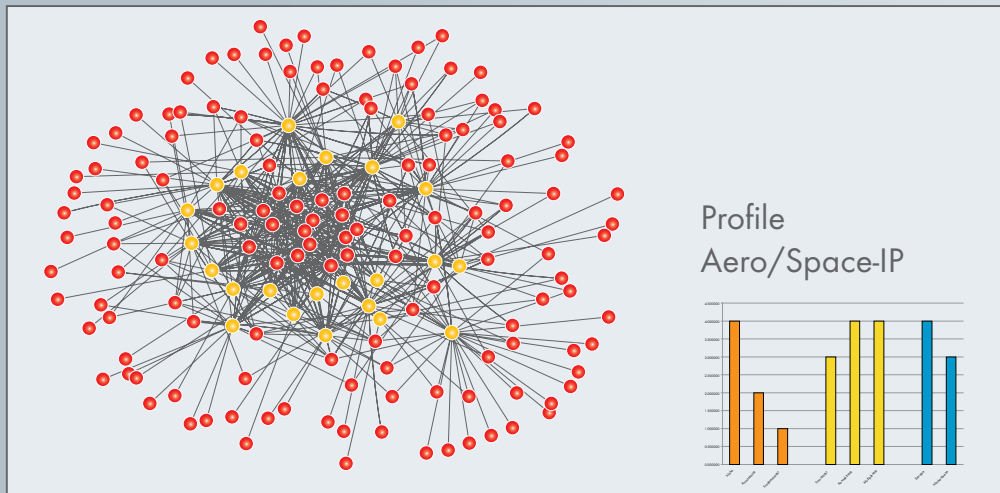
The more diverse the characteristics of the actors are, the more different the experiences and problem solution strategies that can be generated and also the greater the likelihood of radical innovations (breakthroughs). The more diverse a network, the higher the control and implementation costs and the greater the dangers of a Babylonian jumble of languages.

Niche breadth: Niche breadth, a concept closely related to diversity, stems from ecology (KREBS, 1999). It provides information on the type and amount of different resources that are used by the actors. An actor with a large niche breadth plays an influential role in many different areas of a value-added chain (so-called “all-rounder”). This way he often partakes more of the total use of resources. The narrower the niche breadth of an actor, the higher is his/her specialization and the lower his/her share in the total resource turnover (so-called “specialist”). The general principle is that with growing complexity of structures the number of specialists increases. ■

Profile of Excellence Research

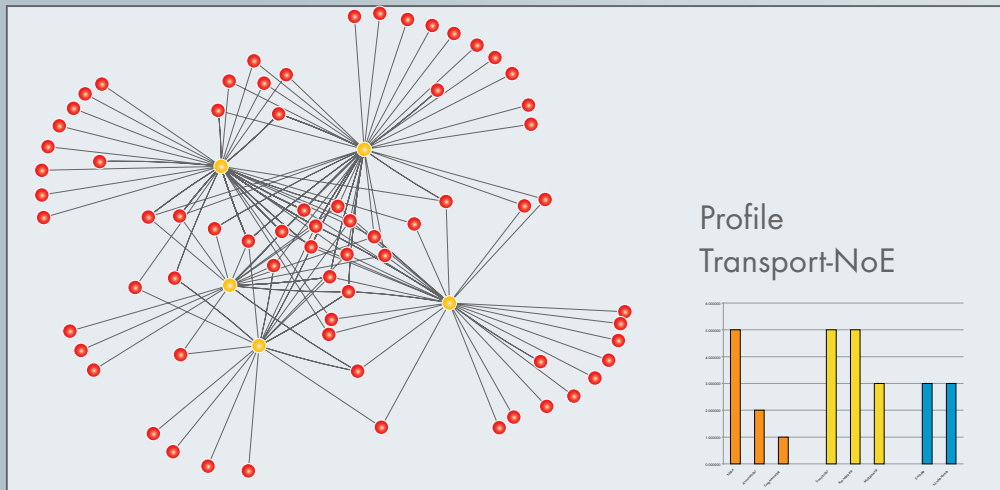
The network in the Aero Space (= Aeronautics and Space) program and the IP (Integrated Project) instrument corresponds in all dimensions to the profile of excellence for research: strong networking (proximity of actors in the center) with high diversity (with regard to the differences in partners regarding citizenship and type of organization) and high connectivity guarantees best conditions for developing new ideas.

