Mapping Innovative Clusters in National Innovation Systems

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Abstract

In the following paragraphs we will discuss the 'mapping of innovative clusters in national innovation systems'. For this we have used a data set of almost 3.000 firms that participated in the first and fifth survey of the Mannheimer Innovation Survey (which is comparable with CIS data). The Community Innovation Survey (CIS) is an initiative of the EU Commission and a joint survey of DG XIII/SPRINT/EIMS and Eurostat. To begin with we will, in the context of a definition of innovation systems, highlight the outline conditions for innovations in Germany, focusing above all on the basis of innovations, science and engineering. This is followed by a step-by-step empirical analysis of the mapping of innovative clusters at the company level which is based on the Community Innovation Survey set of data; and finally the structural influences (size-effect, effects of sectors/industries) on the innovative behaviour or innovative styles are presented. The explanatory power of structural influences on the innovative behaviour will also be analysed as well as the influence of other variables such as information flows and cooperation patterns within the innovation system of Germany. In the summary at the end of this paper we will suggest starting points for potential implications for innovation policy in order to be able to develop generic and specific policies for the different industry clusters.

As far as we know from firms innovating at a certain level of organisation, they use a special portfolio of information and knowledge transfer strategies that can not simply be transferred to firms which are not (yet) innovative. While accepting that innovative in-house activities are necessary to keep track with international developments and competition, a highly innovative atmosphere within the economy which supports innovative activities should be among the main goals of innovation policy. Furthermore, firms need

to have an absorptive capacity to transform knowledge into innovations that bring economic success.

List of Contents

1 Political Terrain and Objectives of Innovation Policy in Germany

New technologies and globalisation are changing the world. Economic competition is taking on new forms. Information is the dynamo of knowledge and social development. In general, the changes taking place reflect the generation, the transfer and the adaptation of knowledge. Knowledge is recognised as the basis of productivity and economic growth. The ‘diffusion process’ or the ‘distribution power’ of knowledge describes both an economic and a social process, for in an economy and society the transfer and use of information play an important role for the effectiveness of the innovative system and its potential to improve economic performance.

With respect to its competitiveness with other countries, Germany still has a leading edge when it comes to technology and know-how. Together with the USA and Japan, Germany is one of the leading technology producers in the world, and it is the leading technology supplier in Europe. Aside excellent training and a well developed research infrastructure important factors of technological advantages are the innovative power and flexibility of firms and industries, especially an efficient small and medium-sized business sector.

During the last decade the R&D intensive sectors in Germany have increased their percentages of innovative products.[1] Between 1993 and 1995, the R&D intensive industries contributed nearly half of the added value produced by German manufacturing industries. The major part of these contributions stems from electrical engineering, machine construction, the chemical industry, the automobile industry and data processing devices and equipment. On average the ‘high-technologies’ cover 3.5 percent of the value added, and the ‘advanced technologies’ 8.7 percent. Among the ‘advanced technologies’ Germany ranks at the top, whereas in the ‘high or cutting-edge technologies’ Germany is placed behind Japan and the USA. The sectors' employment proportions show a similar ranking. In Germany, nearly 13 percent of all jobs are provided by R&D intensive sectors. In contrast to this, strongly service-oriented countries such as the USA and Japan have reported only six or nine percent (BMBF, 1997: 4).

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[1] R&D intensive industries are classified as ‘high or cutting-edge’ (pharmaceuticals, computer/office technology, radio/tv/telecommunications engineering, aircraft and spacecraft industry, precision instruments, optics/clocks) and ‘advanced’ technologies (chemical industry, mechanical engineering, electrical engineering except radio/tv/telecom, railroad industry, automobile industry). The line between both sectors is drawn according to the share of R&D in the turnover. ‘Cutting-edge technologies’ cover goods with an R&D intensity of more than 8.5 percent, whereas ‘advanced technologies’ cover goods whose R&D share is more than 3.5 percent and less than 8.5 percent of the turnover.

Table 1: Domestic production, domestic demand and employment in R&D intensive industries in sample countries selected by OECD 1993 - 1994/95

Industry	West Germany	USA	Japan	France	Italy	Great Britain
Portion of gross value added in % 1993-1995						
R&D intensive industries	12.2	8.5	11.5	7.7	6.4	8.0
• High technology	3.5	3.6	3.9	2.6	1.9	2.9
• Advanced technology	8.7	4.9	7.7	5.1	4.5	5.2
Non R&D intensive industries	13.7	9.5	13.5	11.7	13.9	10.2
Manufacturing industry	25.9	18.0	25.0	19.3	20.4	18.3
Share of domestic demand[1] in % 1993-1994						
R&D intensive industries	7.2	9.0	6.6	6.7	5.6	8.6
• High technology	4.0	3.7	2.2	2.6	2.5	3.0
• Advanced technology	3.3	5.3	4.3	4.1	3.1	5.6
Non R&D intensive industries	16.2	11.0	14.6	12.1	10.8	12.1
Manufacturing industry	23.4	19.9	21.2	18.8	16.4	20.8
Share of employment in % 1993-1995*						
R&D intensive industries	12.8	5.9	9.3	7.5	5.8	8.2
• High technology	3.1	2.5	3.1	2.3	1.4	2.7
• Advanced technology	9.7	3.4	6.2	5.2	4.3	5.4
Non R&D intensive industries	14.9	9.7	13.8	11.0	14.7	11.4
Manufacturing industry	27.7	15.5	23.2	18.5	20.4	19.6

1) Gross value added of the respective industry plus net imports and less net exports in % of the domestic demand (private and public consumption/spending as well as gross investment). Net exports and net imports have been estimated using their share in the real output of the respective domestic production.

*) USA: 1993-1994; Great Britain: 1993.

Source: OECD: STAN-Database; Economic Outlook. - Calculations and estimates from the DIW (see BMBF (1998:4) 'Germany´s Technological Performance'.

Knowledge is created through innovative processes, and R&D is a critical input into those processes. Therefore the most important objective of national and international governmental R&D and innovation policy can be defined as the promotion and preservation of future corporate competitiveness.[2] From the point of view of the German government it is necessary to stimulate private companies to undertake and promote both research and knowledge transfer. In addition, the structure of promotion programmes and supporting institutions has to be capable of adapting to changes in innovation proj-

2 In economic terms, external effects of corporate innovation activities have recently been presented as central justification for governmental intervention. The core argument is, in this context, that the national economic benefits of corporate research expenditure are higher than the benefits for the respective company. Thus, in terms of the national economy as a whole, companies are not investing enough in inventing and developing new products and processes. One explanation for this is that the knowledge-producing firm is unable to reap the full profits ensuing from its investment. For studies focusing on the situation in Germany see Harhoff and König, 1993, Klodt, 1995, Meyer-Krahmer, 1993, Becher and Kuhlmann, 1995.

ects, especially when it comes to 'advanced technologies' and 'cutting-edge technologies'.

An increase of the technological assets of an economy is undeniably based on a knowledge-based society, particularly the economic capabilities at the company level. Based on this perception, the central objectives of a governmental research policy are derived from: (BMBF, 1996: 9-11).

- The promotion of high technology
- An innovation-oriented research policy
- The safeguarding and improving of scientific excellence
- The strengthening and interlinking of the research system
- International openness and cooperation

Although an entrepreneurial spirit and the willingness to take risks in the development of new technologies are business characteristics which can not be substituted by any governmental action, a governmental R&D and innovation policy has to contribute to a dynamic innovative system. The readiness to innovate could also be encouraged by legislation. Therefore the provision of favourable basic conditions has to go hand in hand with the development of cooperative networks within the innovative system. The funding and promotion of research, the stimulation of the exchange of knowledge between science and industry and the creation of an environment that fosters innovative activities are vital characteristics of a comprehensive innovation policy.

The structure of the German innovative system has generally evolved by path dependent evolution, meaning that traditions and historical factors create a basis from which the system can depart. The division of competencies and responsibilities between the federal government and the Laender is seen as a crucial key factor of the German innovative system. According to a very comprehensive view[3], a national institutional framework is a set of rules and understandings which regulate the labour market, the educational system, corporate governance and product markets, all together creating the economic context in which companies or their subsidiaries are embedded (Soskice, 1996: 16). The framework, which German companies face can be exemplified as follows:

- With regard to work organisation, training, hiring and firing, and some influence on wage bargaining, the labour market in Germany is relatively strictly regulated. However, the principles of consensus-based decision making between unions and employer organisations fulfill the requirements of a dynamic innovative system. The balance of opposing powers ensures the participation of both workforce and management. The innovation process is based on a commitment between workforce and management, who have to agree on R&D opportunities, risks and rewards.
- The regulation of the German education and training system has to be seen in the

[3] In section 2 we will discuss an institutional framework of the German innovation system that focuses on the distribution power of business and science. See also appendix 1.

context of a regulated labour market. The system works on the basis of links between business and universities/science. Qualification standards and future training strategies are discussed in an open dialogue among companies, employee associations and educational institutions. From the enterprises´ point of view, company training is long-term investment in human capital. This concept is anticipated by students and apprentices from fields of engineering who are willing to invest in their vocational skills. Basically this system is able to cater for the companies´ needs for specific know-how and skills; however, in terms of reacting quickly to market demands it has its limitations.

