

STB/95/051

**Assessing the distribution power of
national innovation systems
Pilot study: the Netherlands**

Drs. Pim den Hertog
Dr. Theo J.A. Roelandt
Dr. Patricia Boekholt
Hendrien van der Gaag

Apeldoorn, December 1995

Contents	Page
1. INTRODUCTION	
2. DIFFUSION AND MEASURING DISTRIBUTION POWER	
2.1 Distribution power and National Innovation Systems	
2.2 Conceptual framework	
2.3 Clusters as reduced scale models	
3. DIFFUSION FLOWS WITHIN THE DUTCH NIS	
3.1 Introduction	
3.2 R&D-structure of the Dutch National Innovation System	
3.3 Diffusion and technology transfer in the business sector	
3.4 Diffusion and technology transfer from HEIs towards industry ...	
3.5 Diffusion and technology transfer from RTOs towards industry ...	
3.6 Diffusion and technology transfer through bridging institutions ...	
3.7 Policies aimed at enhancing distribution power	
3.8 Distribution power and firm' competitiveness	
4. EVALUATION AND CONCLUSIONS	
4.1 Introduction	
4.2 Concepts and methodological issues	
4.3 Data and indicators	
4.4 Selection of indicators	
4.5 Policy implications	
LITERATURE	
ANNEXES (SEPARATE)	
ANNEX I : STATISTICAL ANNEX	
ANNEX II : CANADA LIST	
ANNEX III : APELDOORN LIST	
ANNEX IV : MEGA-CLUSTERS	
ANNEX V : PARTICIPANTS NATIONAL EXPERT MEETING	

1. Introduction

Background

At the very heart of the theoretical notion of National Innovation Systems (NIS) to understand innovation performance is the idea that both the creation and diffusion of technological knowledge occur primarily via interactions between different types of agents and institutions. The OECD initiated a NIS comparative project that focuses on a particular aspect within NIS i.e. on the flows of knowledge between formal knowledge-producing agents (OECD, 1995, p. 2). Two key categories of flows of knowledge between formal knowledge producing agents were identified¹:

- the distribution of knowledge among universities, research institutions and industry;
- the distribution of knowledge within a market, and between suppliers and users (OECD, 1995, p. 3).

National Innovation Systems

"The network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies may be described as the 'national system of innovation'" (Freeman, 1987).

"... a system of innovation is constituted by elements and relationships which interact in the production, diffusion and use of new and economically useful, knowledge ... a national system encompasses elements and relationships, either located within or rooted inside the borders of a national state" (Lundvall, 1992)

This study elaborates on the notion of "distribution power". This notion essentially conceptualises two ideas. In the first place the idea that it is not simply the creation of new knowledge which counts, but the flow of such knowledge from producers to users. Both the general accessibility of knowledge and the actual diffusion of knowledge in use are central to innovation performance. Secondly the point that understanding inter-country performance differences is in part a matter of the institutional structures and actual patterns of knowledge distribution.

¹ David and Foray introduced the notion of distribution power. Originally they made a distinction between five processes of distribution of knowledge (1994, p. 38-41). Eventually it was decided to concentrate in the various national pilot studies on these two particular categories.

Distribution power

Distribution power of an innovation systems refers to the "capability to ensure timely access by innovators to the relevant stocks of knowledge" ... or "the systems ability to support and improve the efficient functioning of procedures for distributing and utilizing knowledge i.e. by improving transfer, transformation and access to the stock of existing knowledge" (David & Foray, 1994, p. 7; p. 14).

Our main point which we like to emphasize in this study is that the relation between knowledge creation, the distribution of knowledge within a NIS and economic performance are complex and that the role of processes of distribution of knowledge therein are thus far underestimated. To fully understand the importance of these processes and the degree to which especially companies are successful in using the available knowledge, we think it is essential to identify what these processes actually consist of and how important they are to innovating companies. In our view it is essential, also from a policy perspective, to look at both the capacity of business firms to absorb new knowledge and the knowledge generation and R&D-investments of business firms. In a similar vein we consider the transfer capacity of those institutions and companies generating new knowledge as important as their ability to generate new knowledge. Nowadays it seems as if the discussion on the competitiveness or innovativeness of the Dutch economy is directly linked to more static (mainly input and output) indicators such as R&D-expenditures, patents and bibliometric data. We are in favour of a more differentiated approach in which there is also room for discussion on distribution power and the effectiveness of knowledge transfer mechanisms that are aimed at increasing the returns on investments in R&D.

