Networks of Knowledge Production

A study by FAS.research on behalf of:
RFTE - Austrian Council for Research and Technology Development,
FFG - Austrian Research Promotion Agency,
w-fFORTE - Economic Impulses for Women in Research and Technology
Networks of Knowledge Production

The network of knowledge production reveals the links between scientific disciplines (circles) that researchers in basic and cooperative research establish through their activities (lines between circles). The sciences that are part of both basic and cooperative research are shown in red.

Analysis and visualization: FAS.research 2007
Both in basic and cooperative research, the knowledge base is kept alive by the work of scientists.

Their interdisciplinary and transdisciplinary cooperation in countless projects in Austria as well as in an exchange with the international scientific community contributes to continuous development within individual scientific disciplines and promotes findings by establishing a transfer between the disciplines or between industry and science.

Austrian research promotion institutes support scientific activities in some 1,500 disciplines. The brochure „Networks of Knowledge Production“ shows how these disciplines are linked by the activities of scientists and what this means for the dynamic development of the Austrian innovation system.

RFTE - the Austrian Council for Research and Technology Development, FFG - the Austrian Research Promotion Agency, and w-forte - Economic Impulses for Women in Research and Technology dedicate this brochure to the scientists in acknowledgment and appreciation of their achievements. We hope that the brochure will enable readers to better visualize the diversity and importance of research activities.
How significant are cooperation and networking for increasing Austria's innovation potential?

CONSEMÜLLER: The technologies of the future are marked by high investment costs, an increase in interdisciplinary fields, and the growing significance of basic research. In this context cooperation is an indispensable requirement for all kinds of knowledge transfer, forming the nucleus for innovative development in our knowledge-based society.

POHORYLES-DREXEL: The promotion of cooperation between industry and science as well as amongst enterprises is a top priority for the Ministry of Economics and Labor (BMWA). Studies and evaluations of programs that have already been established successfully, such as CD laboratories and centers of excellence, show clear positive effects.

EGERTH: "Cooperation" is the most important prerequisite and therefore the basis for networks. The FFG (Austrian Research Promotion Agency) accordingly takes "networking" into account as a criterion for research funding. Even without these specifications we can see a consistent increase in teamwork – particularly in the bottom-up domain.

POHORYLES-DREXEL: I see great challenges ahead in areas in which research institutes and enterprises are expected to contribute to the solution of sociopolitical problems such as "Aging," "Climate Protection," "Security," etc. The success of such measures depends on the teamwork of a large number of players from diverse fields, both scientific and non-scientific. Amongst other things, we need to cooperate in inter- and transdisciplinary projects and to also include the social sciences.

Which conditions should be established by politics to promote networking between science and industry?

PSEINER: Networking between science, research and industry creates win-win situations and is particularly crucial for the innovation level within a society. A high potential for reflection, confidence-building interaction processes, and cooperative attitudes plays a
central role for the networking and integration of enterprises into research processes. The right conditions have to be established on all levels.

**CONSEMÜLLER:** The foundation of cooperative research centers, such as COMET, CD laboratories, and the Ludwig Boltzmann Institute, is a successful path that we should continue to pursue. Cooperation with industry has to be made more attractive, particularly at the sites where research takes place, i.e. chiefly the universities. Only when researchers’ creative ideas are linked to the needs of “customers,” i.e. entrepreneurs, can the innovation process begin.

**POHORYLES-DREXEL:** Within the last couple of years, the link between science and industry has taken a positive turn in Austria, on the national as well as international level. I still see a need for more targeted support of cooperation between female scientists and industry, however.

**What conditions must politics establish to improve the integration of women in the scientific landscape, particularly in the natural and technical sciences?**

**POHORYLES-DREXEL:** The initiative fFORTE (Women in Research and Technology) promotes women and girls at all educational levels and at all stages of their careers and has been able to establish many positive precedents in the past few years. It is also important, however, to establish conditions that allow women to reconcile the demands of family and career as well as to orient ourselves toward a more contemporary view of parenthood. Allowing a research culture to develop that supports diverse approaches towards research and innovation will also benefit women.

