Tracing Knowledge Flows within the Austrian System of Innovation -

Pilot case study for the OECD project on Knowledge flows in National Innovation Systems

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Introduction

For the Austrian technology policy, parallel to the work carried out at the OECD, the concept of the National System of Innovation has evolved as a linchpin for the design of policy, e.g. it forms the basis in the latest government white paper on technology policy. A deeper knowledge of the functioning of the National Innovation System, especially the ways knowledge is produced, disseminated, adopted and put to use is widely percieved as a necessary prerequisite for advanced policy making in this area. It is in this context that Austria has decided to actively take in the work of the OECD[1].

This paper summarizes the results from research touching three different aspects of knowledge flows within the Austrian Innovation System, namely

- international R&D spill-overs,
- knowledge flows in three clusters of the Austrian economy, and
- interactions between the university sector and the enterprises.

As we shall argue, these three aspects are of central importance to the functioning of the Austrian NIS.

The paper is organised accordingly, starting with a short description of the postwar development of the Austrian NIS, some of its main features (which still form the underlying structure of the Austrian NIS to a certain extent) and the prominent role that technology spill-overs from abroad have had in the process of rapid economic 'catching-up'. It is argued, that this phase of diffusion oriented growth (mainly by imports of capital goods and purchases of patents and licenses) has reached some limits and has to be complemented by more advanced forms of 'adoption capabilities' (increase in firms in-house R&D, more active access to external sources of knowledge etc.) in order to cope with the increased knowledge-intensity of the economic activities.

[1] This paper is part of the Austrian contribution to the OECD project on ''Knowledge flows in National Innovation Systems''. It dwells on work carried out within the framework of the Austrian TIP (technology policy information and consulting programme: see for a short description: http://www.bmwf.gv.at/1bm/board/05tip.htm), a three years research and consultancy programme financed by the (former) Ministries of Public Economy and Transport and Science and Research respectively. The next three years phase of the Austrian TIP will be jointly financed by the newly formed Ministry of Science, Transport and Cultural Affairs and the Ministry of Economic affairs.

The second part is devoted to a description of three clusters (forest, telekommunikation, pharmaceuticals), which are organised very differently with respect to the way knowledge is produced and diffused (in some respect, they might be even called 'paradigmatic cases'). Different types of the classification of the respective 'knowledge-bases' are employed, inculding the taxonomy elaborated by Pavitt (1984). It is shown that Austria only has a 'complete' cluster in the tradtional sector (forest), while the other clusters are 'incomplete' in the sense that improtant parts are located elsewhere. Up to now competitive advantages can predominantly be found in the traditional clusters which at the same time are the larger part of the Austrian industry.

The third part tries to shed some light on the relation between the universities as the main producer of (mainly) scientific knowledge and the enterprise sector. Among other sources, the results from a survey are presented that investigated the interactions between the universities and the enterprise sector from the point of view of the universities. (The next phase will focus on the enterprises' perception and will try to go beyond what can already be depicted from the National Innovation Surveys).

Finally, some general conclusions for the design of technology policy based on (National) Innovation Systems approaches are presented. The main result is that the process of policy formulation must address an increased complexity and, to effectively do so, must develop new ways of co-ordination and interaction and deploy new policy instruments.

Statistical Problems Encountered

In the course of this study, we were facing considerable shortcomings in the availability of statistical information, even with respect to rather conventional statistics. These shortcomings include:

- Long publication lags of basic official R&D statistics;
- outdated input-output tables (most recent year available: 1983) which are indispensible for a number of analytical applications (e.g. for the estimation of inter-industry R&D spillovers);
- a lack of comprehensive statistics on information technologies (in particular applications);
- a lack of diffusion surveys in core areas of technology;
- sporadic innovation surveys (most recent year available: 1990);
- a lack of co-ordination between national and international institutions (including OECD) resulting in
- an insufficient representation of Austria in relevant international comparisons as well as related analytical databases (e.g. ANBERD).

In the following, an overview of relevant data sources and (actually or potentialy) available indicators is given. In the second phase, some of these indicators (as far as possible in coordination with other countries) will be applied or developed.

BOX 1: MEASURING KNOWLEDGE FLOWS BETWEEN ACTORS

Indicators	Available	Not Available	To be Constructed	Source
Overall indicators				
– Percentage of business enterprises with R&D cooperation in Austria or abroad, by type of partner	X			WIFO TIS, ARCS Patent DB
– Barriers to R&D cooperations (national, international)	X			WIFO TIS
– Percentage of business enterprises using external sources of knowledge	X			WIFO TIS
– Information sources for innovation by type	X			WIFO TIS
– Lack of cooperation as a barrier to innovation	X			WIFO TIS
– Importance of various information sources for innovation		X		
– Outsourced R&D as a percentage of total R&D costs		X		
– Role of external inputs in the innovation process	X			WIFO TIS
Intrafirm knowledge flow indicators				
– Percentage of business enterprises with intrafirm R&D cooperation in Austria or abroad			X	WIFO TIS
– Percentage of personnel that attended company or external training programmes			X?	
Interfirm knowledge flow indicators I				
– Percentage of business enterprises with interfirm R&D cooperation	X			WIFO TIS, ARCS Patent DB
– Innovation flow matrix		X		
– R&D flow matrix			X	WIFO IO Data, Ec. Chamber
Interfirm knowledge flow indicators II: Technology Diffusion Indicators				
– Various indicators	X			Various Sources
HEIs – firms knowledge flow indicators				
– Percentage of business enterprises with R&D cooperation with HEIs	X			WIFO TIS
– Income from privately financed contract research at Austrian universities			X	Ministry of Science
– Mobility of R&D personnel from HEIs towards industry			X?	
– Match between fields of knowledge covered by HEIs and fields of knowledge covered by industry			X	
– Participation of HEIs and firms in joint formal R&D networks	X			TIP, ARCS patent DB
– Cooperation between HEIs and firms (structure, enabling factors, barriers)	X			TIP,
RTOs – firms knowledge flow indicators				

– Percentage of business enterprises with R&D cooperation with RTOs	X			WIFO TIS
– Income from privately financed contract research at Austrian RTOs			X	RTOs
– Mobility of R&D personnel from RTOs towards industry			X	RTOs
– Match between fields of knowledge covered by RTOs and fields of knowledge covered by industry			X	
International knowledge flows				
– Technology Balance of Payments	X			Austrian National Bank
– Exports/Imports by technological content	X			WIFO
– International R&D Spillovers (elasticities)	X			Econometric studies

WIFO TIS: WIFO Technology and Innovation Survey 1990

The Austrian System of Innovation in Historical Perspective

Although the Austrian system of innovation has been undergoing a continuous and accelerating process of adaption and change, the historical heritage as reflected in structural features of the economy as well as the particular role played by knowledge generation and distribution within these structures cannot be neglected when analyzing the prevailing features and the functioning of Austria's NIS.

By and large, Austria's economic development after World War II can be rated among the success stories of industrial laggards starting from a comparatively low level of economic performance when compared to the "technological frontier" (represented by the U.S.), gradually narrowing this initial gap in the following decades. As Steindl (1977) and others have argued, the favorable path of economic development taken by Austria's industry after World War II was largely sustained by importing advanced capital goods (embodied technical change) from abroad.