The illustrated Aero/Space-IP network possesses all the structural features which are ideal for basic research, also with regard to radical innovations.

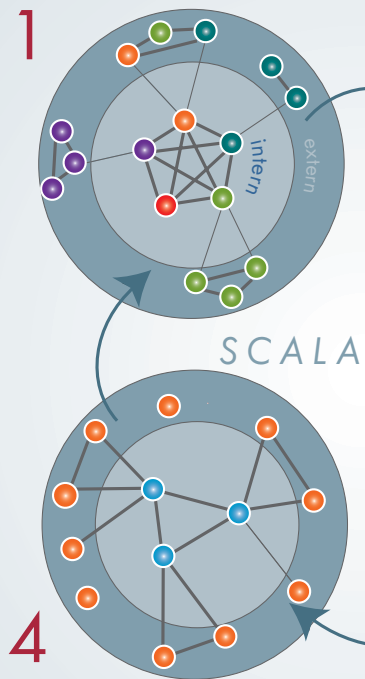


Profile of Excellence Diffusion

The profile of excellence on diffusion is particularly pronounced in TransportNoE, the network of projects and consortium partners in the transport program (Sustainable Surface Transport) and the NoE (Networks of Excellence) instrument. Low diversity, high efficiency and, above all, high transitivity in the network guarantee that there is trust among the participants, which is important for diffusion processes in terms of disseminating innovations, new knowledge but also in terms of introducing new products to the market (word-of-mouth propaganda, adoption pressure through common partners). The structural features of the Transport-NoE network are ideal to trigger diffusion processes.



Prototyp of Exc



The data set of the 6th Framework Program was studied in relation to the project on the level of their pertinence to individual programs (e.g. Transport = Sustainable Surface Transport) and instruments (e.g. NoE = Networks of Excellence), while the project partners were examined on the level of national status and type of organization.

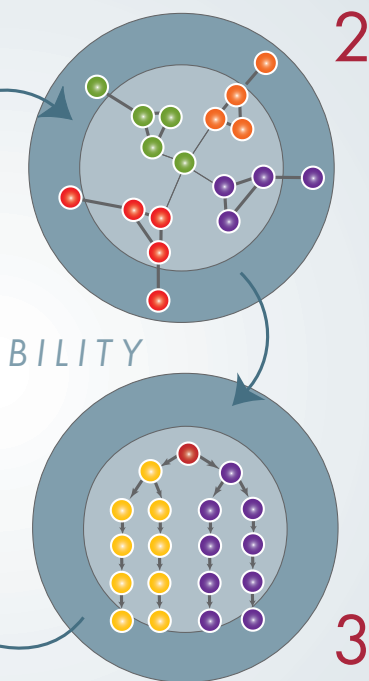
The resulting networks were studied according to the dimensions of excellence, with the findings being ascribed to the individual profiles. For all profiles of excellence, examples were found in the studied data set. An example (taken from many) has been added to this overview. Depending on which target functions the various programs/instruments have been

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Network Analysis for Science and Business

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created, the affiliation to certain profiles of excellence can be good or bad. If an instrument has, for instance, the task of conducting basic research and the network structure does correspond to the profile of excellence "production", the network will not be able to perform its target function effective.

The networks consist of projects (represented by yellow circles) and the project partners (red circles).