- Corporate governance in the German innovative system provides capacities for long-term R&D and innovation projects at a relatively low risk level and at the same time stable shareholding. Monitored by banks and consultants which have the expertise to provide them with sufficient knowledge on technological opportunities, companies are encouraged to engage in innovation strategies if risks and costs can be estimated. The more or less consensus-based risk assessment reduces the likelihood of companies pursuing short-term radical innovation strategies.
- Relationships and cooperation partnerships between companies are also taken into account by German competition policy: the German system allows companies to work together on a consensual basis, and in many cases long-term cooperation partnerships formalised by contracts as well as intensive informal relationships are accepted, whereby the standards for such relationships are the outcome of the mutual dialogue between companies and business associations.

In conclusion, the German innovative system favours innovation in traditional technologies, especially in important industries like machine construction, chemistry, electrical machine construction or automobiles. The advantages of this system are obvious: There is a clear structure of responsibilities and competencies that have emerged over many years of continuous development. This development is accompanied by an industrial and R&D tradition determined by consensus-based governance structures and founded on individual experience and personal relationships. These conditions help to stabilise the system and enable it to cope with external shocks.

In recent years the traditional strengths have increasingly become the target of criticism, being regarded as risky in the phase of a radically changing world. The emergence of new technologies such as computers, telecommunication etc. on the one hand and considerable social shocks such as the German reunification on the other, show that the system may not be flexible enough to cope with extreme challenges. This is also due to the fact that in a system that puts the main emphasis on high quality incremental innovations, radical adjustments and radical innovations are very difficult to realise. However, the question of how to combine radical new strategies with existing competencies still remains to be answered.

2 The German Science and Research Framework

The task that the German innovative system currently has to fulfil is to reform or transform the old system into a new system that is more aware of the importance of radical innovations in emerging technologies and that is also able to transfer the highly developed scientific knowledge in marketable (tradable) products. Theoretically, the actors of the German innovation system should be divided into producers and users of knowledge and human capital on the one hand and knowledge transfer and bridging institutions on the other.[4] Besides universities and industry R&D facilities, there is also a variety of public and semi-public research institutions, for example Max-Planck-Gesellschaft (MPG), Fraunhofer Gesellschaft (FhG), and Helmoltz Centres.[5]

By direct or indirect transfer to business sector enterprises, these institutions account for a large part of the technology transfer as a whole. In terms of research in education and training, for example, it is primarily for three reasons that achievements by public-sector research institutions stimulate industrial innovative success: by increasing human capital, by generating and publishing new knowledge from research work, and by directly supporting companies in solving industrial problems by the provision of respective services. The knowledge is channelled to the companies in form of

- R&D cooperation projects
- direct demand for applied research by industry enterprises, contract research
- consultant projects
- personnel mobility
- education of practice-oriented capabilities in technical colleges.

In addition there is a variety of institutions serving as intermediating facilities for transfer activities. It has been shown what an important role institutions and their interrelationships play in the innovation process as an element in diffusing know-how. Thus, a sound technology infrastructure is one of the most important preconditions in preparing an economy to meet global challenges. But at the same time, institutions (in the sense of institutional, administrative facilities) can also be the source of mismatches and barriers.

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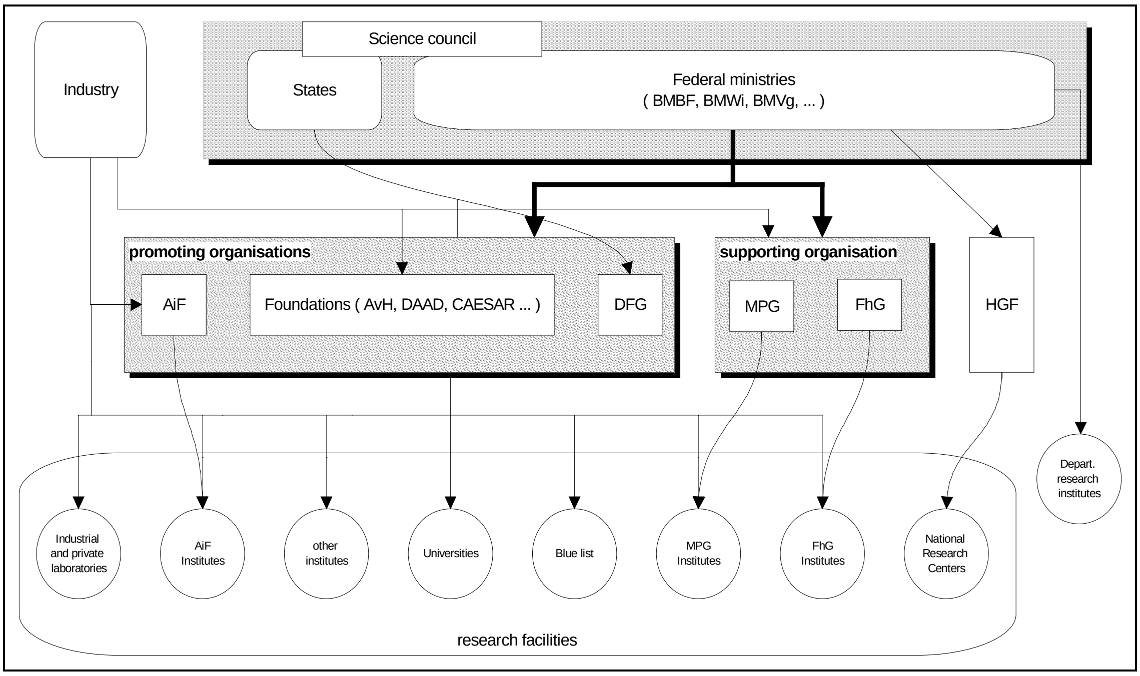
4 Recent research on innovation has revealed that the actual innovation process, to a large degree, can no longer be depicted as a linear model of consecutive phases of innovation, where the research phase, the development of the product and the product design are implemented independently of each other in temporal succession. In the majority of industries or technologies, the phases and sub-processes involved are recursively interwoven with each other, they are mutually contingent, and recur in response to the increasing experience gained in the subsequent phases of innovation. The recursive model of the innovation process implies a long-term interaction between all those involved in the innovative activities concerned. (Kline and Rosenberg, 1986).

5 See appendix 1 for the list of institutions.

Figure 1: The Science and Engineering Framework in Germany



Source: Schmoch et al. 1996

From a theoretical point of view it is possible to divide the innovation system into a technological, a structural, a regional or a national system of innovation; in practice however, all elements work simultaneously, and it depends on the focus of the analysis which categories are used. The active participants in the systems are companies, universities, academic research institutions, private and public-sector educational facilities, political bodies and decision-makers. In addition to structural preconditions, the crucial factors for success (in the sense of influencing the level and direction of technological change and contributing to the innovative power of an industry or a country) are primarily the behavioural patterns of industrial decision-makers - the entrepreneurs and institutions involved - embedded in a proactive context of technical progress.

The efforts of the people involved to generate new ideas, to pass on their knowledge, and to translate it into marketable products, with all the surrounding circumstances of R&D, training and familiarisation, quality testing, market analyses, etc., depend heavily on the extent to which those involved profit from technological change and benefit personally from their innovative efforts. The key issues of that system are the processes of interaction and the processes of competition and selection among firms with different capabilities and innovative performances.[6]

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[6] Nelson and Winter (1982) single out four factors which are fundamental for the establishment of an innovation system and which emphasise the technological and/or sector-related focus: opportunity conditions, appropriability conditions, accumulation of technological knowledge, and the nature of the relevant knowledge basis.

3 Innovative Clusters at the Company Level

3.1 Correspondence Approach of Innovation Styles

3.1.1 Conceptual Framework

When analysing the innovation system, the emphasis is placed on the interdependencies between the corporate production system and the infrastructure of social and economic institutions, as well as other surrounding conditions.[7] For our purpose of cluster analysis the 'correspondence approach of innovation styles' is chosen. This approach stresses the network of agents interacting in a so-called technological environment to generate, diffuse, and use technology. Here, groups of firms with similar innovation characteristics are clustered. The 'value chain approach' focuses on links, interactions and interdependencies between actors in the value chain in the process of innovating and creating added value. However, both approaches may be linked when the 'correspondence approach of innovation styles' is extended to other than innovation variables, combining innovation patterns with other firm characteristics (Roelandt and den Hertog, 1998).