Using the analytically important distinction between an economy's growth*potential* and its *realization* - as put forward by Abramovitz (1986, 1991) - the historical position of Austria's economy after World War II was marked by a large productivity gap vis-a-vis the technological frontier and thus by considerable opportunities or potentials for catching up by adopting advanced production processes and methods of organization. The comparatively low productivity standards of the Austrian industry were due, among others, to the low rates of capital accumulation before the war resulting in an unfavorable age-composition of the inherited capital stock. An exception to this were the industrial complexes, primarily in the domain of heavy industries, which were created during the period of Austria's absorption into Nazi Germany (1938-45) as part of the German war economy. These complexes added a new element to the post-war structure of the Austrian economy and played a vital role in the period of re-construction as implicitly recognized by industrial policies implemented during that period. Furthermore, these new industries - such as basic metals - emerged as an important source of industrial innovation at that time. A well-known example is the the basic oxygen process in steelmaking in which Austria pioneered in the early 1950s (see, e.g., Ray, 1989). Simultaneously, however, their existence - and possibly the delayed initiation of a fundamental process of re-structuring - prepared the ground for the bias of the Austrian manufacturing sector towards the production of raw materials which - to a certain extent - makes itself felt until today. Turning to the second part of Abramovitz's distinction, viz. the realization of growth potentials deriving from a relatively backward position, Austria possessed a sufficiently high degree of "social adoption capabilities" to grasp the opportunities of backwardness. These capabilities included, among others, institutional factors such as the evolution of the genuinly Austrian form of "social partnership", which gave rise to a distinct framework for macroeconomic policy options, or the relatively favorable levels of education and training of the labor force.

At the macroeconomic level, these historical experiences, which were marked by rapid productivity growth and positive growth differentials of per-capita income levels vis-a-vis initially more advanced countries paired with a comparatively low level of domestic R&D activities persistently shaped the attitude towards the role of domestic industry-related research in Austria's economic development. "Progress without research" (Marin, 1986, 1989), based on a strategy of rapid adoption and externally provided equipment and production techniques without investing substantially in domestic R&D appeared as a viable option for economic development.

In recent years, this orientation of industry has come under more ore less intense scrutiny both from economic research and through an increased awareness of industry with respect to its knowledge base. In fact, there are a number of reasons necessitating this re-orientation. The process of catching-up of Austria vis-a-vis the most advanced industrialized countries (in terms of productivity and per-capita-income levels) has virtually reached its limits. Of course, convergence implies that the "advantages of backwardness" vanish as a source of positive growth differentials. With increasing openness of the world economic system and an increasing number of (potential) competitors, the opportunities for creating competitive advantages by more or less "passive" adoption of widely available equipment and technologies are increasingly wiped out. The outstanding role of innovation (and the concomitant temporary monopoly profits accruing to the innovator) in contemporary economic growth - fervently stressed by the Austrian economist Joseph A. Schumpeter in the past - is not only recognized in new strands of economic theory such as endgenous growth theory (see, e.g., Grossman - Helpman, 1991), but has become common wisdom in the business community. Product differentiation, product quality improvements, the flexibilization of production etc. tend to increase the importance of product innovations vis-a-vis process innovations.

Moreover, there is ample evidence both at the firm and the macro level that own (domestic) investment in R&D facilitates the absorption of knowledge produced elsewhere. Studies of technology diffusion conducted at the firm level have indicated that firm's own R&D activities enhance their capabilities to monitor and assess technological developments accomplished by other actors (whether these are located inside or outside the national borders) and reduce the cost of imitation and technology transfer. On the other hand, at the macro level this issue has emerged from the recent research on convergence (of productivity or income levels) across countries. The emergence of this kind of interaction between own and external knowledge stocks or "absorptive capacities" (Cohen - Levinthal, 1989) realistically tends to blur the distinction between "pure" knowledge generation and phenomena of technology diffusion, adoption, or imitation.

Technologically lagging countries may initially rely on more or less passive strategies of importing foreign technology, often channeled by investment decisions of corporations from advanced countries, without engaging in substantial R&D efforts of their own (see on this issue Hutschenreiter - Kaniovski - Kryazhimskii, 1995). More advanced countries, on the other hand, are likely to exhibit a much more complex pattern of interaction between own R&D and externally produced knowledge. With open markets, simple imitation is not a viable strategy for countries having reached a level of unit manufacturing costs close to those of the technological leaders. On the other hand, the creation of "absorptive capacities" is a viable strategic option even for advanced countries which may enjoy an added advantage if there are minimum levels of the domestic R&D capital stock in order to interact effectively with externally produced knowledge. To summarize, these arguments may lead one to expect that the significance of interactions between own and external knowledge stocks increases with a country's level of economic development.

Some Features of the Present State of the Austrian NIS

Today, Austria still exhibits a relatively low ratio of R&D expenditure to GDP (1.55% in 1994, 1.5% in 1995) as compared to the most advanced industrialized nations (see tab. 1).

Tab. 1

	GERD as a percentage of GDP										
	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Austria	1,23	1,27	1,27	1,31	1,32	1,35	1,37	1,42	1,50	1,48	1,52
Belgium	1,62	1,64	1,68	1,68	1,68	1,64	1,70	1,69	1,66		
Denmark	1,19	1,22	1,25	1,32	1,42	1,49	1,55	1,63	1,70	1,75	1,80
Finland	1,36	1,49	1,58	1,68	1,76	1,80	1,83	1,91	2,07	2,18	2,22
Netherlands	1,99	1,93	2,06	2,18	2,28	2,22	2,12	2,02	1,91	1,87	1,89
Sweden	2,55		2,88		2,98		2,94		2,86		3,26
Switzerland	2,28			2,88			2,86			2,68	
EU	1,77	1,81	1,90	1,92	1,97	1,96	1,98	2,0	1,97	1,96	1,97

Source: OECD Main Science and Technology Indicators

Apart from the historical background described above, this comparatively low R&D intensity may be attributed to a number of structural features of the Austrian economy such as:

- The comparatively high share in GDP of sectors with low or negligible R&D expenditure (such as tourism).
- The absence of Austrian multinational enterprises of European, let alone global standards. Despite recent tendencies towards globalization of R&D activities - for an empirical account see, e.g., Pearce-Singh (1992) - the lion's share of the latter still remains concentrated at corporate headquarters.
- "Large" industrial producers are often to be found in less R&D intensive traditional

consumer goods or basic industries (e.g. pulp and paper).

- The predominance of small and medium-sized enterprises.

The last point deserves some additional remarks. Econometric evidence based on the WIFO Technology and Innovation Survey (see Hutschenreiter - Leo, 1994) is consistent with the hypothesis of a proportionate (linear) relationship between R&D expenditure on variables reflecting firm size (employment and sales). This result turns out to be rather robust; it holds uniformly true at the aggregate and sectoral level and irrespective of the size measure chosen. Moreover, the same results hold true for a regression of the more comprehensive independent variable 'innovation expenditure' on size.

The regression of R&D employees (instead of R&D expenditure) on the size variables onthe other hand indicates a degressive relationship which may be due to size-dependent differences in the quality of the R&D labor force or in the factor proportions in R&D activities. Thus, large enterprises can hardly be qualified as Schumpeterian "engines of progress" in Austria. This fact may be interpreted in the context of the two preceeding points regarding multinationals and large "national" enterprises. On the other hand, the estimates of Hutschenreiter and Leo are based on a sample of firms which actually do engage in R&D (or innovative) activities. However, it is well-known that small enterprises face higher barriers of entry to R&D and thus the probability of their entering the population of R&D-performing firms is lower than for large enterprises.

The ability of many Austrian SMEs to utilize external ressources in the innovation process (consultants, universities, domestic and foreign research institutes) is limited. The overwhelming majority exhibits shortcomings in the sphere of management and strategy development as well as organisational problems in the introduction of new technologies (see e.g. Polt, Dell'Mour 1992 for the introduction of advanced manufacturing technologies and Haubert et al. 1994 for the use of patent information by SMEs).

Other indicators measuring inputs in the R&D/innovation process - such as the share of RSE (or university graduates in the labor force, see tab.2) - point in the same direction as international comparisons of the share of R&D expenditure in GDP. The technology balance of payments shows a rather stable coverage ratio of approximately 30%, thus indicating a substantial relative dependence on technology imports (tab.3).