Analysis and visualization:
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Data: European Commission
Source: PROVISO, a project of the BMBWK, BMVIT, BMLFUW and BMWA [www.bmbwk.gv.at/proviso];

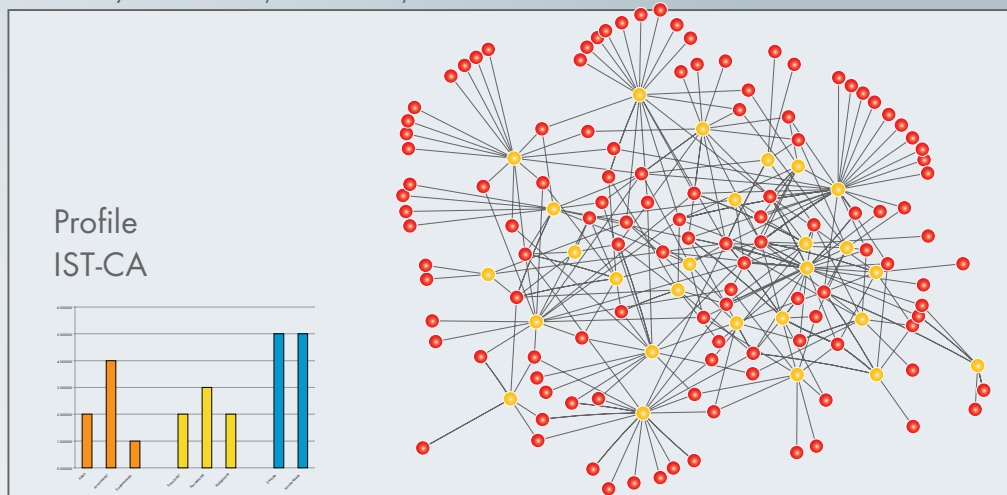
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Profile of Excellence Development

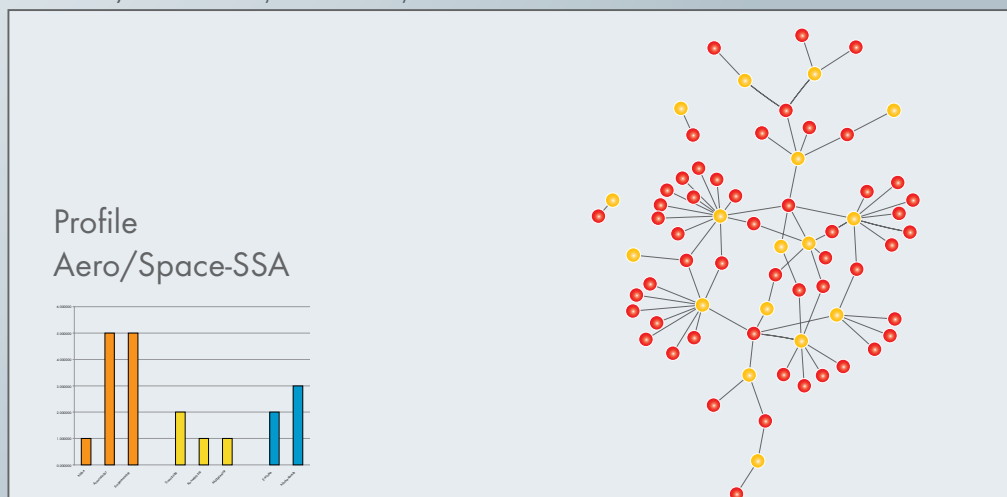
An example for the profile of excellence development was found in the IST (Information Society technologies) and the CA (Co-ordination Actions) instrument: here the lack of a dense center is an indication of the modular structure of the network.

The network structure of IST-CA is ideal for developing prototypes out of the results of basic research or further improving existing technologies (incremental innovations).