**CONSEMÜLLER:** The disadvantages women face in the fields of research, technology and innovation (RTI) are not only a waste of qualified human resources but also a barrier to the development of RTI in Europe. If Austria wants to achieve a leading position internationally, it can no longer afford to do without the creativity and expertise of women.
EGERTH: It's up to society as a whole to support women in their decisions, occupational qualifications and networks. This is where politics is challenged to step in and help. The Austrian Research Promotion Agency (FFG) focuses on targeted sponsorships, actively assisting women and acting as an example in an area it can influence directly: its own staffing policy.

**What is your view of the mutual understanding and interaction between applied and basic research? Do you see a need for mediation?**

PSEINER: Basic and applied research are intertwined in symbiosis. Therefore, it would be a stereotype to postulate a lack of understanding that has to be improved via mediation. It is important, however, to strengthen, deepen, and institutionalize contacts and to search out new partners in order to find the right experts to solve problems and to best serve customers.

CONSEMÜLLER: Despite certain contradictory tendencies between basic research and applied research, progress can only be made if both areas work together closely and inspire each other.

The relationship between basic and applied research has changed. The path from idea to product has not only become shorter, but also more intricate and requires manifold transfer connections between all persons involved in order to create added value.

POHORYLES-DREXEL: We are coming to realize that the differentiation between basic and applied research is not that clear-cut in actual practice. Research and development are more focused on finding solutions for existing problems, geared less to a linear than to an open innovation concept that takes into consideration diverse factors, such as customer needs.
Generating new knowledge means combining existing knowledge in a new way. This requires social networks: Whether scientific teams work together on solving a problem or searching for new and better hypotheses, or a single researcher takes up another’s work and develops it further – the persons involved are always linked together in a network.

But these networks are not made up only of scientists and their relationships. Instead, science brings a whole variety of elements together: persons, organizations, financial resources, technical tools, various forms of knowledge and information – to name only a few.

Networks form the social infrastructure for the allocation of the means necessary for science and research.

FAS.research has investigated at length the knowledge networks of basic and cooperative research. "Networks of Knowledge Production" is based on the findings made in the study "Excellent Networks“¹ and refines its conceptual framework. The following objectives were pursued:

- Description and analysis of the knowledge networks in basic and cooperative research with respect to their innovation potential,
- Profile of the strengths and weaknesses of knowledge networks in both realms,
- Determination and examination of the roles played by the various scientific disciplines and fields in the innovation process (horizontal and local integration),
- Comparison of the knowledge networks of women and men in basic and cooperative research in terms of strengths/weaknesses as well as their role in knowledge production.

The Importance of Knowledge Networks

- Three variables are important for successful research and innovation: financial resources, knowledge, and social networks.
- Networks are a non-material infrastructure that can be built, promoted and controlled in the same way as a material one (transport routes, telecommunication connections, etc.).
- Scientific policy is therefore a kind of infrastructure policy.

The role of scientific actors in the innovation process

Scientific actors have at their disposal varying network structures that determine which role they play in the innovation process:

**Local integration** – Locally integrated actors display strong networking within their own scientific field. This results in integrated specialization and strong scientific communities – prerequisites for incremental innovation, diffusion, and industrial implementation.

**Horizontal integration** – Horizontally integrated actors bring together knowledge from different fields (e.g. natural sciences and humanities). They represent linked diversity – which is indispensable for the development of radical innovations.

The combination of both horizontal and local integration results in four different roles for actors in the process of knowledge production:

- **Globally integrated actors**: strong horizontal and strong local integration.
- **Translationally integrated actors**: connections between different scientific fields, low degree of local integration.
- **Specialist integrated actors**: strongly networked with those in the same field, but few transdisciplinary contacts.
- **Specialist actors**: little horizontal and local networking, very specialized focus.
The Two Evaluation Cultures in Knowledge Production

An analysis of the knowledge networks in basic and cooperative research shows that there are vast differences between these two realms. The two networks are made up of different sciences and display disparate structures.

These networks in fact reflect two different cultures in terms of evaluating knowledge production:

• In basic research, the main concern is the scientific value of the knowledge produced and, in relation to this, the scientific prestige involved. The number of publications produced represents the most important standard of evaluation.
• In cooperative research, economic benefits and industrial utility are the standards by which the value of research work is measured.