Tab.2

	Total RSE (or University Graduates) per Thousand Labor Force										
	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Austria			2,3				2,5				
Belgium	3,2	3,4	3,6	3,8	3,9	4,0	4,3	4,4	4,3		
Denmark	2,8	3,0	3,1	3,3	3,5	3,6	3,8	4,0	4,1	4,4	4,7
Finland	3,7				4,1				5,5		6,1
Netherlands	3,8		4,2		3,9		4,0				4,3
Sweden	4,4		5,0		5,1		5,7		5,9		
Switzerland				4,4			4,6			4,8	
EU	3,5	.	3,7	.	4,0	.	4,2	.	4,4		

Source: OECD Main Science and Technology Indicators

Tab.3

	Technology Balance of Payments: Coverage Ratio									
	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Austria	0,20	0,29	0,26	0,26	0,25	0,27	0,33	0,32	0,26	0,29
Belgium	0,86	0,82	0,86	0,87	0,71	0,70	0,77	0,75	0,82	0,90
Denmark	0,98	0,90	1,14							
Finland	0,06	0,04	0,04	0,05	0,13	0,16	0,16	0,14		
Netherlands	0,89	0,86	0,80	0,96	1,04	0,99	0,92	1,04	0,82	1,01
Sweden	2,19		1,77		3,32		5,47		0,99	

Source: OECD Main Science and Technology Indicators

However, it is worth noting that turning from R&D expenditure to a broader measure of innovative activity (innovation expenditure), Austria's manufacturing sector appears to lag considerably less behind technologically more advanced countries. Innovation expenditure covers not only (R&D) expenditure related to the generation of technological knowledge but also expenditure related to the adoption of technology (outlays for construction and design, utility patents and licenses, expenditure for production and marketing start-ups and process innovation). According to the WIFO Technology and Innovation Survey (Leo-Palme-Volk, 1992), the innovation coefficient (innovation expenditure as percentage of turnover of establishments performing R&D activities) amounted to 4.8% in 1990. The respective figure for the FRG was just 0.6 percentage points higher. However, available empirical evidence indicates that - compared to their counterparts in other industrialized nations - Austrian enterprises invest relatively more in process than in product innovations.

Technology and Foreign Trade

Taking a long-run perspective (see for the following Hutschenreiter-Peneder, 1996), Austria was able to maintain its share in total exports of OECD countries to the world (1960: 1.34%; 1970: 1.30%; 1980: 1.40%) and to increase it to 1.64% in 1992 (followed by some decline in the wake of the appreciation of the Austrian Schilling). However, Austria suffers from a structural deficit in its trade balance. Moreover, unit values (which may be interpreted as an indicator of quality) of exports of manufactures (SITC 5-8) are about one third lower than corresponding import unit values. However, this constellation cannot be attributed to an across-the-board quality deficit at the product level but is mainly due to the structural composition of foreign trade flows, i.e. a "lock-in" in product groups with low unit values.

Looking at the specialization patterns of Austrian foreign trade (by means of an Revealed Comparative Advantage indicator, see tab.4) disaggregated by production technologies, we find a specialization in manufactures produced by ressource-intensive and capital-intensive technologies. For high-technology goods, the RCA indicator is strongly negative. However, the specialization pattern is steadily changing over time in favor of human capital-intensive, high- and medium technology goods and at the expense of ressource- and capital-intensive goods.

Tab.4

Revealed Comparative Advantage (RCA) by Production Technologies						
	Austria		Switzerland		Sweden	
	1989	1994	1989	1994	1989	1994
Human capital intensive	-0,13	-0,06	0,09	0,10	0,03	0,00
High technology	-0,48	-0,32	0,37	0,38	-0,38	-0,43
Medium technology	-0,17	-0,10	-0,00	0,05	0,11	0,18
Capital intensive	0,13	0,09	-0,31	-0,46	-0,55	-0,42
Labor intensive	-0,06	-0,10	-0,06	-0,08	-0,31	-0,34
Ressource intensive	0,45	0,39	-0,26	-0,23	0,46	0,37

Revealed Comparative Advantage (RCA) values measure the export-import balance of a group of commodities relative to total foreign trade: + implies a relative export surplus, - an import surplus.

Source: Austrian Institute of Economic Research (WIFO)

International R&D Spillovers

Empirical evidence regarding the international dimension (international R&D spillovers) is scarce. Empirical research on international R&D spillovers is comparatively young and the body of econometric literature dealing with this issue is much smaller than that on inter-firm or inter-industry spillovers.

Austria being a small country behind the technological frontier contributes to the fact that Austria is less frequently included in international studies of that kind. An exception is the study by Coe - Helpman (1995) which is based on panel data for 21 OECD countries plus Israel for the period 1970-90. Coe and Helpman regress TFP on the domestic R&D capital stock and a spillover variable. The latter consists of the external (foreign) capital stock of the respective country (the sum of the import-share weighted domestic R&D capital stock of partner countries) multiplied by the import share of the country (as a measure of "openness"). Regarding Austria, Coe and Helpman find evidence for an extraordinarily high elasticity of TFP with respect to the German R&D capital stock. The authors estimate a higher elasticity of TFP just for a few other countries (Canada, Israel, Ireland, Belgium, the Netherlands, Norway with respect to the U.S. R&D capital stock and Belgium with respect to the German R&D capital stock). The impact of changes in the U.S. R&D capital stock on productivity in Austria appears relatively small.

Empirical Evidence for R&D Spillovers in Austria

Primarily due to the lack of recent input-output tables, only rudimentary evidence regarding the importance of R&D spillovers (external effects of R&D investment on productivity growth on other firms or industries) is available. Existing estimates are confined to the effects of R&D investment on productivity growth within branches of the Austrian manufacturing sector (Hutschenreiter, 1994, 1995). These estimates include intra-industry spillovers, but do not take into account externalities operating across industry borders (inter-industry spillovers). Nevertheless, the available evidence gives some support to (or at least does not contradict) the hypothesis of a changing role of R&D in Austrian manufacturing.

In the cited study no significant dependence of industry total factor productivity (TFP) growth on R&D intensity could be identified for the period 1972-83. During that period some supplier-dominated industries (such as the textiles and paper industries) were realizing particularly high rates of TFP growth by modernizing their capital stock, thus confirming the "traditional" pattern of sustaining productivity growth by embodied technical change (to a considerable extent imported from abroad) without own R&D. This particular pattern of TFP growth and R&D intensity appears to have changed in the 1980s (1978-89). In the 1980s, the rate of return on R&D investment was significant and estimated to be in the range of 33-39%. This supports the view that a change in the productivity growth "regime" was under way. However, it has to be noted that even in the 1980s significant returns could be attributed only to the "D" (development) component and not to the "R" (research) component of R&D investment. This may be due to the fact that Austrian industrial research suffers from segmentation and inefficiencies, while incremental experimental development is much better established and integrated in manufacturing companies. Thus, the Austrian industry seems to be rather far removed from a situation - typical for a number of advanced industrialized countries - where more basic research activities are promising high social rates of return. Moreover, deviating from the results of numerous studies, the estimates for Austria do not substantiate a statistically significant difference between privately and government funded R&D investment. However, it has to be borne in mind that the role of basic research appears to vary across countries or NIS. For Japan (in contrast to results for the US), Mansfield (1988), for example, found higher rates of return on applied research than on basic research. Also, the decomposition of total R&D investment into privately and publicly financed R&D seems to reflect institutional factors such as the role of government in the innovation system and the "rules of the game" (Lichtenberg, 1992, p. 3) of financing R&D. Among the possible explanations for lower rates of return on government financed R&D figure the selection criteria for public R&D funding or the fact that government funding of R&D is, in many cases, biased towards the defense or aerospace industry which may create comparatively low inter-industry spillovers or are notoriously plagued by problems of real output measurement.