We assume that the complexity of the innovation systems justifies a variety of different lenses for their analysis. Every concept stresses partial aspects and provides helpful details to paint a comprehensive picture of the relationships between the different parties involved and game rules. The identification of groups of firms with similar innovation behaviour patterns in different economic and technological environments should reveal economically meaningful types of innovation strategies pursued by firms. It may enable us to test the impact of factors necessary for these strategies to be successful, especially those referring to knowledge infrastructure and company behaviour patterns in the innovation system. If our assumptions and perceptions of the innovation behaviour at the company level, the integration of enterprises in the innovation system, and the profits companies gain from the system are right, the innovative power of a company has to be regarded as an endogenous key variable. Sector-related, technical, partial, or structural

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[7] For some years now academics have been discussing systems of innovation in a multitude of theoretical and empirical studies. These discussions deal, above all, with the incidence and variety of collaborations between industry and the science sector and the impact on the innovative performance of the business sector. In trying to evaluate the innovative potential at the company level, alternative definitions of innovation systems as well as alternative innovation approaches might be useful. See Acs and Audretsch, 1990, Kleinknecht, 1987, Breschi and Malerba, 1997, Carlsson, 1994, Carlsson and Stankiewicz, 1991, Cooke and Morgan, 1994, DeBresson, 1989, Edquist, 1997, Harrision, 1991, Marceau, 1994, Smith, 1995, and the following literature for works related to national systems of innovation: OECD, 1996, 1997 and 1998, David and Foray, 1995, Freeman, 1974, 1988, 1990, Lundvall, 1992, Nelson, 1988, 1993, Nelson and Rosenberg, 1993, Porter, 1990, McKelvey, 1993, Patel and Pavitt, 1994.

aspects are conditions which might have an impact of the innovation behaviour of a company, but this aspect should not be the starting point of the analysis.

The first step of the analysis is the search for a proper indicator, which summarises the innovation and system behaviour of a number of firms. The indicator should reflect three factors, together forming innovative clusters:

(3-1) Step one: $$\text{Innovative Cluster (IC)} = f\begin{Bmatrix} \text{Innovation (Inno)} \\ \text{Knowledge Transfer (Know)} \\ \text{Information (Info)} \end{Bmatrix}$$

- First, at the company level there are innovative capacities and potential which can be measured by the innovation intensity, or innovation and R&D performance that occurs at different institutionalised company levels. This aspect refers to some conditions of appropriability, as well as to the accumulation of knowledge or the continuity of innovative activities. Therefore, we use the term innovation style or innovation status (Inno).
- Second, the company's capacities and readiness to interact are important. These can be measured by examining the networking activities or various knowledge transfer channels. The knowledge basis of a firm reflects the nature of know-how and the means of technology transfer and communication (Know).
- Third, the information and management behaviour of the firm is needed. For this we use information sources important for the enterprise's innovation activities. These indicators capture both the sources of technological opportunities and the knowledge basis (Info).

The cluster defined by using these variables is a pure innovative cluster. It is possible to examine whether such as cluster is sensitive towards variables that are not directly linked to the innovation process. Such variables used here are size and industry characteristics.

(3-2) Step two: $$\text{Innovative Cluster (IC)} = f\left\{\begin{matrix} \text{Inno} \\ \text{Know} \\ \text{Info} \end{matrix} \middle| \begin{matrix} \text{Industry (Indu)} \\ \text{Size (Size)} \end{matrix}\right\}$$

Judging from the studies of innovative industries in Germany, it is clear that there will be a significant correlation between the innovative behaviour of a firm and the industry it belongs to. Therefore we suggest that ex post large firms have carried through their innovation processes more successfully than small firms.

3.1.2 Empirical Findings

A very simple model of the above mentioned approach is an innovative cluster only on the basis of innovation behaviour on the company level (Inno).

(3-3) $$IC_j = \text{Innovative Cluster (IC)} = f\{\text{Innovation } (Inno_i)\} \qquad j = 1...n,\ i = 1...4$$

- $Inno_1$: non innovative firm

– $Inno_2$: innovative firm without R&D

– $Inno_3$: innovative firm with R&D, but without R&D department

– $Inno_4$: innovative firm with R&D and R&D department

The innovative power on the company level resulting from innovation and R&D activities is a first step to evaluating the technological competence of a firm, its market opportunities and conditions of appropriability. For this purpose we differentiate four types of innovative firms, judging from the success of innovation activities on the company level.[8] The definition of these variables brings about an order of different degrees of innovative behaviour, or what we call an innovation style or innovation status. This order reflects the structural organisation of a company's innovation activities. It starts with no innovation and ends with a highly organised and formalised system of innovative activities.

The objective of the cluster-oriented analyses based on this theoretical framework is to show the interdependencies between so-called innovation structures at the company level, and input behaviour and output results. We are going to answer the following questions:

- whether a company's innovative engagement and resource allocation depends on a company's innovation style, and
- whether the performance of a company is affected by its innovative power.

We chose this variable as a starting point since we have reasons to assume that the decision of being innovative, at which point in time and on what level of organisation, is one of the very first decisions made. The incentives to use a special set of transfer and information channels ensue from how the company answers these questions.

A first example for the alternative cluster approach, the 'correspondence approach of innovative styles', refers to the innovation expenditure of small and medium-sized enterprises (SME).[9] We distinguish between different components of innovation expenditure, such as R&D, construction and design, training etc., and three different types of innovative firms, the innovative clusters $Inno_2$, $Inno_3$, and $Inno_4$.

The innovation budget consists of different components, but most of the budget is spent or invested in R&D, construction and design, pilot plants and projects, and investments

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8 Alternatively, the innovation input could be a reasonable criterion for forming innovative clusters at the company level. The measure for a comparable group of enterprises would be the innovation expenditure. Innovation expenditure covers current expenditure (labour cost, material etc.) and tangible assets (equipment, buildings, etc.,). Another way of measuring innovation behaviour is the examination of R&D intensity. In section 3.3 we will cluster firms according to different levels of R&D intensity.

9 The following discussion on the basis of table 2 is a brief summary of the in-depth analysis of the innovation behaviour of small and medium-sized firms by Harhoff, Licht et al., 1996 on the basis of German CIS I data. See also Beise, Licht and Spielkamp, 1995.

in new products and processes. The distribution of these forms of expenditure does not vary much within the three groups of innovative enterprises. The aforementioned components consume nearly 85 percent of the budget. Among the different innovative clusters it is obvious that R&D and investments, including the purchase of equipment, are substitutive actions. Firms without R&D invest nearly 40 percent in new equipment, whereas firms with R&D departments spend only 15 percent of their innovation expenditure on this item. On the other hand, they spend 30 percent on R&D, mainly for R&D staff. The results lead to the assumption that, for small and medium-sized firms, R&D activities are strategic, long term business decisions. They are based on certain organisational forms, require highly qualified staff, and go beyond some sporadic or operative work related to innovation.

Table 2: Innovation expenditure of SME by innovative clusters

Expenditure on	Mean distribution of innovation expenditure of companies with 5-499 employees		
	Innovative without R&D	With R&D, but without R&D department	With R&D department
R&D	0%	14%	28%
Pilot projects	19%	22%	20%
Construction, product design	26%	21%	23%
Gross investment for new products and processes	38%	24%	15%
Market entry costs	3%	5%	5%
Patent registration and renewal	1%	3%	3%
Purchase of licenses	3%	2%	1%
Staff retraining	6%	7%	5%
Other	4%	2%	1%
Total	100%	100%	100%

Source: ZEW (1995): Mannheim Innovation Panel

Table 3 shows that firms with a more highly organised innovative behaviour (last column) also have more intensive export activities. On average, all firms that undertake R&D in a systematic way perform better than the average of the entire sample. The investment rates do not differ dramatically for firms that undertake innovative activities, no matter on which level. This points to a high potential for all groups of firms.

Table 3: Company performance in relation to the innovative style

Variables with a significant difference	Sample means	Non-innovative Firms	Innovative firms without R&D	Firms with R&D, but without R&D Department	Firms with R&D Department
Share of turn-over with new products	48.8%	-	45.9%	49.4%	51.1%
Share of firms with exports	56.8%	28.9%	42.5%	63.4%	83.7%
Average export ratio of export-ers	16.8%	6.3%	9.5%	17.7%	29.1%
Average in-vestment rate of investors	13.9%	11.6%	14.3%	14.2%	14.7%

Source: ZEW (1995) Mannheim Innovation Panel

It turns out that a company's performance and its innovative behaviour are comparable to each other. It is also obvious that innovative firms behave differently from firms with R&D in the same industry. Of course, there are industry effects: for example we find more innovative firms in the chemical industry than in the textile industry, but innovative firms in these industries act similarly and they show a similar firm profile or performance attitudes with respect to the different firm characteristics.[10] Whether and how enterprises are integrated in the national innovation system and how the input-output-performance of the companies is influenced by its innovation cluster, are the questions which follow.