Goals and policy relevance

This pilot study for the Netherlands, similar studies are performed in parallel in various other OECD countries, clearly has an explorative character. It is in the first place aimed at identifying methods and a set of relevant indicators to assess and analyze - using available statistics and indicators - diffusion in the Netherlands. This first goal mainly serves to:

- test the robustness and feasibility of the key concepts used ;
- assess the availability of data in general and identify zones where data are clearly lacking or on the contrary are abundantly available;
- identify themes and topic areas for which additional indicator development and/or data gathering are both needed and promising;
- discuss possibilities of developing and selecting a concise set of key indicators for measuring diffusion.

It is also clear that from a policy-perspective it is essential to understand the diffusion processes as well as the factors which promote or hinder them. This would allow

policy-makers to think about policies aimed at technology generation and technology diffusion in a more complementary fashion. The idea behind technology policies in which clear diffusion-elements are included, is that "a more efficient system for accessing and distributing knowledge could increase the social value of existing stocks of knowledge:

- by reducing the risk that resources in knowledge creation would be wasted because of the lack of capabilities to exploit this new knowledge;
- by allowing innovators to gain rapid access to the knowledge required for their specific needs and the solution of specific problems;
- by increasing the likelihood of innovative, value-creating, combinations of existing pieces of information "(OECD, 1995, p. 2).

Therefore, a second central goal of the OECD-exercise as a whole is to derive some tentative policy implications and more precisely to see to what extent nodal points in the knowledge distribution system can be identified and where catalytic action by government might improve knowledge flows and overall innovation performance (OECD, 1995, p. 2).

This pilot study mainly focuses on the first goal as serious policy recommendations can only be made after the various national pilots are finalized, diffusion capabilities of the various national innovation systems systematically compared and *best practices* identified.

Points of departure

As both distribution power and the notion of NIS were never systematically operationalised and assessed in terms of indicators, it is clear that this pilot study by definition has an explorative character. The aim is not to provide definitive answers regarding the distribution power of Dutch NIS. We hope to start a fruitful discussion on the measurement of diffusion and distribution power and to identify some promising avenues for both research and policy-making. For that reason, we would like to define and delimit the approach adopted here somewhat further by presenting briefly the points of departure of this study:

1. *Interactionist interpretation of innovation.* As a frame of reference we adopted an interactionist model of innovation in which no clear dichotomy exists between generation and diffusion of technological knowledge as these processes are in practice intermingled through the continuous feedback mechanisms between producers, users and researchers (see section 2.1).
2. *Systems approach.* To operationalise the notion of distribution power, a systems approach is adopted and more precisely a NIS-approach. This approach might at first glance be confusing for two reasons. In the first place the concept of NIS is a broad concept and not necessarily limited to flows of scientific and technological knowledge. Secondly, NIS pre-supposes at least a national focus, while especially in science and technology transnational relationships (e.g. multinational enterprises,

international science communities) are quite common. However, what is in our view appealing about the NIS approach, is its focus on learning processes and accumulation of knowledge and the clear links between knowledge production, diffusion and use. Finally, its institutional focus i.e. explicit attention for systems of interrelated agencies and actors in which knowledge is created, diffused and used is equally important.