Clusters of the Austrian Economy - different knowledge basis, different knowledge flows

While a look at the aggregate level of the NIS in total does already reveal some basic characteristics of a NIS, it has to be complemented by anaysis on a more disaggregate level as well. One especially promising way to conceptualize such a 'meso-level' is the analysis on industrial or technological 'clusters'.

As 'clusters' we define a closely interrelated set of economic activities in a production chain that is characterized by strong input-output relations, a common institutional framework and high externalities within the cluster[2]. The character of such externalities was already a central focus of the work of Alfred Marshall. As a source of such externalities, he identified what modern terminology would call a pooled labour market[3], specialised supplier industries[4] and knowledge spill-overs[5].

[2] Other authors using a different labeling use rather similar definitions: e.g. Glatz, H. et al.1991, Ahonen, P. 1995 define "Industrial complexes" as networks between (a) public authorities, (b) R&D institutions, (c) firms and (d) consumersusers of the goods and services .. produced within the complex. These networks have (formal and informal) governance structures, determining the interactions, and thus the innovative activities, of the actors. For an overview of meso-level systems approaches see Marceau 1995.

[3] "...a localized industry gains a great advantage from the fact that it offers a constant market for skill. Employers are apt to resort to any place where they are likely to find a good choice of workers with the special skill they require"

[4] "...subsidiary industries devoting themselves each to one small branch of the process of production, and working it for a great many of their neighbours, are able to keep in constant use machinery of the most specialized character, and to make it pay its expenses"

[5] "...inventions and improvements in machinery, in processes and the general organization of the business have their merits promptly discussed: if one man starts a new idea, it is taken up by others and combined with suggestions of their own; and thus it becomes the source of further new ideas" (all quotations from MARSHALL 1920, 271)

The rational for embarking on that kind of meso-level analysis is at least threefold:

- First, it can be observed that nations - whatever their *overall* level of innovation activities - succeed not across the whole range of industries, "..but in clusters of industries connected through vertical and horizontal relationships" (Porter 1990). This specialisation pattern is also a reflection of the different technological trajectories which are prevailing in a country.
- Second, the patterns of knowledge flows differ strongly between clusters - and between countries specialised around different clusters. Qualitative empirical analysis about the specificities of knowledge flows can hence only be obtained on this more disaggregate level.

Third, instead of either carrying out policy measures only on a general level which will effect different industries very differently or supporting special branches of even individual firms, technology policy could find a special leverage in measures supporting clusters. Policy measures of that type might be seen a means to maximise the leverage effect (using the potential high externalities that are supposed to prevail within a certain cluster) while avoiding the danger of being either too general or too narrowly defined.

In the course of the Austrian TIP programme, three (potential) clusters were studied: (a) the Forest cluster (see Bayer et al. 1993), (b) the Telecommunications Cluster (see Leo etal. 1994) and (c) the Pharmaceutical cluster (see Joerg et al. 1995). The results of these (broader) cluster studies with regards to the different types of knowledge flows and interactions between the main actors within the cluster are presented below. It turned out that - not surprisingly - the modes of knowledge production and channels knowledge flows differ markedly between the clusters. The taxonomy of Pavitt (1984) was employed to describe these differences. According to this taxonomy clusters can be labeled as either being (a) science-based, (b) supplier-dominated or (c) production (i.e. scale) intensive. In both of the latter categories, technology is mainly imported, but in very different ways combined with knowledge generated in the sector itself.

In science-based clusters (e.g. pharmaceuticals, bio/medicine, electical and electronical engineering) close collaboration with the universities and research institutes and sometimes also strong formal links to the institutions of the technological infrastructure can be found.

They also exhibit a high R&D- and patent-intensity, generally employ the majority of scientists and engineers in the enterprise sector and it is in these fields that firms also co-publish papers with scientific institutions in a growing number.

Science-based clusters in most of even highly developed industrial economies account for only a small, albeit growing, share of total output. This is even more so in the small economies where ‘resource-intensive’ clusters (oil, forest) have a prominent role like Norway, Finland and Austria. In these clusters, it is maily the interplay of specialised suppliers with (often) scale intensive users and specialised parts of the technological infrastructure that drives innovation. Here, not the access to the frontier of scientific knowledge that is essential, but the skillfull „management of socially distributed knowledge“ (Gibbons) of all kinds. Innovative firms in these clusters - although not ‘research-intensive’ by standard measures - increasingly use a multiplicity of sources of advanced and specialised knowledge stemming from the suppliers of specialised equipment, (leading) users, technical centres, etc.

The Austrian Forest Cluster - the Austrian NIS in a nutshell

General description

The wood and paper cluster is one of the most outstanding sector within the Austrian industry. This position is not only based on the fact, that it is the largest single sector, but results also from a series of characteristics, which are both paradox and at the same time highly typical for the Austrian industry and innovation system.

The Austrian wood and paper cluster is the largest single sector within the Austrian industry. It covers 5,6 % of all companies and 5,7 % of all employees (= 126.000). Austria ranges on the 6th position in timber production after Schweden, Germany, Finland, France and Poland. The value added is around 45 billion ATS, which equals 4,7 % of the total industry value or 9,5 % of the productive sector.

The comparatively higher share of employees than that of the share of value added indicates a productivity rate beyond the average (80 %). Although there is a high productivity rate in paper and fibre board production, these subsectors cannot outweigh the low productivity rate of sawing, furniture, and construction sector.

Austria has a share of exports within the OECD countries of about 1,6 %. Any single subsector - except pulp - has a significantly higher export rate as compared to the overall export. The dominating subsectors in this respect are timber and paper production. Although the wood-paper cluster exhibits a high export specialization, the export range is to some extent restricted and vulnerable due to low unit-values of exports as compared to its competitors. In fact, there is a inverse relationship between export rate and unit-value: (i) higher levels of export specialization in low-prize segments, and (ii) the lower prizes in low-prize segments.

Characteristics of technological change in the Austrian Forest cluster

A comparison with Sweden, Canada, Finland (with rich wood resources) and Germany and Italy (with poor wood resources) reveals a striking characterisitic of the paper-wood sectors throughout different countries: The better the resource endowment, the weaker the value added from this endowment. Countries with a large wood base concentrate their techno-economic activities mainly on the early stages of the value-added-chain, while countries with a poor endowment are more focused on goods and products with high value-added and unit-values.

The strong focus on sawing and sawing products, which cover the main part of the wood-paper cluster are to some extent locked-in into paths, established in the 70ies and early 80ies. These paths are determined by heavy investment into a new generation of (large scale) sawing technologies, which had their productivity optimum at higher production volumes. Thus modernization compelled expansion of firm size. A shake-out-process could then be observed: Large firms became larger, smaller ones closed down, medium sized firms came under pressure to grow or to diversify up-stream or to close.

A similar pattern of inflexibility could and still can be observed in the paper and pulp subsector as well as in fibre board production, which is caused by the large scale equipment in paper or board production machinery and equipment.

Although there is a strong need for innovation and diversification into products with higher value added, the attempts for innovation and structural change are rather low. The expenditures for RTD are less than half of the average of the industry as a whole. Furthermore, these expenditures are predominantly (2/3) oriented towards process optimization. The potential for endogenous innovation is rather low, most of the innovations are stimulated from outside: equipment suppliers and suppliers of materials and components (mainly from the chemical industry) are the main sources of (improvement) innovations. At the same time there is both a certain lack of advanced demand and a lack of significant input from academic research or from contract research organizations. Generally, the mayor players in the arena of invention and innovation are equipment suppliers and suppliers of products and components. Hence, the main activities are improvement and optimization and thus highly conservative.