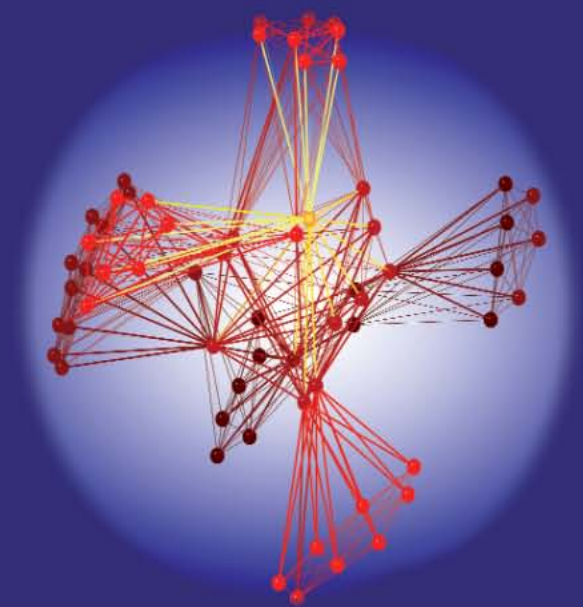
Profile of Excellence Production

Aero Space SSA, the network of projects in the Aero Space (= Aeronautics and Space) program and the SSA (Specific Support Actions) instrument show us the image of a completely different structure. Only a few actors have the structural control in this strongly hierarchically structured network. The profile of the Aero/Space-SSA network displays a linear, top-down network structure, which is ideal for processing standardized products and services (like for instance the organization of congresses).



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Strategy 2010

Excellence

Members of the Austrian Council

Imprint

Strategy 2010

"Perspectives for Research, Technology and Innovation in Austria", August 2005 / Executive Summary.



With this "Strategy 2010 – Perspectives for Research, Technology and Innovation in Austria", the Austrian Council for Research and Technology Development is opening a new phase of the public debate on RTI policy. The objective is to intensify a strategic discourse that should culminate in the development of a national action plan.

The "Strategy 2010" is geared to the global objective of:

Strengthening the competitiveness and dynamics of the Austrian economy in order to provide for sustainable economic growth and an expansive increase in the levels of employment.

Review and outlook

The starting point for "Strategy 2010" is an assessment of the progress Austria has made in terms of its RTI policy at the end of the first term of office of the Austrian Council for Research and Technology Development (established in 2000), and three years after the Austrian Council published the National Research and Innovation Plan. Overall, it shows a gratifying picture. In recent years Austria has managed to catch up in terms of RTI policy. Over the last five years, the research quota in Austria has risen from 1.9 to 2.35 percent and is now significantly above the EU average.

Important structural reforms such as the establishment of Austria Wirtschaftsservice Gesellschaft (AWS), the Austrian Research Promotion Agency (FFG) and the reform of the Fund for the Promotion of Scientific Research (FWF) promise greater efficiency in the innovation system.

Today these results show that Austria has the prospect of catching up with the top European per-

formers in research, technology and innovation. Realizing this chance requires both a firm commitment from all the players in the innovation system to further increase the support they have so impressively demonstrated in the catching-up process, and maintaining investment in research and development (R&D) at the steep rate of growth seen in previous years. At the same time, it is necessary to substantially improve the quality and efficiency of the Austrian innovation system, thus increasing the return on investments in R&D.

The new strategic orientation can be summarized in three basic principles:

- Promote quality on a broad level and excellence at the top.
- Strengthen networking and co-operation between science and industry.
- Improve the efficiency and effectiveness of the promotion system. ■

<http://www.rat-fte.at/UserFiles/File/Strategie2010.pdf>

Goals and fields of action

In keeping with this strategic orientation the Austrian Council has identified ten strategic fields of action and formulated specific recommendations for each:

1. At the universities it is essential to create and guarantee for the future conditions that enable research and teaching to meet the highest standards of international excellence.

The Austrian Council therefore recommends:

- increasing funding for the university research infrastructure program
- increasing the FWF budget by some nine percent per year
- promotion of special and distinct profiles at universities that will lead to a concentration of degree programs

2. Strengthening the innovative ability of business enterprises is crucial for actively shaping the structural change that is taking place in the wake of globalization and is consequently a central objective of RTI policy.

The Austrian Council therefore recommends:

- optimizing the system of indirect research promotion
- increasing the FFG budget by some nine percent per year
- optimizing the instruments for strengthening start-up dynamics and expanding the Headquarter Strategy

3. Collaboration between players from science and industry in the co-operative sector is essential to ensure the efficiency of the innovation system and must be stepped up.