These two evaluation cultures are in conflict with one another. Scientific and economic values are diametrically opposed standards by which to evaluate the knowledge produced. This tension-charged relationship represents the driving force behind knowledge production. It cannot and should not be done away with, but must instead be harnessed productively to the benefit of the innovation process. A mixture of these two cultures, allowing every scientist to learn to see his or her own work from the perspective of the other side, would by all means have a positive impact on the innovation process.

New ideas call for linked diversity, the connection between actors with differing resources. The selection and reinforcement of ideas calls for distributed diversity, actors specializing in different fields that can take up ideas and develop them further in a specific direction. Finally, the implementation and application of ideas calls for connections between industry and potential users (linked research).

Grafic: FAS.research 2007
How Knowledge Networks Come About

The knowledge networks in basic and cooperative research are made up of scientific disciplines linked by way of scientists, projects, or institutions. “Statistik Austria” has classified these disciplines in the Austrian Systematic Classification of Scientific Disciplines. Using various data sources and its own investigations, FAS.research has determined the main basic and cooperative research areas in which female and male scientists are involved as well as identifying the networks between these disciplines and how they are linked.

**Basic Research**

Data source: Project database of the Austrian Science Fund (FWF: www.fwf.ac.at). Funding period: 01/01/1992 to 11/16/2006; with 6,902 projects financed, assigned by the applicants to 1,070 scientific disciplines (women: 598, men: 1,025). Disciplines are considered linked when they are jointly named in connection with at least one FWF project.

**Cooperative Research**

**At the level of the centers**: main research disciplines of the institutions for cooperative research (K-kind, K-net and Kplus centers as well as Christian Doppler laboratories). Status: November 2006. Source: Federal Ministry of Economics and Labor (BMWA), www.appliedresearch.at. Disciplines are considered linked when they are jointly assigned to at least one center. **At the level of the researchers**: interviews with research associates (50 women and 168 men) in K-kind, K-net and Kplus centers on their main areas of research (women: 218, men: 427). Disciplines cited by at least one person are connected with one another. Interview period: January to April 2007. Survey: FAS.research. **Institutional networks**: Research and business partners, K-kind, K-net and Kplus centers, and Christian Doppler laboratories. Status: December 2006. Survey: FAS.research.
Depending on what goals a science pursues, different network structures will work to its advantage. If the aim is to develop radical innovations, the network should bring disparate scientific disciplines into a dialogue. Only then is there an opportunity to combine existing pools of knowledge in novel ways in order to give birth to new ideas. Sciences exhibiting this kind of network structure are known as “translational sciences” because they enjoy a pronounced horizontal integration and a high degree of transdisciplinary orientation. These include for example the formal sciences (mathematics, computer sciences), whose methods and models are applied in a wide variety of scientific fields (in both the natural sciences and humanities).

Horizontal integration, i.e. the creation of cross-connections between separate scientific disciplines, is not enough, though. It is also necessary to combine fields of research with one another that are as disparate as possible (linked diversity). Namely, the wider apart the interests of two cooperating actors or sciences are, the greater the likelihood that both of them will profit from collaboration since each has at its disposal resources the other one doesn't have, and they thus complement one other.

Joining this diffusion effect created through horizontal integration and diversity is the third factor of local integration. A new idea begs to be put to use; it needs to be translated into a prototype and prepared for practical applications. This in turn requires a critical mass of relationships with actors who are similar and who together can pursue the goal of implementation. Local integration is in addition necessary for the continuity of the research work of specialized scientific communities.

The following pages illustrate the landscape of basic and cooperative research in Austria. They show which network structures both areas display and what role each scientific discipline plays within these structures.