The Telecommunication Cluster: A sheltered Cluster in Transition

As almost in any country the Austrian telecommunication market was highly protected over decades by a monopolistic network operator and service provider vis-a-vis a national oligopoly in the transmission, switching, and terminal equipment market. This stable structure which was the basis for a distinct pattern of innovative activities disappeared successively as a result of a stepwise liberalization of the telecommunication market throughout Europe. Looking at the "embedded" structure of the corresponding innovation processes we can observe a variety of patterns of innovation behaviour.

General characteristics of the Austrian Telecommunications Cluster

Telecom: The sheltered Cluster in transition

- large monopoly in infrastructure and telephony
- oligopoly in switching equipment
- national clustering along the entire value-chain
- supplier / scale dominated regime (equipm. - network services - applications)
- many small start-up-firms in VANS and content, new entrants (GSM)
- polypoly in terminal equipment and software
- emerging: new entrants from abroad, alliances
- orientation towards services applications, user needs, content (with lacks in multimedia/broadband)

The monopolistic regime: Technology imports and adaptation

Core technology of any telecommunication system is switching technology. It determines to a high degree the architecture, the range of services offered, and the performance of a telecommunication system. With respect to the Austrian telecommunication system a decision concerning network-digitalization was made in the late 70ies to adopt two different systems, one from Siemens (Germany) and one from Northern Telecom (Canada). In this respect a direct technology transfer by licensing occured. A second decision was made, to join these two systems and to create a new one in order to meet specific service features which was desired by the Austrian PTO.

Actually we find here some sort of joint policy action: One the one hand (of the PTO) a decision was made aiming at an advanced telecommunication infrastructure, while on the other (of the federal government) this telecommunication policy decision was enriched and overlayed by innovation and industrial policy rationales. The very central goal was to build up capabilities for R&D in switching technology and to establish and maintain a strong domestic supplier market.

Summarizing up, we can observe a variety of patterns of innovation and policy behaviour:

- Technology transfer from abroad by licencing.
- Technology adaptation to taylorize an Austria-specific switching system.
- Linking telecommunication policy with innovation policy: Stimulation of innovation processes and creation of R&D capabilities by advanced public procurement.
- Linking telecommunication policy with industrial policy to create and maintain strong domestic firms and employment in a high technology sector.
- Knowledge flows: A strong flow of know-how and codified knowledge from the licencees to the domestic switching supplier, at the same time a considerable determination of the PTO rather then the opposite - supplier / technology driven.

The stage of transition: Liberalization by standardization

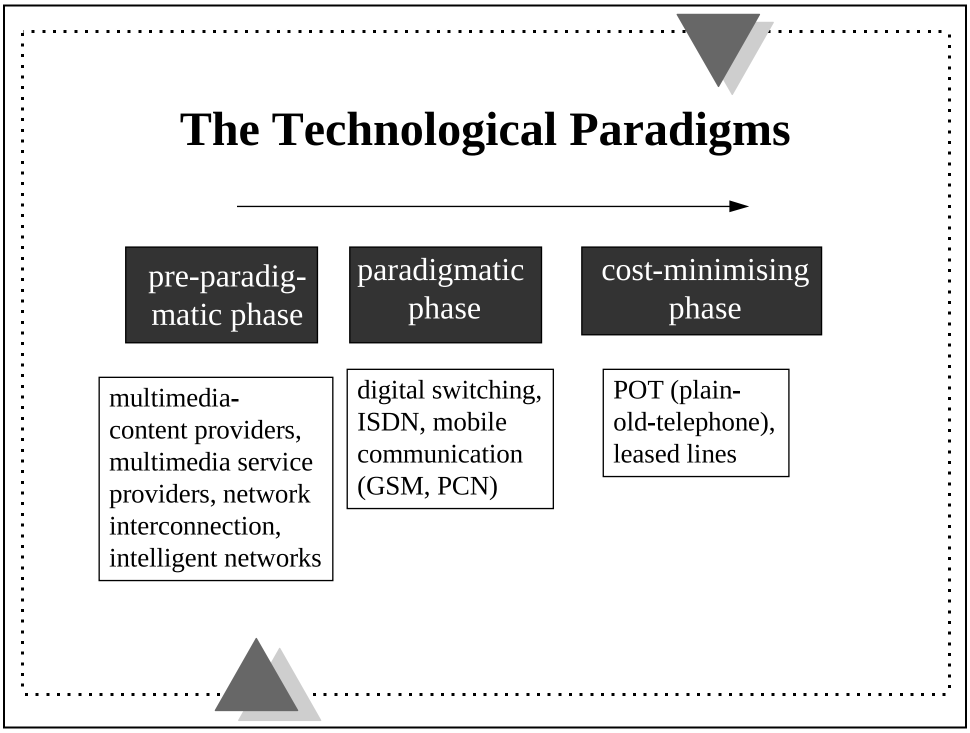
In the course of the liberalization process, which occured first in the terminal equipment market, then in the value-added-services market and eventually with 1998 in the network infrastructure sector, a gradual detoriation of the tight monopoly-oligopoly structure took and still take place. The implementation of advanced services or services platforms and transmission and switching technologies such as ISDN, intelligent network features, SDH, ATM, GSM etc., combined with a strong need for interconnectivity and interoperability triggered the adoption of worldwide and / or European standards. This setting and adoption of standards, in turn, triggered and enabled firms to enter these former protected markets.

Summarizing up, we can observe the following types of market and innovation dynamics and knowledge flows:

- The parallel process of liberalization and standardization detoriated the established market structure and allowed the entrance of alternative suppliers. This process is still going on and will have a peak with the finalization of the liberalization process.
- The setting and adoption of standards (which can be considered as the creation and adoption of public-good-type knowledge) attracts alternative, former excluded firms to develop and market goods (esp. terminal equipment, switching components, software) and services (telecommunication services, consulting).
- Most of these new entrants have either diversified from related products areas, technologies, and markets or have entered alliances. While diversification occurs mainly domestic, new firm establishments and alliances is to a high degree a business of foreign direct investments (FDI). Diffusion of technology and knowledge by diversification and FDI accordingly occurs both by diversification and apoption as well as by new firm set-up and direct investment.

The stage of liberalized markets: Reverse direction

Refering to the well-known Abernathy-Utterback-model of technical change - preparadigmatic stage □ paradigmatic stage □ cost-minimizing stage - a rather paradoxical pattern occurs (see Fig.): Starting from a highly stable, variety-poor market and technology regime, changing into a regime of expanding the variety of products and services by implementing technical standards, a third stage of innovation behaviour and knowledge flows is coming about the next years and even the next decade: The emergance of a large number of rather small and often start-up firms in the wide and turbolent market of content/media-production. This market is highly unstable, 'dominant designs' are far from being realized and implemented, innovations are mainly technology and opportunity driven vis-a-vis a poor, fragmented, and ill-articulated demand.



The public sector as a major player in the content and media sector (except TV) will play a crucial role in being a market for advanced applications services, and contents as well as in creating market opportunities by opening museums, libraries, collections, public sector information with private good character for market activities.

With respect to innovation behaviour and knowledge flows, the following dominant characteristics can be observed:

- Technology and opportunity driven innovations dominate.
- Universities and small-technology based firms are entering the market.
- Established firms are entering the market - endogenous - by diversification or exogenous by alliances and mergers, hence collaboration, alliances, and mergers of distributed knowledge and capability assets are dominant patterns.

The Pharma Cluster - an 'incomplete' science based cluster

General description

Globally, the pharmaceutical cluster is one of the best performing of high technology clusters. Thanks to steadily rising demand for drugs during the last few decades and the high market entry barriers, competition was not primarily focused on prices but rather on the development of new drugs. However, with increasing cost pressures in the health sector resulting in a higher price elasticity of demand, the days of assured growth now seem to be over.
Two major trends, one concerning changes in the market structure, the other concerning technological developments are changing the industry:

- Competitive pressure on pharmaceutical companies has increased due to the escalating cost of developing new drugs in recent years accompanied by the increased market shares of 'generica' (i.e. reproduced drugs after their patent protection has expired). This development made it harder for the research intensive companies to recuperate their R&D outlays.