The Austrian Council therefore recommends:

- the consistent continuation of the growth strategy for the co-operative sector
- the rapid implementation and provision of appropriate funding for the program for the further development of the competence centres
- merging the BRIDGE programs at the interface of basic and applied research started by the FWF and FFG and increasing the funding for these programs.

4. The development of a strategy of excellence accompanied by a campaign to improve quality at all levels of the innovation system should guarantee Austria's advance to a position as an international frontrunner.

The Austrian Council therefore recommends:

- implementing the concept for a university of excellence under the title "Austrian Institute of Advanced Science and Technology" (AIST)
- developing a concept for a strategy of excellence encompassing all sectors of performance
- comprehensive strategy of excellence
- measures to facilitate the emergence of further centres of excellence in all sectors of performance

5. The development of the European Research Area requires that national RTI policy has an international orientation development of clear participation strategies

The Austrian Council therefore recommends:

- the development of a national strategy for participation in the program lines ERA-NET, ERA-NET plus and Art. 169 prograes within the scope of the 7th Research Framework Program
- increased participation in existing research structures in Europe

6. The **regional dimension** plays an important role in the innovation system, making the efficient co-ordination of regional and national R&D activities a priority.

The Austrian Council therefore recommends:

- establishing a co-operation platform to harmonize federal and provincial activities
- increasingly positioning the universities of applied science as regional crystallisation points for research network
- bundling federal technology transfer programs

7. Safeguarding **human resources** for R&D requires an increase in the percentage of women in research, first-class university education as well as measures to foster mobility.

The Austrian Council therefore recommends:

- the implementation of gender mainstreaming (GM) in all areas of RTI policy and the continuation of the fforte initiative to promote women in research and technology
- the development of an Austrian strategy to promote lifelong learning
- the reorganisation of grant programs

8. The **state** must act strategically in its diverse roles as a promoter, customer, regulator and administrative manager in order to increase the dynamism of innovation processes.

The Austrian Council therefore recommends:

- the nationwide expansion of e-government services
- the reinforcement of research themes with double dividends such as the FORNE strategy for sustainability research or the program on security research

9. Following institutional reforms the promotion system now requires efficient management of the **funding portfolio** at the program level with monitoring and evaluation instruments.

The Austrian Council therefore recommends:

- concentrating the RTI competences of the Federal Government at two ministries
- outsourcing programs to the funding agencies that in the past have been handled by the ministries
- drawing up an integrated overall concept for the portfolio of RTI funding programs
- obligatory evaluation for all programs with a life of more than five years or a volume of at least one million euros

10. After the gratifying development in recent years, **spending** on R&D must be steadily increased and focused upon strategic objectives.

The Austrian Council therefore recommends:

- an increase in public funding for R&D by seven to nine percent annually
- the largest increase in R&D expenditure in the co-operative sector (an increase of some 80 percent by 2010), a 70 percent increase for the business sector and an approximately 40 percent increase for the university sector
- clear structural logic commensurate with the use of the individual sources of financing (financing of basic programs and open-ended expenditure from the ordinary budgets, National Foundation for RTD funding for new programs and initiatives with a long term focus, Action Program funding for impulse programs of a temporary nature)

Excellence – a Question of Gender?

Equal opportunities for women in research and technology. *By Brigitte Tiefenthaler*

In Austria women make up more than half of the student population at the universities. Since 1999, they are also the majority of graduates. At the same time only a third of all assistants and less than ten percent of the professors are women. Women can secure a place as students, but they are not able to assert themselves to an equal extent as researchers in science and business. They continue to be under-represented, and this most notably in top decision-making positions, in industrial research as well as in most scientific and technical disciplines.