The results of the analyses on the following pages do not constitute an appraisal of the subject matter. The fact is that, as we said before: Which network structures are good and which are less beneficial depends on what goals a scientific discipline pursues and where it is located in the field of knowledge production.
The Knowledge Network of Basic Research

Knowledge Network of Basic Research. Linkage of scientific disciplines through FWF projects (1992 to 2006). Included are all disciplines that are linked through at least three projects. Size of circle: number of sciences with which each discipline is linked. Colors identify scientific fields (see Key). Within the dotted ellipses are found the attractor zones in basic research: historical sciences, formal sciences (mathematics, computer sciences), physics, biology, and medicine. Analysis and visualization: FAS.research 2007

Characteristics of the knowledge network of basic research. The knowledge network of basic research is made up of several rival attractor zones (it is multi-peaked): historical sciences, mathematics and computer sciences, physics, biology, and medicine. This leads to a constant imbalance in the innovation landscape (a prerequisite for dynamic developments and innovation). At the same time, these local attractor zones and their scientific communities stabilize the dynamic. However, there are few connections between the different centers. There are gaps in particular between the natural and cultural sciences, and between medicine and technology.

The (few) links between the attractors are created by the transdisciplinary sciences: mathematics, computer sciences, interdisciplinary social sciences and humanities.

Classic research disciplines (such as molecular biology) dominate the network of basic research. The ratio of young sciences is 29 percent (sciences for which codes were added to the classification system after 1989).
Characteristics of the knowledge network of cooperative research. In contrast to the situation in the realm of basic research, the knowledge network of cooperative research has formed around a single center (it is single-peaked), which consists primarily of formal and technical sciences. These are grouped like a star around computer-aided simulation. This kind of structure is ideal for the formation of a critical mass, incremental innovation, and diffusion.

The sciences at the center of cooperative research are the same ones that are found on the periphery and act as brokers in basic research: the technical and formal sciences (above all the computer sciences).

Cooperative research has mainly settled around young scientific disciplines whose ratio here is substantially higher than in the network of basic research (46 percent are codes added after 1989 to the classification of sciences). New disciplines seem to evolve in greater numbers in the realm of applied research than in basic research.
New knowledge emerges through the novel combination of existing knowledge. These new combinations call for the existence of networks, which constitute the infrastructure for the allocation of resources necessary for knowledge production. The characteristics and structure of these networks are vital to the success of an innovation process. Research into networks and their complexity has shown that three main characteristics are decisive here: Local Embeddedness, Horizontal Embeddedness, and Diversity.

The illustrations on the following pages represent a visualization of the scientific landscapes of basic research (on the left) and cooperative research (on the right). They show which sciences in both areas exhibit a pronounced horizontal and local integration and which are integrated into very diverse networks. The further to the right a science is located in each illustration, the greater its horizontal integration (x-axis), and the higher up it is, the greater its local integration (y-axis). The background color represents diversity (z-axis). The position identifies the role each science plays in the process of knowledge production (global, translational, or specialist integrated and specialist).

Following the illustration from left to right, from basic to cooperative research, one moves away from a polar orientation on fundamentals toward an orientation on practical application. The sciences can thus be compared with reference to their position between these two poles. It can also be seen which evaluation culture is likely to pertain for a particular discipline – that of scientific value or that of economic utility.
Horizontal Integration

Horizontal integration exists when disciplines link areas of the knowledge network that are usually separate. Such disciplines allow knowledge transfer to take place between unconnected fields and thus promote novel combinations of existing knowledge. This is why they offer high potential for radical innovations.

- Sciences with strong horizontal integration

Local Integration

Local integration means that sciences are integrated to a large degree with other disciplines with a similar orientation. Such disciplines give rise to specialized scientific communities with an ongoing research tradition. This enables the development of incremental innovations and the implementation and practical application of new ideas.

- Sciences with strong local integration

Diversity

A discipline can be said to have a diverse network at its disposal when it is connected particularly frequently with sciences in other fields (e.g. natural sciences with humanities or social sciences). The result is linked diversity, which ensures the novel combination of particularly wide-ranging knowledge – a decisive factor for the emergence of new ideas.

- Sciences integrated into highly diverse networks


Not only research disciplines are networked; scientific institutions are as well. In the realm of cooperative research, the Kplus, K-kind and K-net centers are linked by way of common research institutions and businesses. The two illustrations on the right show which centers and institutions are especially well integrated into the network and which have particularly diverse connections.

The network of centers and partners consists, like the knowledge network of cooperative research, of an attractor zone and is itself densely networked – providing prime conditions for implementation and application.