- A new technological window has opened in the form of new biotechnologies, which have now become one of the pharmaceutical industry's most important sources of innovation.

Economic benchmarks of the Austrian Pharma cluster

Overall, the share of the Austrian pharmaceutical industry in total industry is relatively small. In 1992, the pharmaceutical companies in Austria accounted for little more than two per cent of Austrian industry's net production value. However, the vigour of its growth is impressive: It's share both in total net production value and in the total number of industrial employees has doubled since 1980. With a decline in the number of companies at the same time, the average company size has risen significantly in the last decade. With 145 employees, the average pharmaceutical company is twice as big as the average industrial firm in Austria. While the parmaceutical sector can generally be labeled as a science-oriented or R&D-intensive sector, a closer look at the Austrian situation reveals that two very different types of

companies can be identified within the Austrian Pharma cluster:
The first group includes a small number of large science-based companies with strong international focus. They are almost all owned by foreign concerns based in Germany and Switzerland. The second group is made up of small and medium-sized companies (mainly of Austrian ownership) which concentrate there innovation activities mainly on the improvement of already established products and focus largely on the domestic market. Innovation activities within the Austrian pharma cluster are highly concentrated on a small number of players. As far as the private sector is concerned, no less than three quarters of all research expenditure performed in the pharmaceutical business sector are spent by the three largest companies. Furthermore, the five companies with the largest innovation capabilities are without exemption subsidiaries of pharma multinationals. Within their group they are usually in charge of one specific market segment. As recent studies indicate (Joerg et al. 1995), in the recent years the majority of this subsidiaries have been able to solidify their position within there group. Comparing the single areas of technology orientation of each of this firms shows strong overlapping: Most of them were able to built up strong research capabilities in the biotechnologies.

Information flows within the Pharma cluster: global trends

The shape and direction of information-flows is strongly affected by the specific pre-conditions of the search for new drugs. The development of new drugs can very often not be derived directly from basic discoveries, but remains largely dependent on chance and for the most part is still based on large scale 'trial and error' experimentation. Also in this science-based sector, the key to the industrial success in developing new active agents is therefore increasing the likelihood of 'scoring a hit'. The more chemical structures can be tested, the greater the likelihood of finding a substance with the desired therapeutic properties, although in many cases the underlying mechanisms of the effects are not fully understood (and are subsequently areas of more basic research).

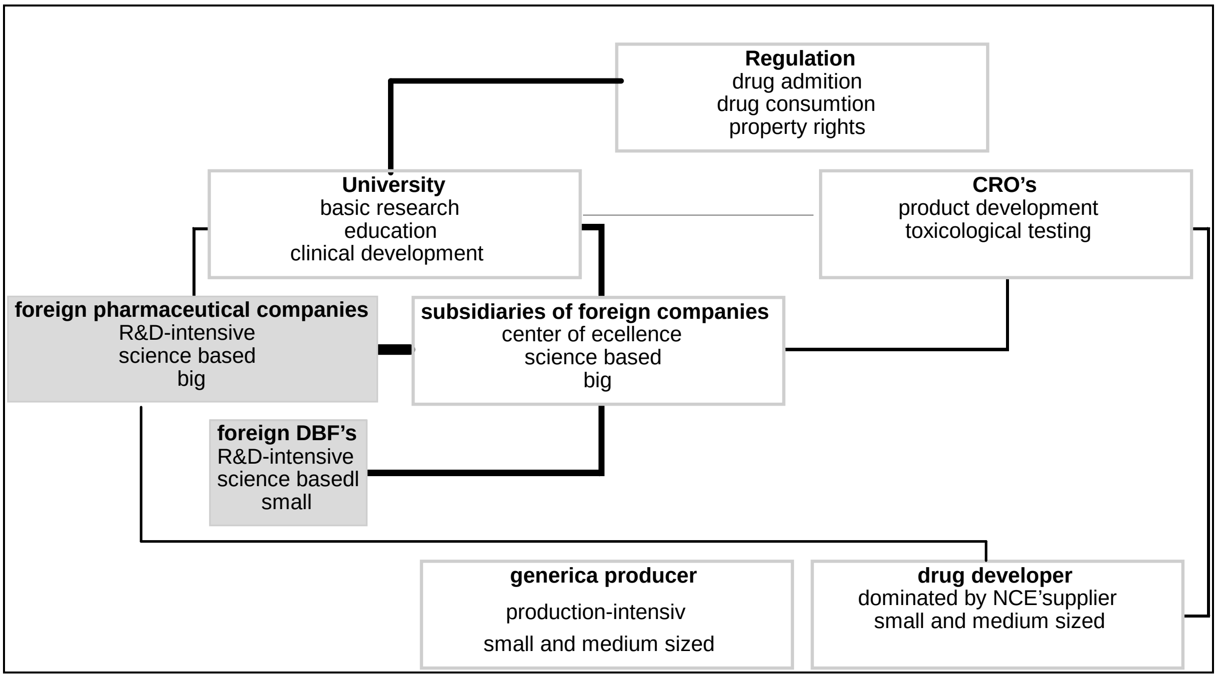
Nevertheless, it is clear that the need for basic research is particularly great in this field. Not only does basic reasearch open up new fields on which to experiment, but it is also a feedback mechanism, once the ways the drugs operate has been fully discovered and explained. Accordingly, the standard division of labour between academia and business sector does not apply in pharmaceutical research. Traditionally, pharmaceutical firms are highly integrated and strongly involved in basic research. Usually they maintain strong links to the academia. This also holds true for the Austrian research intensive firms, which have established very close, although mostly informal ties to the respective university institutes.

With the enormous increase of R&D-costs which are necessary to develop a new chemical entity, R&D-cooperations between firms became an important mean in the risk and cost-management. Furthermore, R&D-cooperations within the Pharma cluster have been inforced with the appearance of the new biotechnologies. The new biotechnologies were first adopted by a group of small Dedicated Biotechnology Firms (DBF) founded mainly by people with academic background. By cooperating with them, the established pharma firms used the DBF´s as gatekeeper to this new window of opportunity. Altogether, the last decade has shown a strong increase of inter-firm as well as university-firm R&D-cooperations.

The Austrian example

This typical picture of knowledge flows within the Pharma cluster is not reflected in Austria. Overall, the picture in Austria shows several 'islands of R&D' with strong cross-bred links and *almost no links within Austria*! Besides the strong links between university and the large pharma firms via education and R&D-cooperations the inter-firms flows are poor. One explanation for this lack of information flows within the NIS is due to the fact that the Austrian Pharma cluster is an 'incomplete' one. The group of start-ups especially in the new biotechnology area is completely missing. Access to competence to biotechnology can only be reached by cross-border cooperations. The second explanation refers usually to the general poor cooperation culture in Austria. In the case of the Pharma Cluster the reluctance to cooperations may also be inforced by the fact that cooperation strategies of the major players in the Austria are determined (and constrained) by their foreign based headquarters.