The reasons for this situation are diverse and complex, ranging from the often “typical” selection of profession to lack of support in studies and career, all the way to structures that strongly limit the career opportunities of women. Scientific findings have shown that in some processes of selection and evaluation procedures, the performance of men and women is assessed differently. Excellence is also not just a product of talent, hard work and individual performance. Excellence is in part a product of good networks and personal support.

If one wishes to understand and improve the situation of women in RTI it is essential to address the concepts of scientific quality and excellence against the backdrop of social role ascriptions and expectations and to analyse evaluation procedures, career development and stereotypes. The following questions are important in this connection: According to which criteria and with which procedures is scientific excellence being measured and assessed at present? Are these criteria and procedures gender-neutral? Under what conditions is it possible for women, to the same extent as men, to develop scientific excellence, to work in excellent research networks and to climb to top positions?

The discrimination of women in RTI does not just mean a waste of qualified human resources, it is also an obstacle for the development of RTI in Europe. If Austria wishes to reach an internationally leading position, it cannot, and should not, do without the creativity and know-how of women for very long. One of the goals of “strategy 2010” is thus to secure equal opportunities for both men and women in RTI and to ensure that women are equally represented in all sectors and levels of RTI.

The necessary instruments are gender mainstreaming and the promotion of women’s interests. A central role is played by the inter-ministerial initiative fFORTE initiated by the Council to promote women in research and technology. fFORTE has proven to be valuable and is thus an initiative that should be continued, and if necessary, developed further. Discriminating conditions and structures that bring forth inequality could be changed with consistent gender mainstreaming. Gender mainstreaming was legally enshrined in Austria in 2001 as binding for all political areas. However, gender mainstreaming and the promotion of women’s interests are not tasks that can be assumed by the government alone. The equal status of women in research and innovation can only be achieved if all actors in the innovation system advocate this in their realm of action. ■



Brigitte Tiefenthaler,
*Office of the Council for
Research and Technology
Development*

The Members

Austrian Council for Research and Technology Development.

On September 6, 2005, the Austrian Council for Research and Technology Development began its second consultation period, which will last until 2010. The Council was established by the Austrian Government in 2000. It has been a separate legal entity since September 1, 2004. The Council's area of competence comprises the entire national innovation system. Its recommendations are directed to both federal and provincial government authorities. Its goal is to make a significant contribution to a future-oriented policy of research, technology and

innovation. The Council has eight members that are eligible to vote. Four of them are appointed by the Federal Ministry for Education, Science and Culture and the other four by the Federal Ministry of Transport, Innovation and Technology. Further members of the Council (without a vote) are the Federal Minister of Transport, Innovation and Technology, the Federal Minister for Education, Science and Culture, the Federal Minister of Economic Affairs and Labour, and the Federal Minister of Finances or representatives appointed by these ministries.

Austrian Council – members with voting rights:



Dipl.-Ing. Dr. Knut CONSEMÜLLER – Chairman of the Austrian Council ■

Knut Consemüller, a native German from Dortmund, studied steel metallurgy and business. In 1991 Consemüller was appointed as head of research and development on the corporate board of Böhler-Uddeholm. From 1976 to 1984 he was a member of the German

Board of Technology. He was elected chair of the board at the constitutive session of the Council on September 6, 2000 and was confirmed in this office for the second period of the Council from September 2005 to September 5, 2010.



Univ.-Prof. Dr. Günther BONN – Vice Chairman of the Austrian Council ■

Günther Bonn, born in Innsbruck, studied chemistry at the Leopold Franzens University in Innsbruck. In 1995 he accepted an appointment as Full Professor for analytic chemistry at the Institute for Analytic Chemistry and Radiochemistry at the University of Innsbruck. Bonn

was a member and consultant of the FWF until 2003. At present he is on the university council of the Medical University in Innsbruck. The Federal Ministry for Education, Science and Culture appointed him a member of the Council.



Univ.-Prof. Dr. Dervilla DONNELLY ■

Dervilla Donnelly was born in Dublin and studied chemistry at the University of Ireland. In the mid-1980s she received a professorship for photochemistry. Donnelly has served as a member and vice-president of the executive board of the European Foundation for Science

and the European Science and Technology Assembly ESTA. She is on the board of the Dublin Institute for Advanced Studies. The Federal Minister for Education, Science and Culture appointed her to the board in 2000 and 2005.