3. *Scientific and technological knowledge.* Although it is acknowledged that apart from scientific and technological knowledge various other categories of knowledge are relevant when assessing the way in which knowledge is disseminated and diffused within a NIS, we choose to restrict ourselves in the first place to scientific and technological knowledge (see section 2.2 for a discussion on knowledge types and knowledge carriers).
4. *Flows and 'throughput' indicators.* Indicators can be looked at from two perspectives. In the first place a distinction can be made between stock and flow indicators. Stock indicators are generally thought of as providing a snapshot picture at a particular point in time (e.g. number of R&D personnel), while flows are considered to relate to movements in or out of a stock over a given period, usually a year (e.g. research outsourced to an Higher Education Institution in a year by a company). A second typology of indicators is that between input (e.g. R&D expenditures), output (e.g. patents or bibliometric data) and 'throughput' indicators (e.g. formal and informal R&D networks). Throughput indicators typically measure the degree to which knowledge that is produced is subsequently distributed and used. In practice it is not always possible to make a clear distinction between the various categories of indicators. However, in this study we will attempt to mainly concentrate on flow and 'throughput' indicators as these measure most closely what is meant by distribution power.
5. *Cluster-level.* In our analysis of distribution power we see a NIS composed of networks of strongly interrelated economic activities, enterprises and branches of industry, including the institutional arrangements that go with it. These enterprises and branches of industry are linked because of their specific position within the value adding production chain. This interrelatedness is reflected in the supply of (raw) materials, the supply of capital goods, but also in the exchange of knowledge and technology. In our view the throughput of materials, capital goods and knowledge in production chains is essential for identifying diffusion flows. For that reason we adopted a cluster instead of a more traditional branche of industry approach. Therefore our reference category will be, if feasible and available, clusters.
6. *Available data and statistics.* As the aim of this pilot study is in the first place to see whether the notion of distribution power can be operationalised and not to collect new data, we will use available data and statistics. However, if we find out

that some data or statistics are lacking, this observation should be perceived as a useful product of this exercise as well.

The points raised here will be discussed more extensively in chapters 2, 3 and 4.

Activities performed

Within the framework of the Dutch pilot study the following activities were performed:

- review of available sources and selection of relevant material (tables, figures, including micro-data SEO-innovation survey 1992) on the basis of an indicative list of indicators provided by the OECD ("Canada list", see Annex II);
- review of theoretical work on diffusion and its link to innovation theory (see section 2.1);
- development of a conceptual framework to systematically identify and monitor distribution power of NIS (see section 2.2);
- review various cluster-approaches used in the Netherlands and relate them to the notion of distribution power (see section 2.3, Annex IV));
- selection of indicators and indicator development (see Annex I);
- analysis of selected indicators, with an emphasis on flow and throughput indicators (see section 3);
- overview of missing themes and topics which could be used for indicator development ("Apeldoorn list", Annex III).

A national expert meeting was organised on November 16th 1995 as part of the pilot study². The aim of this meeting was, apart from discussing an earlier version of this report, threefold i.e.:

- a. to collect opinions of experts on the distribution power of the Dutch NIS;
- b. to comment upon and subsequently select the most important forms of diffusion;
- c. to develop a relative small set of indicators to measure diffusion.

Following the discussion during this expert meeting, some of the issues raised during the meeting are elaborated on in this final report and some suggestions included.

² For participants see Annex V.

2. Diffusion and measuring distribution power

2.1 Distribution power and national innovation systems³

To put the notion of distribution power into perspective we will first discuss some of the theoretical background. Particularly relevant here are in the first place thoughts on the linkages between knowledge creation, innovation and diffusion and the way these are conceptualised in the various theoretical models. Secondly, a brief assessment of the main lines of theoretical work on the linkages between distribution power and performance of NIS or competitiveness will be presented to complete the theoretical perspective of this pilot-study.

From the traditional linear to the integrative model

The developments in the thinking on diffusion and innovation are closely interlinked. An increased sophistication in the theories on the innovation process, has congruently affected the role of diffusion as part of that process. Looking at nations in terms of their distribution power is a relatively new perspective, especially in relation with assessing differences in competitiveness. This should be seen within the framework of innovation theory which evolved in the last two decades.

The most eminent change is the shift from the traditional linear innovation model to the interactionist or integrated model of innovation. In the linear model "... one does research, research then leads to development, development to production, and production to marketing" (Kline & Rosenberg, 1986, p. 285). Many contributors on the process of diffusion define its position within this linear model. Innovation in this model is perceived as a process with logical and chronological sequences, diffusion being the third and last phase of the process, after first invention and subsequently innovation. It is usually defined as the first commercial introduction on the market. Successful diffusion thus indicates the wide spread adoption of innovations among a population of potential adopters. Diffusion in this view is thus a static last phase of the innovation process: the creative mechanisms have already taken place in the former phases. In the linear model the initiator of innovation is science, both at the firm level as at the aggregate level. There are no feedback loops during the process. In the innovation literature, the dominant linear model has been criticized⁴ and gradually replaced by a much more complex 'integrated model of innovation', mainly under the influence of the so called evolutionary economists, whose contributions in

³ The following draws heavily on the Phd thesis of P. Boekholt titled *The European Community and Innovation Policy: reorienting towards diffusion*, Aston University, Birmingham, September 1994.