We define innovative styles not only by the formalised or institutionalised innovation or R&D activities, but consider also alternative or complementary sources of innovation and channels of knowledge transfer. Taking these issues into account, the description of technology diffusion among firms in the national innovation system requires a more complex model. Therefore we introduce an indicator for innovative clusters which covers the innovation structure, but also the knowledge and information aspects of companies' innovation activities: [11]

$$(3\text{-}4) \qquad IC_j = \text{Innovative Cluster}\,(IC) = f\left\{\begin{matrix} \text{Innovation } (Inno_i) \\ \text{Knowledge Transfer } (Know_i) \\ \text{Information } (Info_i) \end{matrix}\right\} \qquad j = 1....n$$

$Inno_i$: i = 1...4; $Know_i$: i = 1...4; $Info_i$: i = 1...5

10 The analysis is based on regression models (Probits) where the industry dummy is controlled. That means that the results are significant among the clusters and that there is no industry bias. See also appendix 2.

11 At this stage, the clusters defined here are still a rather theoretical constructure. No "natural" grouping variables such as regional, branch or technology information are taken into account. Described are groups of firms that can be categorised by specific characteristics of innovation structure with a characteristic transfer channel portfolio and typical information sources. For a description of the variables see appendix 2.

– $Know_1$: firms stating that they had transferred or acquired knowledge using formal channels such as licences, or that they had purchased equipment, etc.

– $Know_2$: firms preferring informal ways of acquiring information, e.g. by way of communicating, hiring skilled people etc.

– $Know_3$: firms transferring/ acquiring know-how using international channels.

– $Know_4$: firms using only national channels.

– $Info_1$: firms using their own sources within the enterprise or within a group of enterprises.

– $Info_2$: market-related external (vertical) sources of information such as suppliers or customers.

– $Info_3$: market-related external (horizontal) sources of information such as competitors.

– $Info_4$: science-based links to public R&D institutions and universities.[12]

– $Info_5$: general information such as patents disclosures, fairs, conferences.

We use the innovation structure in the same way as in the previous section and add the knowledge and information variables. The characteristics of the knowledge variable will reflect formal and informal ways of acquiring and transferring technological know-how. A further distinction is made between national and international transfer mechanisms. Finally, we cluster innovative enterprises according to their sources of innovative ideas and according to how which transfer channel is used to direct information into new projects.

Equally as important as the different transfer channels of new knowledge are the various sources of information that firms use to become acquainted with new ideas. The information attitude or the management behaviour of a company comprise both - the sources of technological opportunities and the knowledge basis. Some sources, e.g. suppliers, customers or competitors, are closer to the market than others that are more related to science and research like universities or private or government R&D labs. It is interesting to examine whether information strategies in manufacturing industries are rather "pulled" by demand or "pushed" by technological development. In many cases, it is not technologies or products that are transferred, but the mere knowledge which is then turned into technical products by enabling companies to develop market-driven innovations themselves, thus also expanding their own innovative potential. In this context, the following questions are to be answered:

- What kind of mechanism do firms use to acquire and transfer technological know-how?
- Which sources of information stimulate innovative ideas and activities?

[12] See also the description of ‘public R&D institutions’ in appendix 1.

Sources of information used for the creation of a basis for internal knowledge show an intuitive pattern: firms with rich and highly organised internal sources of innovation obviously show a lower tendency to use external information than to use internal sources of information (Table 4, $inno_4$). If a company carries out regular innovation activities and has annual R&D expenditure (Table 4, $inno_3$ and $inno_4$), the incentives to gather all information available in the innovation system are high. However, for most of the firms internal information plays an important role. A more specific behaviour can be observed with companies with R&D departments ($inno_4$). Besides the high importance of internal knowledge diffusion, the opportunities to access and exploit public information are highly developed. This is consistent with the argument that companies with a higher innovation intensity experience a demand-pull from customers and technology push incentives (public and other information) more intensively than firms innovating at a lower level.

For innovative firms without R&D (Table 4, $inno_2$) indirect external and internal sources of information are most important, while all other external sources are less frequently used. It seems logical that half of these firms try to gather their information from sources which are easy to exploit. Within a company, information flows at almost no cost. Market-related external information can not be obtained without resorting to costly resources. Besides the cost factor, another possible interpretation of the phenomenon that only one third of these firms uses public and direct external information could be the fear of a loss of know-how, as they may have not much experience with the trustworthiness of external partners, especially with public institutions. With regard to their information management, firms with their own R&D activities differ from firms with less formalised innovation activities. If a company is innovative and has regular R&D activities, the incentives to gather all information available in the innovation system are high. However, internal information is very important for most firms. While internal sources of information are not of significant importance for companies innovating at a less formalised level, external information resources become much more relevant for them. However, across all levels of innovation intensity, indirect external information is almost equally important (Table 4, $info_2$).

Table 4: Firms and their innovation style and information behaviour

Share of firms preferring certain sources of information	Non-innovative firms $Inno_1$	Innovative firms without R&D $Inno_2$	Firms with R&D, but without R&D department $Inno_3$	Firms with R&D department $Inno_4$
Internal information $Info_1$		53 %	69.4 %	85.4 %
Vertical external information $Info_2$		51.1 %	54.2 %	59.7 %
Horizontal external information $Info_3$		38.4 %	46.1 %	57.6 %
Public information $Info_4$		37.1 %	53.1 %	70.4 %
General information $Info_5$		38.8 %	53.9 %	77 %

Source: ZEW (1997) Mannheim Innovation Panel Note: % refers to the whole sample of 2859 firms.

The use of transfer channels, whether they are formal or informal (Table 5, $know_1$ and $know_2$) is much more likely in a more institutionalised innovation environment: the more formalised the innovation activities are, the more elaborate and formalised are the transfer channels used, e.g. joint ventures, cooperation with research institutes, etc. (Table 5, $know_1$). A logical conclusion is that firms with regular R&D expenditure and/or an R&D department have better opportunities to organise a formal knowledge transfer. As we have mentioned in the context of information strategies, the more formalised the innovation behaviour is, the wider is the range of the transfer channels. The reason for this are better developed appropriability conditions. Looking at the last two columns of Table 5 ($inno_3$ and $inno_4$), it becomes clear that in both groups of innovators with R&D a slightly higher fraction uses formal channels of knowledge transfer. In firms without R&D the opposite is the case. Enterprises with less formalised innovative activities depend on a personal knowledge transfer, on few highly skilled employees hired or on human capital in general.

Table 5: Firms and their innovation styles and knowledge transfers

Share of firms preferring certain transfer channels	Non-innovative firms $Inno_1$	Innovative firms without R&D $Inno_2$	Firms with R&D, but without R&D department $Inno_3$	Firms with R&D department $Inno_4$
Formal channels $Know_1$		44.3 %	62.4 %	73.0 %
Informal channels $Know_2$		48.5 %	57.4 %	66.3 %

Note: % refers to the whole sample, comprising 2859 firms. A channel type was assigned to firms if they used that kind of channel in at least one form.

Source: ZEW (1997) Mannheim Innovation Panel

Table 6: Firms and their information behaviour and knowledge transfers

	Formal channels $Know_1$	Informal channels $Know_2$	International channels $Know_3$	Only national channels $Know_4$
Internal information $Info_1$	74.1 %	74.5 %	59 %	78.6 %
Vertical external information $Info_2$	59.3 %	58.8 %	50.4 %	60.8 %
Horizontal external information $Info_3$	54.1 %	53.7 %	41.7 %	53.8 %
Public information $Info_4$	63.4 %	61.6 %	48.3 %	60.5 %
General information $Info_5$	63.5 %	62.5 %	53.8 %	61.9 %

Note: % gives the share of firms preferring the respective information source; this percentage refers to the whole sample comprising 2859 firms grouped into transfer channels. Channels and sources of information types were assigned to firms if they used each of the two characteristics in at least one form.

Source: ZEW (1997) Mannheim Innovation Panel

The different sources of information are closely related to each other. If a firm uses at least one of these sources, this means in almost all cases that it uses, in fact, more than one, sometimes a wide portfolio of sources. There is reason to assume that a successful use of public sources of information, such as universities, goes hand in hand with the exploitation of indirect external information like suppliers and customers. Surprisingly, information strategies are hardly affected by the way the knowledge transfer takes place (Table 6, $know_1$ and $know_2$).