Fig. Information flows in the Austrian Pharma cluster



Knowledge flows in the Austrian pharmaceutical cluster

- via personel mobility (business start-ups) - low
- interactions between firms - little
- interactions between firms/universities - good
- cooperation between firms/CROs - poor
- adoption potential (organized search activities in codified knowledge) of large firms - good

In the end, it has to be stressed again, that the analysis of clusters and NIS in total are no competing, but rather complementing approaches: It is hard to get a meaningful picture of a national innovation system without including a detailed analysis of the clusters of specialisation, while on the other hand the general framework conditions in terms of technological infrastructure, institutions of higher education, regulatory framework, labor relations etc., that form the characteristics of a NIS. Thus, it seems justfed to conclude that ‘‘regardless of what type or level of system approach is being adopted, it is clear that the national level is highly relevant in conceptualising systems. (...) Of course many aspects of behaviour are sector-specfic or technology-specific (...) At the same time, however, these sector or technology effects operate within the institutional constraints referred to above, and this makes the understanding of the specificities at the national level an important task.’’ (Smith, Dietrichs, Nas 1996, 6)

The Relation between Universities and Enterprises - a conceptual and an empirical approach

Traitional views (like the one endorsed by the influential report by Vannevar Bush in 1945) see basic research as the prime engine for technological and economical advancement: "Basic research leads to new knowledge. It provides scientific capital. It creates the fund from which the practical applications of knowledge must be drawn. New products and processes do not appear full grown. They are founded on new principles and new conceptions which in turn are painstakingly developed by research in the *purest realms of science*." (p. 18/9, our italics). These sentences neatly summarize what later as been labeled the 'linear model' of technological change, which is, to some extent, still rather prominent in practical technology policy.

In the course of the post-war development of the 'science system', a term that we use to describe all distinct institutions that contribute to the production and distribution of scientific as opposed to various other forms of knowledge, a deeper division of labour in the production of scientfic knowledge emerged, but the sketchy picture Patel/Pavitt (1995, 14) draw still is by and large valid: "There are two major sources of funds: business and government. Business funding is in general larger than the latter, and is spent in-house mainly on applied research and development activities. Government funding is divided amongst basic research performed mainly in university-type institutions, the technical support for the provision of other public goods (e.g. health, environment and in a few countries - defence), and for agriculture and industry, performed mainly in the laboratories of government agencies and business firms."

This clear cut division of labour and its efficacy for the process of innovation is becoming inceasingly questioned from the side of theoretical research as well as from the side of policy[6]. While research points to transformation of the innovation process itself, with

[6] "The post-1945 system was organized as if research proceeded along a linear path with clearly defined distinctions between basic research, applied research and development. Today's knowledge explosion and collapsed cycle times have blurred the lines between the types of research and have complicated the understanding of the R&D process. The post-1945 system generally could function in a way that respected the boundaries of research disciplines. Today, new fields of research, such as biotechnology and materials science,

causation of scientific progress stemming from technological development (e.g. from demand for scientific explanation of successful engineering solutions or from the technological advancement of scientific instrumentation, see e.g. Rosenberg (1994)), policy is facing severe budgetary constraints, which are passed on to the institutions of the science system, especially to the universities. Universities are increasingly asked to contribute more directly to the production of knowledge with an economic purpose.

Research is more and more carried out in networks of researches with different institutional backgrounds. Universities do still play a central role in this division of labour in the 'research enterprise', but a number of other institutions have become producers of specialised scientific knowledge as well. *Institutional border crossings* become central, a development that has been termed 'mode 2' of nowledge production (Gibbons). In some areas of science the way from basic research to application seems to be very short, in other areas, the time has shortened considerably (e.g. as measured by the decreasing lag between the date of scientific publishing and the first citation in a patent). In short, even the production of science depends more and more on the close interplay of several actors of the innovation system.

University Research and the Enterprise Sector

In the following, we will briefly present the results of an empirical analysis of the University sector (see Joerg, Polt 1996). The restriction to the university sector is justified by the prominent role this secor has within the Austrian NIS and its science system. Public outlays for R&D in Austria are - much more than in other countries - dominated by the universities and other higher education institutions. E.g. in 1994 roughly three quarters thereof are fuelled into that sector. As a complement, the publicly funded research institutes occupy but a minor place in the Austrian NIS. By goal of research, 'general advancement of knowlwedge' without any specific socio-economic target ranks very high in Austrian Universities (see OECD Main Science and Technology Indicators 1993 or BMWF 1995 for the latest figure).

often emerge at the intersection of those boundaries. Finally, the post-1945 system developed in a period in which the scope for cooperation was sharply limited by geography. Today, information technologies are revolutionizing the nature of collaboration by shrinking both time and distance." (US Council on Competitiveness 1996, 11)

Although this category might reflect a residual, it can be taken as an indication of purely curiosity-led (or 'basic') research.

The basis of this analysis was threefold: (i) the (obligatory) annual working reports of the institutes [7], (ii) the Austrian Research Documentation (FODOC)[8], a survey of research activities among the institutes on a voluntary basis, and (iii) an own survey, using a standardized questionnaire[9].

The main questions we raised concerned the structure of research and research output, as well as the interactions of the university institutes in the process of research, among which the interactions with the enterprise sector deserved special attention. Here only the part covering the interactions will be described. Nevertheless, it has to be kept in mind that this first part of the analysis covered just the perception of the universities of this interaction. The next phase of the project will focus on the enterprise side.

Comissioned R&D

The private sector funded approximately 38% of all externally financed research projects at the Austrian Universities in 1992/3. In the technical sciences this share rose to 60%, while for social sciences it amounted to 42%. A concentration of these projects on a limited number of institutes could be observed: the top quartile accounted for 47 percent of all projects. Nevertheless, no 'economies of scale' could be observed: per scientific employee there was roughly the same number of projects (as well as other output indicators like publications or teaching hours).

[7] Only a selection of 587, i.e 73 % of a total of 813 university institutes was analysed. Institutes were apparently no contacts were to be expected were neglected.

[8] covering 1.232 'priority research areas' which comprised 8.930 individual research projects (by beginning of 1996)

[9] Out of a sample of 587 institutes, more than 37 percent responded, with a clear bias in favour of the engineering, natural sciences and medical faculties.

Cooperation with other institutions

Roughly half of the institutes were engagend in some kind of cooperative project with another institution, while a quarter was not at all. A remarkable high degree of internationalisation was prevalent not only in the standard measures of scientific output (publications), but also in R&D projects. Contrary to what could have been expected, projects with purely Austrian participation were no substitutes for internationally oriented ones. Institutes with larger numbers of international projects also were very active in Austria. The demarcation line is not between nationally or internationally oriented, but between cooperation-intensive institutes and those who are not.

Tab. 6 Joint R&D projects at the univverstity institutes (Austria 1992/3)

Faculty group	with Austrian and foreign partners		only with Austrian		only with foreign		no cooperation		Total
Construction	20	26%	7	9%	14	18%	36	47%	77
Engineering Sciences	31	39%	4	5%	23	29%	22	28%	80
Argiculture	27	46%	3	5%	12	20%	17	29%	59
Medicine	78	61%	6	5%	19	15%	25	20%	128
Natural sciences	110	69%	3	2%	26	16%	21	13%	160
Social sciences (incl. Business and Economics)	29	35%	1	1%	25	30%	28	34%	83
Total	295	50%	24	4%	119	20%	149	25%	587