The pivotal centers of excellence: LCM in Linz (mechatronics), MCL in Leoben (materials technology), VIF in Graz (automotive technology), AC2T in Wiener Neustadt (tribology)

The pivotal partners: AVL List, Siemens, MAGNA, Böhler Uddeholm, Joanneum Research, ARC GmbH

The universities (above all the TU Vienna and TU Graz) are strongly horizontally integrated, but less integrated locally, thus playing the role of brokers in the network.
Comparison of Knowledge Networks of Women and Men

The networks of the women and men are similar in the natural sciences and medicine but differ in the social sciences and humanities: There is a distinct transdisciplinary alignment among women and a specialization in historical sciences among men. In the natural sciences and in medicine, women and men tend to work in similar areas of research, and in the social sciences and humanities in differing ones.

Women are clearly underrepresented in the formal and technical disciplines (which would potentially link natural sciences with humanities). The links between mathematics/computer sciences, physics, and electrical engineering/electronics are almost exclusively established through projects carried out by men.

Women are on the other hand strongly represented in the humanities and social sciences (which were added to the classification system in 1989, including women’s research, feminist theory, cultural history, and cultural studies).
Comparison of Knowledge Networks of Women and Men

Women are clearly underrepresented in the sciences that dominate cooperative research (computer sciences, mathematics, mechanical engineering, electrical engineering, etc.). Women are found in the greatest numbers in the chemical and medical disciplines. These count among those disciplines with strong horizontal integration that tie together divergent scientific fields (in particular linking medicine with the natural sciences). Female scientists thus create connections between different research fields in the realm of cooperative research.

This is evidenced as well by the relatively high significance of interdisciplinary technical sciences and natural sciences for female researchers. The result is that men dominate the center of the knowledge network while women act on the semi-periphery and periphery as brokers between the various scientific fields.
Conclusions and Recommendations

There is a pronounced divide between basic research and cooperative research. The formal and technical sciences that are peripheral or semi-peripheral in basic research are at the center of cooperative research. A stronger mixing of the two realms—in terms of personnel, institutions, and above all evaluation cultures—would by all means benefit the innovation potential of the Austrian research landscape.

Important here is to more strongly involve businesses, clusters, and technology centers as well as universities of applied sciences in basic research and, on the other hand, to enlist universities (cultural science institutes) more consistently in cooperative research. As far as the scientists themselves are concerned, it would help to create more opportunities for them to switch between the two realms.

The divide between the two research realms mirrors that between classic industry and the creative industries. Providing more support for cooperative efforts would help cultural researchers working in the creative industries to make a connection with industry, improving what is often a precarious work situation. Joint research areas might be found primarily in aesthetics (design) and the processing of symbols.

Funding programs with a more explicitly transdisciplinary focus would help to bridge the gap between the natural and cultural sciences in basic research. The aim here would be to promote greater cooperation between the cultural sciences and formal disciplines (“Philosophy meets Informatics”) because the latter, with their universally applicable models, unite both “knowledge cultures.”
A heteronomy of evaluation criteria is desirable. The sole standard in basic research should not be purely scientific value, and in cooperative research it shouldn’t all come down to economic usefulness. In basic research, the same people continually sanction the same knowledge through the peer review procedure. In applied research, on the other hand, economic pressure prevents the emergence of radical innovations (due to the expectation of quick return on investments). This is why it would be beneficial if additional, network-oriented criteria were to be applied in evaluating research results:

- Has a research project changed the morphology of the knowledge network (linked once-separate fields of knowledge, increasing diversity, opening the door for new disciplines)?
- Has a project linked scientists or institutions that never cooperated with one another before?
- The actual criterion for evaluation should be the scientific value chain: Has the research work produced an output that might constitute an input for another project? Is knowledge now available that can generate new knowledge?

Gender policy aspects: Women are underrepresented especially in those disciplines that link natural and cultural sciences in the realm of basic research, and in those at the center of the cooperative research network (the formal and technical sciences). Programs for promoting female scientists in these fields should by all means continue to be expanded.

Female researchers noticeably play a substantial part in the dynamics within the cultural sciences. Young sciences have emerged there particularly in the disciplines where women are found in force: women’s research, feminist theory, interdisciplinary social sciences, and cultural studies. If these disciplines were less isolated and above all more strongly linked to the formal sciences, this would substantially strengthen the position of female scientists (“Gender Studies meet Informatics”).