3.1.3 Characteristics of Innovative Clusters - Size and Industry Effects

Judging from the analysis we assume that the decision of being innovative to a certain degree of organisation and the decision of using certain transfer or information channels are simultaneously determined variables.[13]

When trying to put the results so far into relationship to each other it turns out that the following three main clusters, or types, of innovative firms emerge:[14]

(IC_1) Firms with R&D department having a broad internal research and basis of

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13 Based on the assumption that information and transfer strategies are independently chosen instruments (exogenous variables) to define the level of innovation, or innovation styles (endogenous variable), the above made statements and the cluster definitions are additionally supported by a ordered probit analysis shown in appendix 2. We carried out this analysis for all combinations and also took the simultaneity into account.

14 These results base on a qualitative evaluation of the internal potential or the absorption capacity of a company's information management (e.g. ‘demand pull’ or ‘technology push') concerning the, and judging from the degree of formalisation of the knowledge transfer.

knowledge: external information is, above all, used as a ‘technology push’, even if other sources of information are also considered for a global information management. Reflecting the specific company potential and human capital, formal transfer mechanisms with a high degree of organisation are preferred, although companies also maintain informal contacts on a high level.

(IC_2) Firms with their own R&D activities which are less formalised, but nevertheless represent a very sound know-how and absorption basis for the company. Supported by this company potential, external sources of information are of considerable importance, showing a slight preference of the ‘demand pull’ compared to the ‘technology push’. Public research institutions are also important sources of stimuli. The degree of organisation of the knowledge transfer is still relatively high in this group. Formal transfer channels have a high importance.

(IC_3) Innovative firms without R&D capacities which, besides their own qualities, strongly focus on a market-related know-how of customers and suppliers: these companies rely on informal transfer channels and a face-to-face exchange of knowledge. Due to a lack of experience, they are little interested in formal collaboration, e.g. in the form of cooperation partnerships particularly with public research institutions, and rather resort to spontaneous actions in order to react to the current competitive situation. Innovation is seen rather as every-day-business than as a continuous process.

When describing innovative clusters that are heterogeneous in terms of their innovative styles, and including in particular a heterogeneous use of the innovation system, the classification as clusters provides a sufficient background of information on companies' innovative behaviour and strategies. The substantial differences between innovative clusters that arise although decisions how to use the innovation system are presumably made simultaneously within the company, are effected by the differences in the degree of R&D formalisation, which can also be described as structural R&D.

Structural innovation behaviour is closely related to the size of the company. Thus, clusters following the definition IC_2 and IC_3 differ significantly in their size structure compared with IC_1 clusters. That firm size and innovative behaviour are simultaneously determined is one implication of Schumpeter’s hypothesis. Concerning the choice of a transfer channel and a source of information, the firm size has some kind of threshold effect. Firms with less than 250 employees have a significantly lower propensity to use the full range of sources of information sources and transfer channels. Additionally, most innovating firms that do not spend money on R&D systematically also employ less than 250 people.

There are also industry effects. The level of organisation of innovative activities is considerably higher for R&D intensive industries like chemistry, machinery, the computer industry, electrical machinery, and the software equipment industry than for less R&D intensive industries, such as mining, paper, wood, or construction. However, the knowledge transfer and information strategies are much more determined by the structural innovation behaviour than by the technological characteristics of the environment for which the industry is an indicator. There is no significant industry-related difference among firms with an R&D department which also use different transfer channels and different information sources. The large groups of innovative companies resort to different ways of organising their knowledge transfer and information flows. But it seems as if these different strategies of using internal and external, formal and informal means can be seen as complementing each other.

An informal transfer is determined by an intensive exchange of experience and hiring of qualified employees. Therefore human capital plays a key role in the innovation system. Even for firms with R&D departments it makes a difference as to how they organise the diffusion of knowledge. Formal channels such as the purchase of licences, external know-how on the form of machines or cooperation within joint ventures are much easier to achieve. They may require a lot of money and abstract knowledge, but less creativity and personal efforts. Informal channels depend heavily on the conditions and incentives a firm can provide. This tendency can also be observed in firms which do innovate on the basis of systematic R&D expenditure, but on different performance levels. The investment rates do not seem to be affected by the degree their innovation activities are organised. Moreover, firms which do not innovate systematically often have higher investment rates.[15]

With respect to the firms' usage of the ‘national’ innovation system it is worthwhile mentioning that there is a huge potential of cooperation opportunities with foreign firms or institutions which are not exploited and transformed into economic success. Judging from the cluster definition, there is only a small fraction of firms that innovate on a highly organised level and that use international transfer channels. It is possible that only a small number of these firms, mainly large ones, have the capacity to process the huge amount of knowledge that comes in from outside the country - from foreign firms or institutions. Additionally, small firms and firms with a low degree of formalised innovation in particular are confronted with a language problem. And the propensity to use the national innovation system, especially the public sector, correlates with the size of a country. German enterprises as well as firms in France and the United Kingdom have closer relationships to national partners or institutions than companies in smaller countries like Denmark or the Netherlands.[16]

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15 Table 1 shows that expenditure on innovative activities is distributed between R&D and construction, pilot projects and investment in R&D. Additionally, companies invest in physical capital such as machines, technology etc. If the investment rate is defined as the ratio of investment to the entire expenditure, then firms which do not innovate or have no systematic R&D expenditure but invest in new products or technologies have, by definition, a higher investment rate.

16 See MERIT, 1995, PACE-Report Arundel et al., 1995. From the information available in this report it is not possible to judge whether the behaviour of German firms reflects a strong national German innovation system and technological leadership or whether it is a sign of weakness and a lack of internationalization which might cause negative feed-back in the future. See also Beise and Felder, 1997, Harhoff and Licht et al., 1996, Licht, 1994.

3.2 Sources of Innovation-related Information

3.2.1 Effects of the German Technological Infrastructure

For a great number of firms across industries it is true that universities or publicly financed research institutions are less important sources of information for the innovation activities of a firm than internal and other external know-how. Depending on the organisational level of innovative activity which already exists, firms differ in the way they make use of the innovation system. The incentives to use external sources of information decrease with the degree of formalisation of a company's innovation activities. On the other hand, other sources of information can be exploited much better when the innovation activities are more formalised and when firms dispose of in-house capacities to use a wide range of information for their innovation process. This is especially true for public sources of information.

In international comparison, the scientific infrastructure in Germany is highly developed. Nevertheless, the efficiency of the system has recently been questioned. Thus it was criticised that there was an inconsistency between the aims and motives of technological research institutions and the aims of innovating enterprises. Universities, senior technical colleges or polytechnics and research centres produce specialised know-how which, when used by enterprises, requires a skilled workforce which has been trained accordingly. Therefore it comes as no surprise that the importance of the technological infrastructure as a source of information increases with the level of structural R&D (IC_2, IC_3) and the size of the enterprise's R&D intensity.[17]

In this context, an analysis has to be made as to whether it is enterprises with high R&D-intensity who benefit most from information originating from universities, senior technical colleges and research centres. The Mannheim Innovation Survey from 1996 has shown that this is particularly true for the research centres (FhG, MPI), the majority of which are indeed aimed at industries with a high R&D-intensity. In universities and senior technical colleges, however, it is rather industries with medium R&D intensity who profit most from this source of information.

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17 In the following we use the R&D intensity as an indicator to distinguish between different styles of innovation. For reasons of simplification we separate R&D intensive and non R&D intensive industry sectors. As we pointed out in section 1, R&D intensive industries are grouped into 'high or cutting-edge' (pharmaceuticals, computer/office technology, radio/TV/telecommunications, aircraft and spacecraft industry, precision instruments, optics/clocks) and 'advanced' (chemical industry, mechanical engineering, electrical engineering, except radio/TV/telecommunications, railroad industry, automobile industry) technologies. The line between both sectors is drawn according to the proportion of R&D in the company's turnover. 'Cutting-edge technologies' cover goods with an R&D intensity that lies above 8.5 percent, whereas 'advanced technologies' cover goods whose R&D makes up more than 3.5 percent and less than 8.5 percent of the turnover.

The degree of how strongly academic research work is made use of by enterprises from ‘Cutting-edge technologies’, measured by the innovation expenditure of these enterprises, is 23 percent and thus corresponds to the percentage that this group of companies makes up for in the innovation expenditure of all innovating companies.[18] Enterprises from ‘advanced technologies’ account for almost 50 percent of the entire expenditure and thus exceed their percentage in innovating companies with less than 40 percent. The majority of research institutions other than universities are directed towards industries with a high R&D intensity - ‘Cutting-edge technologies’- while industries with medium R&D intensity - ‘advanced technologies’ - are represented approximately proportionally to their percentage in innovating companies. The non-R&D intensive industries are underrepresented, both with regard to their use of academic research work and their resorting to research institutions other than universities (Licht and Stahl, 1997: 38-39).