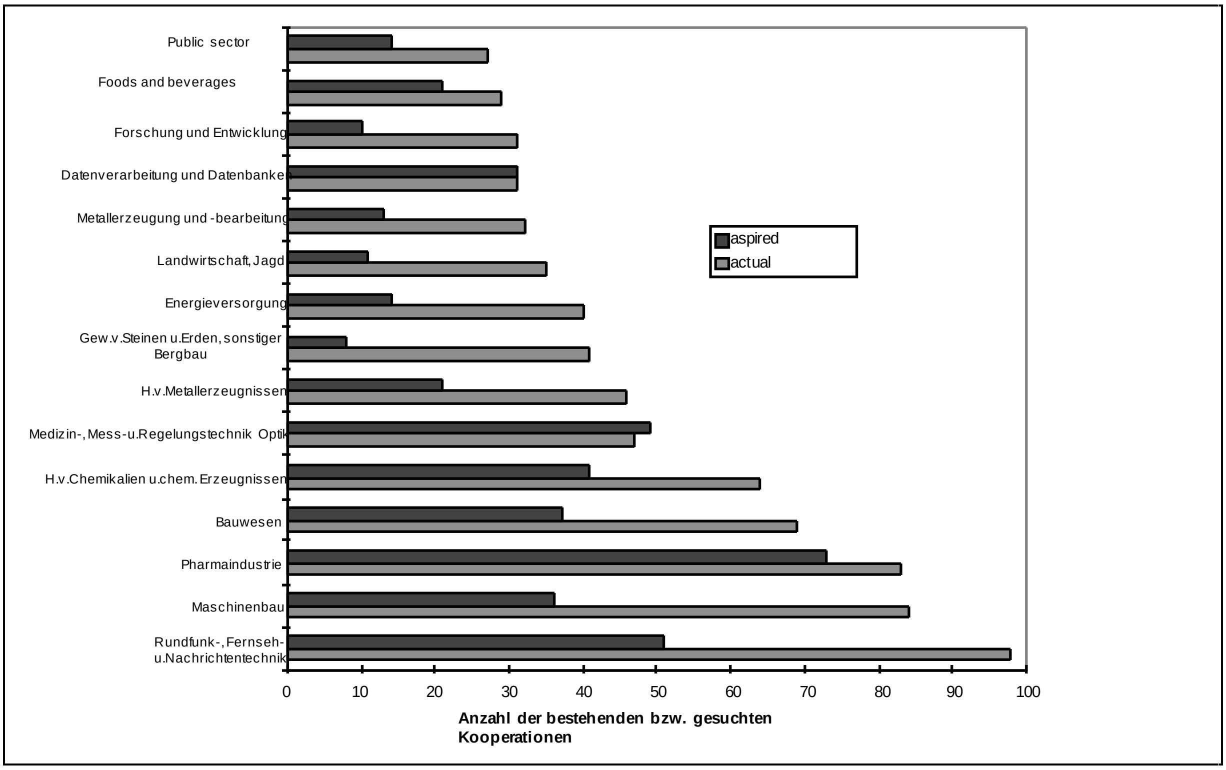
Source: BMWF, own calculations

Rather surprising is the high share of institutes from the engineering sciences that cooperate exclusively with foreign partners (29 %). This could be an indication for a mismatch: these institutes probably lack Austrian counterparts on the side of the enterprise sector. This questions might be subject to further analysis, disaggregating scientific fields and corresponding industrial sector.

Cooperations wth the enterprise sector

An analysis from the data obtained from FODOK provides a first glance at the structure of the cooperation partners (see fig.1) broken down by industrial sector. The numbers are only rough indications, because they reflect only the frequency of the branche cited as one with which cooperations do exist, but not the number of projects.

Figure 1 Cooperations between university institutes and enterprises, by branch (NACE)



Source: FODOK, own calculations

Again, a rather high concentration can be observed: 35 percent of all 'actual' cooperations are in five branches (construction, pharmaceutical s, mechanical engineering, telecommunication engineering, chemical industry). The difference between 'actual' and 'aspired' cooperation can be interpreted as a non-cleared market for R&D cooperation, with the universities finding no response from the enterprise sector. The difference is most marked in pharmaceuticals, medical equipment, metrology and data processing and databases.

For a further characterisation of the enterprises involved in cooperations with universities, their motives and barriers, a seperate survey was carried out. 220 out of 587 institutes responded, of which 152 had cooperations with enterprises. The structure of the enterprises involved in the cooperations is depicted in tab. 11

Table 11: Structure of cooperation partners

Type of enterprise	# of enterprises	# of projects	# of institutes
Austrian Les / industry	173	237	73
Austrian SMEs / industry	253	312	90
Foreign LEs / industry	119	158	62
Foreign SMEs / industry	45	62	22
Austrian enterprise /service sector	147	183	52
Foreign enterprise /service sector	20	39	12
Total	757	991	(152)

Source: TIP-University-survey

While Austrian SMEs rank highest in absolut numbers, they are unerprepresented, given their share in the overall economy (99% of all enterprises have less than 500 employees). Rather high is the share of foreign enterprises, mostly large ones. Other studies have shown, that especially enterprises from the southern part of Germany are very actively exploiting the resources of the Austrian universities by engaging in cooperative R&D ventures.

Impulse for cooperation

The single most important impuls for establishing a cooperation is personal contacts (74 % od the answers)(see tab. 12). A study on the cooperative behaviour of the 50 most R&D-intensive firms in Austria came to similar conclusions (Buchinger 1996). Trust and the establishment of a common view of the problem and the potential for cooperation are shown to be a prerequisite for successful cooperation.

A second, but most likely related , channel for initiating cooperations is via graduates (63%). A remarkably high number ascribed the active role in the search process to the enterprises

(62%).

Conferences and publications, very frequently named as important mpluses for scientific cooperation, do virtually play no role in establishing cooperations with enterprises. Also, and more interesting for technology policy, hardly any cooperations are initiated by technology transfer institutions (tab. 13).

Table 12: Impulse for cooperation

	importance (# of responses)				
initiated via	1	2	3	4	5
Graduates	55	63	27	14	28
Conferences	30	52	59	31	16
Scientific Publications	12	57	58	40	18
Enterprise initiatve	54	64	47	14	10
Institutes initiative	51	58	46	24	11
Personal contacts	71	67	31	11	7

* 1= very important role, ... 5 = not important at all

Source: TIP-University-survey

Table 13: Initiation of cooperation by transfer institutions

	Importance*				
	1	2	3	4	5
funding agencies	6	3	14	38	114
'partner auctions' ("Partnerbörse")	0	2	7	31	134
external contact institutes of the universities ("Außeninstitute")	1	4	12	38	120
other	6	2	4	0	5

* 1= very important role, ... 5 = not important at all

Source: TIP-University-survey

Barriers to cooperation

With regard to this question, again the caveat has to be kept in mind that the answers reflect only the perception of the university institutes. For them, the most important barrier to cooperation is the lack of knowledge about the research potential of the university institutes (see tab. 14)

Table 14: Barriers to cooperation between university and enterprises

Barrier	Importance				
	1	2	3	4	5
Lack of interest on behalf of the enterprises	36	48	61	31	23
Research capabilities of the institute are not know outside the university	56	71	43	14	12
No spare capacities	58	47	48	25	25
Cooperation has no scientific merit	14	45	59	41	32
Financing of the cooperation	39	48	41	40	20
Labour regulations hampering cooperation	6	11	27	56	89
Poor resources on the side of the institute	5	15	45	51	73
Different time horizons between university and industry partners	19	42	52	42	38
other	10	3	2		2

* 1= very important role, ... 5 = not important at all

Source: TIP-University-survey

Factor analysis revealed a second group of respondents: namely those who see barriers to cooperation with enterprises in "the lack of scientific appeal" and "different time horizons of enterprises and universities". This might be interpreted as a perception of too big a difference in 'cultures' of the respective institutions.

Roughly half (46 %) of the institutes named the problem of financial resources for cooperation. This might be especially so for the institutes experiencen the above mentioned 'cultural differences', as these might increase transaction costs considerably

Some tentative conclusions

The analysis of the interface between the universities and the enterprises has so far produced the following results:

- there seems to be a discrepancy between the ‘supply structure’ on the side of the universities and the ‘demand structure’ on the side of the enterprises. The research profile of the Austrian universities with its strong focus on medical and natural sciences is somewhat different from the specialisation pattern of the Austrian industry
- there also seems to be an awareness problem (given that the university institutes are right in judging their research potential as being of at least potential interest to the enterprise sector).
- A few institutes have managed to engage in intensive cooperation with enterprises. These institutes nevertheless are also among the most active as regards publications. There seems to be no marked ‘trade-off’ between scientific research output and acitivites directed towards more practical needs.

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