In cooperative research, on the other hand, women are strongly represented in those sciences that connect medicine with the other research fields. Providing support for the broker sciences (medical/natural science fields) would likewise strengthen women’s standing.
Mission and Goals

The Austrian Council for Research and Technology Development is the central advisory body to the Austrian federal government in all issues relating to research, technology, and innovation policy. Established by legislation on August 1, 2000, and deemed an independent legal entity (corporate body under public law) as of September 1, 2004, the Council has as its main mission the systematic, independent, and professionally sound provision of consulting services to the government.

A key task in this connection is the development of long-term RTI (research, technology, and innovation) strategies for Austria. The Council also makes suggestions regarding the focus of national research and technology programs and the funding policies of all RTI-oriented institutions in which the federal government is involved. These activities culminate in the Council’s ongoing recommendations for international and national research and technology projects.

The chief goal of the Council is to make a decisive contribution to the creation and implementation of forward-looking RTI policies. It views itself as the network hub of the extensive Austrian technology and research landscape. The Council is the coordinator and driver for a wide range of activities, acting as a connecting link between the players, but also as a filter and setter of priorities.

Composition

The Council is made up of eight members with voting rights from a wide variety of business and scientific fields, who are appointed by the Federal Ministry of Science and Research and the Federal Ministry of Transport, Innovation and Technology for a five-year term of office. The Ministers themselves are non-voting advisory members of the Council. Since the beginning of 2001 the Council has had at its disposal an office for carrying out its operational activities.

For further information on the current composition and activities of the Council, please visit www.rat-fte.at
Success through Networking

To position themselves successfully in various markets and take advantage of market opportunities, Austria’s enterprises need ideas, competent employees, expertise, networks, and the right partners.

The Austrian Research Promotion Agency (FFG) is a national funding authority for research and development that acts as a partner for Austrian enterprises, offering a broad and targeted program portfolio to enable efficient support of research projects. FFG acts as an interface between enterprises and the public authorities, and responds closely to the needs of the market.

FFG’s goal is to strengthen Austria as a business and research location to lasting effect by supporting the competitiveness of Austria’s economy and its sciences on a national and international level as part of the Austrian innovation system.

Innovation is a precondition for competitiveness and for the creation and protection of jobs. Innovation requires research and development; research and development in turn form the foundation for a highly developed business location.

Additional impetus is provided by the public authorities, especially through the FFG programs. FFG provides more than 30 custom-built promotion programs and a broad range of services for Austrian enterprises, but also for universities. As a central contact for R&D issues, FFG knows the market and acts in line with the latest developments. It has the best access to research projects and cooperations as well as to technological trends and developments on the European level. FFG systematically takes advantage of its access to the latest information to continually optimize its own activities as well as to assume the role of a think tank for the various government departments and for the Austrian Council for Research and Technology Development (RFTE).
Goals of w-fFORTE

- Increase the proportion of women in business, research, and innovation, especially at the executive level
- Develop measures to publicize the research and innovation achievements of female scientists, managers, and self-employed women
- Launch initiatives to promote careers for women in research and technology
- Encourage gender mainstreaming in technology programs and initiatives

w-fFORTE – Economic Impulses for Women in Research and Technology was initiated in 2005 as the third program of the interministerial initiative fFORTE launched by the Federal Ministry of Economics and Labor (BMWA). Since January 2006, the technology program, which is part of the Austrian Research Promotion Agency (FFG), has been active in three areas: Contact Point, Laura Bassi Centers of Expertise, and Knowledge Base.

Laura Bassi Centres of Expertise

The Laura Bassi Centers are designed to provide unique impetus to publicizing excellent research achievements and the scientific management skills of women at the interface of science and business. Six Centers are planned, which will join forces with enterprises to build a high level of scientific expertise over the course of seven years.

Contact Point

The Contact Point is a center for information and networking for women in research and technology. It acts mainly via its website, email contacts, and specific events for target groups:

- Career
career information and workshops
- Promotion programs
exclusive information on programs and applications
- Excursions
to R&D departments in industry

Internet tools and active media work provide further support for career issues.
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