However, this does not account in any way for how the information is used in the enterprise’s innovative process and how valuable the information is for industrial innovations. In the tradition of studies by Mansfield (1991) the aim was to identify the kind of public research that is utilised by private enterprises and that is in place for private research activities (Mansfield, 1991, 1998, Beise and Stahl, 1998). Hence, another question that had to be answered was whether there had been any product or process-innovations between 1993-1996 which would not have been possible or would have been considerably delayed without the information gained from the aforementioned external sources.

Weighted by the number of companies the analysis comprised somewhat less than 38,000 companies, which can be subdivided according to a ratio of approximately 25:75 in R&D intensive ‘Cutting-edge technologies’ and ‘advanced technologies’ on the one hand and non-R&D intensive enterprises on the other. Only ten percent of the enterprises questioned (of these slightly less than four percent of the R&D intensive and slightly more than five percent of the non-R&D intensive companies) stated that they could not have realised innovations without public research. Represented above average were again industries with high R&D-intensity (see Table 7).

Table 7: Economic Effects of Academic Research

[18] With the entire innovation expenditure for 1996 in millions of DM set at 100 percent, 23 percent of that expenditure was made by ‘Cutting-edge technologies’, 47 percent by ‘advanced technologies’ and 30 percent by non-R&D intensive industries. The ratio of the three groups of enterprises according to their number is 23:36:41 (Licht and Stahl, 1997: 38).

	All innovators		Among them companies which could not have realised innovations without public research	
	numbers		total	
	absolute	in %	absolute	in %
All companies	37,780	100	3,430	9.1
Among them				
• R&D intensive industries	9,030	23.9	1,480	3.9
• Non R&D intensive industries	28,750	76.1	1,950	5.2
	The scientific support was given mainly by[1]			
Source classified	-		2,480	6.6
Among them	-			
• Universities	-		1,080	2.9
• Polytechnics	-		720	1.9
• Other publicly-funded labs	-		1,470	3.9
Not classified	-		950	2.5

Notes: [1] several answers possible; in some cases the sum of the percentages therefore exceeds the total number. Figures weighted with the numbers of companies involved.

Source: ZEW (1997): Mannheim Innovation Panel (see Licht and Stahl, 1997: 39)

The scientific sources classified as main supporters of public research based innovations are public research institutions (mainly FhG) and universities. Nevertheless, in comparison to their relatively low research budget, polytechnics perform very well. As Beise and Stahl (1998) revealed, large companies have a bias for universities, which are normally better equipped than polytechnics, whereas smaller firms get relatively more support from polytechnics. In comparison to polytechnics, universities also play a role for innovation of small companies (Beise and Stahl, 1998: 11). These findings correspond to our empirical examinations and underline the definitions of innovative clusters used here, especially the innovation styles of IC_2 and IC_3.

If one relates these sample results to the economic success ensuing from the support by public research, it turns out that almost 50 percent of the additional turnover is made by companies from R&D intensive industries which, as it was shown above, account for only a quarter of all enterprises.

Table 8: Turnover of products which would not have been realised without research results of universities or publicly-funded laboratories [1]

	Total		R&D intensive industries		Non R&D intensive industries	
	million DM	in %	million DM	in %	million DM	in %
Total turnover	19,900	100	9,700	49	10,100	51
Among them:						
• Universities	13,600	68	5,800	29	7,800	39
• Polytechnics	8,000	40	2,500	13	5,500	28
• Other publicly funded laboratories	10,800	54	3,800	19	7,000	36

Notes: [1] several answers possible; in some cases the sum of the percentages therefore exceeds the total number. Figures weighted with the numbers of companies involved.

Source: ZEW (1997): Mannheim Innovation Panel (see Licht and Stahl, 1997: 40)

Most of these sales with research-based products can be attributed to universities, that is 68 percent. Research by polytechnics is used much more for non-R&D-intensive products, suggesting that the high-tech sectors prefer research of universities and research laboratories for their main product innovations (Beise and Stahl, 1998:12). It is therefore justified to say that R&D intensive industries benefit most from the technological infrastructure.

3.2.2 Clusters towards Innovation Styles and Production Chain

In the sections above the characteristics chosen to summarise innovative firms as clusters show a rough pattern of links of knowledge transfer and information exchange between companies and between companies and public-financed research facilities. To highlight the former case, the cooperation between single firms and whole industries as well as the similarities of innovative behaviour of companies, we wish to combine the 'correspondence approach of innovative styles' that we used together with an analysis of input-output tables with the 'value chain approach' in order to obtain a precise picture of industrial links within the economy.

In recent years the flow of information along the value added chain has increasingly become a centre of attention. Increased cooperation with customers and suppliers reduces risk and speeds up the whole process, thus increasing the quality of innovations. Since customers of advanced-tech enterprises more likely stem from the producing sector and customers of R&D intensive high-tech enterprises usually from the service sector, it makes sense to differentiate between these two types of customers. Customers of the manufacturing industry represent an important source of information, especially for companies with medium R&D intensity. More than half of these companies think that information from these customers is vital for their innovative process (Licht and Stahl, 1997). The opposite is stated by companies with high R&D intensity. A minor part of them think that customers coming from the manufacturing industry are an important source of information; they prefer customers from the service sector. For non R&D intensive industries the importance of customers, from both the manufacturing and the service sector, is relatively low. As far as suppliers are concerned, it can be said that suppliers of intermediate products, materials and components are of major importance across the industry, while the importance of suppliers of machinery and equipment is considerably lower; the latter ones are only highly important for industries with medium R&D intensity.

As a first step, we drew a detailed picture of where information came from and where it went to, and into which direction technology transfer went. All this information about the pattern of links between industries created by knowledge diffusion had to be completed by the determination of which companies were the suppliers, the customers or the competitors of firms within the innovation survey. This could be obtained by an input-output analysis which revealed a structural pattern of links and collaboration between industries and services. At first sight the differences among industries in using transfer channels are not that obvious. The service sector is one of the leading sectors with respect to the industry linkages. Consulting in particular is a very intensively used mechanism to diffuse knowledge.

The structural analysis using input-output tables revealed an intuitive pattern of relationships between industries. Links in the form of flows of intermediate inputs serve to illustrate industry clusters and identify industries linked through the main products they deliver or use. This method illustrates the approach of clustering within or through the chain of values. Combining the aforementioned approach with the ‘correspondence approach of innovative styles’, paves a way towards an integral analysis of flows of goods and knowledge.

4 Examining Innovation Policy - Principles of an Effective Transfer of Knowledge

The variety of institutions in Germany classified as ‘producers’ of technical knowledge might be interpreted as a reflection of the heterogeneity of firms. Therefore, an efficient technology transfer or (German) national innovative system has to be flexible and decentralised. At the company level there are obviously different needs and wishes. Large companies use the innovative system more intensively than SMEs, and all forms of knowledge transfer are taken into account. Technology transfer here is a strategic function and is part of the general information management of the company. In contrast to that, small and medium-sized firms prefer informal communication with local agents; they are focusing on personal contacts and like to be independent, and they act spontaneously and on an operative level.

In general, any kind of technology transfer or collaboration among firms or between the business sectors and research institutions is based on trust and experience. The socially interwoven academic and business communities is a crucial factor. When direct contacts and informal networks form the primary channels for transmitting scientific findings and technical knowledge in the innovative system, a flexible, decentralised and deregulated practice of technology transfer promotion can most effectively contribute to establishing and stabilising these informal networks.

Studies on technology transfer reveal that a substantial part of existing technology transfer in an innovative system is self-organized and takes place directly between scientists and corporate technicians and managers. Firms integrated in the national system of innovation and cooperating companies see a close correlation between knowledge exchange with universities and corporate success.[19] These firms differ from companies interested in starting their first cooperative project, instead wishing to start with only a relatively small budget. The reason behind this hesitation on the part of companies basically interested in cooperation is thus not a general liquidity problem. It is more true to say that during the first cooperative project the company’s risk is increased by the uncertainty of both procedures involved and chances of success, plus a yet-to-be established confidence in the partner concerned. This creates an inhibitory threshold, which companies that have not yet cooperated with academic institutions have to overcome if they are to effectively utilise technology transfer from these institutions on a long-term basis.