Dipl.-Ing. Albert HOCHLEITNER ■

Today's general director of Siemens AG Austria studied physics at the Vienna University of Technology. In 1985 he joined the Viennese Schwachstromwerke (company for producing weak voltage) and soon took over the section for software development. In 1992 he was appointed to the board of directors of the corporation and

in 1994 he was elected chair of the board. For several years Albert Hochleitner has offered consultancy services as an expert on business-relevant issues of research and technology policy. In 2000 and 2005 he was appointed a member of the Council by the Federal Ministry of Education, Science and Culture.

■ **Dipl.-Ing. Reinhard PETSCHACHER**

Reinhard Petschacher can be seen as one of the very first specialists in the area of semi-conductor technologies. After studying information technology at Vienna's University of Technology he worked on optical systems for Daimler Benz in Ulm. In 1980 he moved to Siemens center for the development of microelectronics in Villach. He later took over the development management for

telecommunication components at the Villach and Munich locations. Reinhard Petschacher is head of development in the automotive, industrial and multi-market section of Infineon Technologies Ltd. He was appointed a member of the Council by the Federal Minister of Transport, Innovation and Technology in 2000 and 2005.



■ **Mag. Hans SCHÖNEGGER**

Hans Schönegger studied business administration and business education at the University of Innsbruck. In 1995 he became the head of the funding section of the Carinthian Business Support Fund (KWF) which he was appointed to direct in 2002. Since 1988, Hans Schönegger has been the managing director of the Carinthian Betriebs-

ansiedelungs- und BeteiligungsgmbH and since 2002 managing director of Lakeside Science & Technology Ltd. He is responsible for the planning, development and construction of this unique science and technology park. He was appointed a member of the Council by the Federal Minister of Transport, Innovation and Technology.



■ **Prof. Dipl.-Ing. Jürgen STOCKMAR**

After studying machine building Jürgen Stockmar, a native German, worked for Audi and later for Steyr-Daimler-Puch where the board appointed him as the head of research and development in 1985. After being appointed to the board of Audi AG he returned to Steyr-Daimler-Puch. After heading the development department at Adam Opel AG he was in charge of

international development and technologies at Magna International from 1998 on. Since 1997 he has been teaching at the Vienna University of Technology and initiated the Frank Stronach Institute at the University of Technology in Graz. Jürgen Stockmar was appointed a member of the Council by the Federal Minister of Transport, Innovation and Technology.



■ **Dr. Gabriele ZUNA-KRATKY**

After completing her training Gabriele Zuna-Kratky worked from 1981 to 1988 at the Lehramt für Polytechnische Lehrgänge (polytechnical training courses.). In June 1988 she completed her doctorate in philosophy and then worked for the Federal Ministry for Education and Art in the department for school-TV, school-radio and media education. In October 1997 she was appointed director of the Austrian archive of sound recordings (Österreichische Phonotheek). Since January 1,

2000 she has been the first woman director of a technical museum – Vienna's Technical Museum. Zuna-Kratky is also on the university council of the University of Applied Arts in Vienna, a member of the board of the Deutsches Museum in Munich and a member of the board of the foundation of the Berlin Museum of Technology. In September 2005 Gabriele Zuna-Kratky was appointed a member of the Council by the Federal Ministry of Education, Science and Culture.



Consulting members:

■ **Martin BARTENSTEIN** – *Federal Minister of Economics and Labor*

■ **Elisabeth GEHRER** – *Federal Minister of Education, Science and Culture*

■ **Hubert GORBACH** – *Federal Minister of Transport, Innovation and Technology*

■ **Karl-Heinz GRASSER** – *Federal Minister of Finances*

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All contributions represent the opinion of the authors. Publication of these contributions indicates neither approval nor disapproval of these opinions. The Editors.

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