Joint research projects are usually conditional upon ongoing R&D activities amongst the companies involved. The partner can contribute only complementary knowledge. In the case of cooperative projects with public-sector research institutions in particular, companies cannot outsource the necessity to design market-driven product/process innova-

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19 For an in-depth analysis of the R&D cooperation behaviour of SMEs on the basis of German CIS data see Beise et al., 1995. See also Harhoff and Licht, 1996, König, Licht and Staat, 1994, Licht, 1994.

tions. Universities and public-sector institutions, remote as they are from the market-place, are of limited suitability for developing finished products for the real market.

There remains an uncertainty in the final analysis as to what politicians can do in order to improve technology transfer. Of course there is no lack of suggestions on how technology transfer could actually be enhanced, but it has to be accepted that not all companies participate equally in technology transfer:

- An important factor is the size of the firm. The strong relationship between size and the degree of formalised innovation activities on the one hand and of formalised innovation activities on the other suggest that at a certain size it is much easier to establish systematic R&D activities and to successfully bring about innovations. It has also been demonstrated that the initial commencement of R&D activities constitutes the main inhibitory obstacle for small companies. What could be termed 'threshold sponsoring', i.e. assistance primarily for companies not yet operating their own R&D activities, will expand the group of companies eligible for cooperative R&D projects with public-sector research institutions.

  An effective technology transfer policy thus does not replace R&D sponsoring for small and medium-sized companies, but complements it. 'Threshold programmes' supporting small firms from all technological sectors could help to establish successful innovative institutions in these firms. There is a high potential of creative ideas in small firms that has to be activated. The aim of these 'threshold programmes' should be to stimulate and promote the innovative activities and capabilities of companies. Thus, it seems more effective to provide firms with certain information, such as fairs on new technologies, seminars or other means of non-formalised technology transfer.

- To increase the efficiency of technology transfer or knowledge flows within the national innovative system, the usual recommendation is to establish additional institutions, designed to act as an intermediary between research institutions and companies. In a way similar to the so-called employment exchanges in the labour market, the idea is to 'place' the outsiders in technology transfer with the appropriate academics, and to compensate for any entrepreneurial shortfalls in project/innovation management. The crucial factor then will be a cooperation between these institutions that benefits optimally from synergy effects, thus justifying the existence of an institutional network. This institutionalisation is fundamentally aimed at involving the research institutions into business promotion, even though it is primarily meant to compensate for management/innovation shortfalls in companies. But information and promotion alone are not enough. The facts on information strategies known to us imply that there is a correlation between the innovative behaviour and the capacity to use information and know-how effectively. Therefore it is necessary to create an innovative atmosphere and provide incentives for all dimensions of knowledge diffusion. Otherwise companies, especially those which do not have much experience with public information services, will hesitate to use the opportunities. Market mechanisms as they are traditionally conceived would appear to have only limited use for coordinating the transfer of knowledge and technologies. In none of the situate environments inhabited by public-sector research can pure market conditions be found, neither in the labour market for researchers, nor in R&D contracts and engineering services. Assigning an a priori status to the market process thus bypasses the core of successful technology transfer in the research field. Promotion of technology transfer should not aim to compensate for the market's putative failures, but should help to overcome the problem of knowledge diffusion at the boundary between pure research and development phases in the innovative process. Firms know much more about their potential and markets than any private or public institution intending to provide support for innovative activities can achieve through observing the companies and their markets.

By comparison, the concentration on the core question of how new research results can successfully find their way into companies (i.e. be really applied), would not necessarily require institutionalised support. On the contrary, empirical feedback from successful technology transfers demonstrates the importance of self-organisation by innovative companies and technology-driven new businesses. The bottleneck of technology transfer in individual fields of technology is then constituted by the small number of insiders really involved in the national innovative system. Effective promotion of technology transfer should therefore aim at establishing long-term cooperation partnerships between companies and between companies and academics.

- For companies which do not innovate at all it is not possible to tell how to change them into an 'innovative firm'. Institutionalised support seems to be no way out of the insider-outsider-situation. Hardly any of these firms is willing and able to make use of institutions acting as mediators. Aside the weak in-house capabilities they have not much experience with the trustworthiness of external partners, especially with public institutions or mediators.

  As far as we know from firms innovating at a certain level of organisation, they use a special portfolio of information and knowledge transfer strategies that can not simply be transferred to firms which are not (yet) innovative. While accepting that innovative in-house activities are necessary to keep track with international developments and competition, a highly innovative atmosphere within the economy which supports innovative activities, should be among the main goals of innovation policy. Furthermore, firms need to have an absorptive capacity to transform knowledge into innovations that bring economic success.

5 Appendix

5.1 Appendix 1: The Science and Engineering Basis

A summary of the financial sources, size and main research areas of the research institutions, universities and laboratories described above is listed in the following.

Figure 2: Financial resources and main support

Institution	Expenditure DM million	Number of institutes	Employees	Public support DM million	Relation of support federal/state
AiF		107		170	100/0
MPG	1,533	98	11,901	1,429,9	50/50
FhG	1,261	49	6,099	578	90/10
Helmholtz-Centers	4,171	16	22,501	2,900	90/10
Blue List	1,321	83	10,000	1,200	50/50
DFG	1,927			1,147	100/0
DAAD	372,6			354	90/10
AvH	87.7		78	87.7	100/0
Stifterverband	141.7			Assets of foundation	
Volkswagen-Foundation	113		93	assets of foundation dividends	
CAESAR	750			685	
Federal Institutions	2,867	57	18,682	2,867	100/0

Source: BMBF (1996)

- Arbeitsgemeinschaft industrieller Forschungsvereinigungen (AiF) comprises more than 100 industry research organisations. AiF promotes applied research and development mainly to support small and medium-sized firms. Since this organisation maintains a spirit of community and common interest, the activities are focused on industries and branches.
- Max-Planck Gesellschaft (MPG) is a sponsoring organisation with 71 research institutions active and represented all over Germany. The MPG is mainly involved in pure research in selected areas of natural sciences, social sciences as well as the arts. The society takes up especially new, promising research topics which do not yet have an adequate position at universities. The MPGs cooperate with universities, for example by allowing them to use their technical equipment. The expenditure in 1994 amounted to 1,616 million DM and 1,708 million DM for 1995. The MPGs employ a staff of 11,500, among them 3,015 scientists.
- Fraunhofer Gesellschaft (FhG) is a non-profit sponsoring organisation with 47 institutes for applied research and two service facilities in 14 federal states. Additionally, there are three further offices in the USA. Carrying out contract research projects for the economy and the public sector, the FhG contributes to transferring pure research findings into practice. The institutional promotion by the Federal Government and the German States enables the FhG to deal with self-chosen research topics for securing their scientific potential and the development and constant observation of new technologies. The FhG offers firms and public authorities its services in the area of

microelectronics, information technology, production automation, production technology, materials and components, process engineering, energy and structural engineering, environment and health, technical-economic studies and professional information. The close relationships with universities are institutionalised through the joint appointment of Fraunhofer directors as regular university professors.

- National research centres or Helmholtz Centres are promoted jointly by the Federal Government and the state governments. Research with large-scale equipment and with a focus on specific priority topics, primarily large accelerators, neutron and synchroton sources as well as observatories and telescopes is the special focus of Helmholtz Centres, of which there are 16 in Germany. Helmholtz Centres contribute significantly to long-term pure research in several fields by their own projects and as partners of universities and other research institutes.
- Institutions on the "Blue List" are characterised as one of the four mainstays of the common promotion of research of the Federal Government and the German States. It covers all major fields of natural and social sciences, technology and applied technological research.
- DFG (German Research Council, Deutsche Forschungsgemeinschaft), is the major promoting and self-governing organisation for science and research activities in Germany. One of its main tasks is the financial support of research projects, supporting research cooperation and promoting young scientists. Secondly, it is an important adviser of policy makers in terms of scientific questions. Thirdly, the DFG develops and entertains the relationship and cooperation with international research institutions.
- German Academic Exchange Service (Deutscher Akademischer Austauschdienst) is the organisation which supports and organises exchange programmes for students, postgrad and post-doctorate researchers with foreign universities and research institutes.
- Alexander von Humbold Stiftung (AvH) promotes foreign scientists and researchers. There are programmes launched by the AvH which support cooperative research projects between Germany and other countries. Additionally, there are scholarships and prizes for academics.
- Stifterverband is an association of firms, several private non-profit organisations and private persons. It supports science and technology projects as well as institutes or other organisations which need additional financial or organisational help to perform R&D. The Stifterverband provides services such as statistics of economic indicators, seminars and an infrastructure for scientific activities.
- Volkswagen-Stiftung (VW-Stiftung) has three main tasks: 1) promotion of pure research in special fields, 2) improvement of the infrastructure for research, teaching, and scientific communication, 3) promotion of research oriented towards cooperation with foreign countries.
- CAESAR (Center of Advanced European Studies and Research): This foundation is oriented towards research and development of new technologies. A research centre in Bonn undertakes a combination of basic and applied research in the fields of technology and natural sciences.

5.2 Appendix 2: Sample Description and Variable definition

For the empirical cluster definition we used the German sample, comprising 2,859 firms that participated in the first part of the Mannheimer Innovation Survey (which is comparable with CIS data). The Community Innovation Survey (CIS) is an EU Commission initiative and a joint survey of DG XIII/SPRINT/EIMS and Eurostat. The CIS was developed between 1991 and 1993, the year when the data was collected. In 1993 a common statistical survey questionnaire was distributed amongst the member states. The database created contains almost 41,000 observations coming from the twelve Member States at that time and Norway.

Table 9: Innovation styles in relation to industries and size in Germany

	Non-innovative firms $Inno_1$	Innovative firms without R&D expenditure $Inno_2$	Firms with R&D, but without R&D department $Inno_3$	Firms with R&D department $Inno_4$
Utilities / mining	51.5 %	30.6 %	14.4 %	6.3 %
Food	26.3 %	43.2 %	17 %	13.6 %
Textile, leather	28.6 %	31.8 %	23 %	16.7 %
Wood, paper	29.4 %	49.7 %	14.7 %	6.3 %
Chemicals	10.3 %	11.9 %	20 %	57.8 %
Plastics / rubber	19.4 %	32.2 %	30 %	18.3 %
Glass, ceramics	18.9 %	25.6 %	34.4 %	21.1 %
Metal industry	14.7 %	25.3 %	34.7 %	25.3 %
Steel construction	21.3 %	31.4 %	31.4 %	16 %
Machine construction	9.1 %	16.9 %	29.9 %	44.2 %
Mechanical engineering	7.6 %	12.6 %	33.3 %	46.5 %
Other mechanical engineering	16.9 %	18.5 %	29.2 %	35.4 %
Data processing	13.6 %	12.7 %	18.2 %	55.5 %
Electrical equipment	16.8 %	16 %	28.6 %	38.7 %
Medical instruments	11.3 %	20.9 %	22 %	45.8 %
Automobile industry	10.8 %	20.4 %	31.2 %	37.6 %
Other vehicle construction	26.2 %	21.4 %	19.1 %	33.3 %
Furniture, musical instruments	20.8 %	23.8 %	26.7 %	28.7 %
Construction	43 %	36.9 %	14.8 %	5.4 %
Services	21.1 %	25.9 %	35.3 %	17.7 %
Aerospace	15.4 %	23.1 %	23.1 %	38.5 %
5-49	32.4 %	34.7 %	24.1 %	8.8 %
50-249	18.4 %	26.5 %	31.3 %	23.8 %
250-499	9.1 %	20.2 %	28.2 %	42.5 %
500-999	8.9 %	16.5 %	21.2 %	53.5 %
1000 and more	9.2 %	8 %	18.4 %	64.4 %
Total	20.2 %	25.5 %%	26 %	28.3 %

Source: ZEW (1997) Mannheim Innovation Panel Figures unweighted.

The three canonical variables for the cluster definition are:

(1) Formalisation of Innovative Behaviour

$Inno_i$ describes the degree of formalisation or organisation of the innovative activities. This definition can be pictured as an ascending order of the degree of formalisation or organisation of R&D behaviour. The firms were asked whether they had introduced any technologically new or improved products or processes within the last two years.

(2) Formalisation of Knowledge Channels

$Know_i$ describes the transfer channels used by the firm. The question that was posed to the companies was whether they really used the different transfer channels and with which countries they cooperate. Dummy variables were created for firms matching certain criterias. The aggregation of the information sources was carried out as follows:

Table 10: Formalisation of knowledge channels

	Obs	Means	SD	Min	Max
$Know_1$	2859	.48	.50	0	1
$Know_2$	2859	.46	.49	0	1
$Know_3$	2176	.39	.49	0	1

Formal channels: $Know_1$ = 1 if firms purchased or sold licences or purchased or sold consulting services or purchased or sold research results of external research institutes or purchased or sold new technologies linked to investment goods or purchased or sold new plant that produces new technologies. $Know_1$ = 0 else.

Informal channels: $Know_2$ = 1 if firms exchange innovation experiences with other companies or hiring or sending of qualified personnel. $Know_2$ = 0 else.

International channels: $Know_3$ = 1 if firms transfer knowledge from or to at least one foreign country. $Know_3$ = 0 using only national channels

(3) Formalisation of Information Sources

$Info_i$ describes the information sources used by the firm. The question posed to the companies was how they evaluated different information sources. If the sum of the aggregated evaluations was beyond the means of the sum of all companies, the dummy variable $Info_i$ was set 1. The aggregation of the information sources was carried out as follows:

Table 11: Formalisation of information sources

	Obs	Mean	SD	Min	Max
$Info_1$	2138	.75	.43	0	1
$Info_3$	2199	.58	.49	0	1
$Info_2$	2182	.50	.50	0	1
$Info_4$	2167	.57	.49	0	1
$Info_5$	2203	.59	.49	0	1

Internal information: $Info_1$ = 1 if firms using information coming from different departments inside the company. $Info_1$ = 0 else.

Vertical external information: $Info_2$ = 1 if firms using information coming from competitors, consultants, private research institutes. $Info_2$ = 0 else.

Horizontal external information (market-related information): $Info_3$ = 1 if firms using information coming from suppliers, clients, customers. $Info_3$ = 0 else.

Public information: $Info_4$ = 1 if firms using information coming from universities, public research institutes, public technology transfer institutions. $Info_4$ = 0 else.

General information: $Info_5 = 1$ if firms using information coming from patents, fairs, conferences. $Info_5 = 0$ else.

Table 12: Ordered Probit Models of the degree of formalisation of R&D Coefficients (Standard Errors)

Dependent variable **Degree of formalisation of R&D**		(1)	(3)
Internal Info:	$Info_1$	0.432 (0.060)	0.311 (0.623)
Direct external Info	$Info_2$	-0.044 (0.057)	-0.051 (0.059)
Indirect external Info	$Info_3$	-0.185 (0.054))	-0.093 (0.061)
Public Info	$Info_4$	0.294 (0.054)	0.221 (0.061)
General Info	$Info_5$	0.517 (0.055))	0.408 (0.058)
Formal transfer:	$Know_1$	0.336 (0.055)	0.244 (0.057)
Informal transfer:	$Know_2$	0.160 (0.053)	0.151 (0.056)
International transfer	$Know_3$	0.545 (0.053)	-0.236 (0.077))
Utilities / mining			-1.134 (0.212)
Food			-0.865 (0.169)
Textile, leather			-0.531 (0.163)
Wood, paper			-1.051 (0.168)
Chemicals			0.430 (0.149)
Plastics / rubber			-0.384 (0.145)
Glass, ceramics			-0.528 (0.176)
Metal industry			-0.567 (0.184)
Steel construction			-0.447 (0.132)
Machine construction industry			-
Mechanical engineering			0.131 (0.148)
Other mechanical engineering			0.011 (0.143)
Data processin equipment			0.550 (0.181)
Electrical equipment			-0.079 (0.163)
Medical instruments			-0.150 (0.147)
Automobile industry			-0.198 (0.170)
Other vehicle construction			-0.305 (0.253)
Furniture, music instruments			-0.078 (0.176)
Construction			-1.228 (0.176)
Services			-0.333 (0.150)
Aerospace			-0.399 (0.396)
5 - 49 employees			-1.33 (0.113)
50 - 249			-0.990 (0.098)
250 - 499			-0.681 (0.110)
500 - 999			-0.446 (0.120)
1000 and more			-
Firm-size dummies Chi-squared (df) (p-value)			166.3 (4) (p<0.001)
Industry dummies Chi-squared (df) (p-value)			241.9 (20) (p<0.001)
N		2012	2012
Chi-squared (df)		461 (8)	887.3
log L		-2044	-1831
pseudo-R-squared		0.1013	0.1950

Note: The table displays the coefficients from a ordered probit specification. They can be interpreted as the impact of the exogenous variable on the decision process in one of the classes of formalised innovative behaviour (innovative styles $inno_1$ - $inno_4$). A direct interpretation is not possible, only the sign and the level of significance contain information. For the ordered probit analysis we used the assumption of an ascending status of innovative power and defined the innovation styles 'inno' with values from 1-4. Inno = 1 if $Inno_1 = 1$, Inno = 2 if $Inno_2 = 1$, Inno = 3 if $Inno_3 = 1$, Inno = 4 if $Inno_4 = 1$.

Source: ZEW (1997) Mannheim Innovation Panel

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