⁴ "Models that depict innovation as a smooth, well-behaved linear process badly misspecify the nature and direction of the causal factors at work" (Kline & Rosenberg, 1986, p. 275).

literature became more influential from the late 1970s⁵. This eventually led to the widespread recognition of the integrative model of innovation, as described by Kline and Rosenberg (1986).

The general set of theories that derived from the new evolutionary line of thought, have wide implications for the concept of diffusion, which now forms a part of the dynamic innovation process, a process of continuous 'creative destruction'. The evolution of technology moves along natural technological trajectories, where there is a constant rivalry among technological alternatives. Diffusion is one of the stages in this process where the market enters to select the innovations and 'winning solutions' (Cainarca et al., 1989, p. 61). This selection process is not straightforward: the technology will undergo incremental innovations during the whole diffusion process. Besides it will not necessarily be the best performing technology that finds widest diffusion. Powerful market strategies of oligopolistic companies or government interventions can lead to the diffusion of 'sub-optimal' technologies (Jacobs, 1990). Where on the one hand the innovation process knowledge creation is most important, in the diffusion process on the other hand the emphasis is on the spread of technology and the adaptation by (potential) users.

Diffusion in this integrated approach can be seen as an integral phase where incremental innovations occur through the various feedback loops, between producers, users and researchers. Distribution power affect organizational learning of firms and institutions, which is an essential feature of the innovation process. It increases the accumulated knowledge available to all actors involved. The OECD report *Technology and the Economy, The Key relationships* defines diffusion as all those actions at the level of the firm or organisation taken to exploit the economic benefits of the innovation (1992, p. 48).

Distribution power, NIS and competitiveness

Linking distribution power with national performance came from two different angles in innovation literature. Henry Ergas (1986) introduced the dichotomy between diffusion oriented versus mission oriented countries, describing the dominant patterns in innovation policy in several industrialised nations. In his publication *Does Technology Policy Matter* he reveals the importance of diffusion oriented policies as a factor of economic success in certain nations. He looks at diffusion at the macro level of countries and at the meso level of institutions involved in diffusion. The orientation of countries is for a large degree dependent on the technology trajectory in which its dominant sectors find themselves. If most of the firms are in the emergence phase of a technology trajectory, knowledge creation and experimentation are an important source of innovation. When firms are in the maturity phase they rely

⁵ Important contributions came from Nelson and Winter (1977 and 1982), Dosi (1982) and Dosi et al. (1988), Freeman (1982), Freeman and Perez (1986) and Rosenberg (1976).

more on existing knowledge and rivalry between alternative technologies. In this case access to information and technology determine the success of firms. So the character of the diffusion process is different for each firm and each sector.

In almost the same period Freeman introduced the concept 'national system of innovation' (NIS) defined as "the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies ... " (Freeman, 1987). Freeman's approach centres around the actors involved in the NIS. These could include a wide variety of organisations such as firms, research centres, government innovation bodies, intermediaries etcetera. This NIS approach is subsequently used as a framework for analyses in the comparison of nations. An incentive for greater awareness of such a systemic approach was Michael Porter's (1990) book *The Competitiveness of Nations*. This book drew attention to the importance of national factors determining the competitiveness of industrial sectors. These included institutional factors such as the effectiveness of the R&D system and networking between firms. Recent contributions such as Lundvall's (1992) and Nelson's (1993) integrate several elements of new innovation theory into the NIS concept. The role of institutional learning, user-producer relations, networking, scientific institutions, finance and so on, are all discussed, but not integrated into a systemic analyses.

As we have seen in the integrative innovation model, research and development are not the sole determining factors of innovative capability. Thus diffusion or flows of knowledge are not solely concerned with research related knowledge either. Institutional learning and managerial capacity, public support for innovation and the availability of a technology transfer infrastructure, to name a few, are also vital. Questions such as: how good are actors in absorbing new information and technology?; how is innovation integrated into the business strategy?; and is the NIS capable of providing the necessary risk capital? are equally important to assess distribution power.

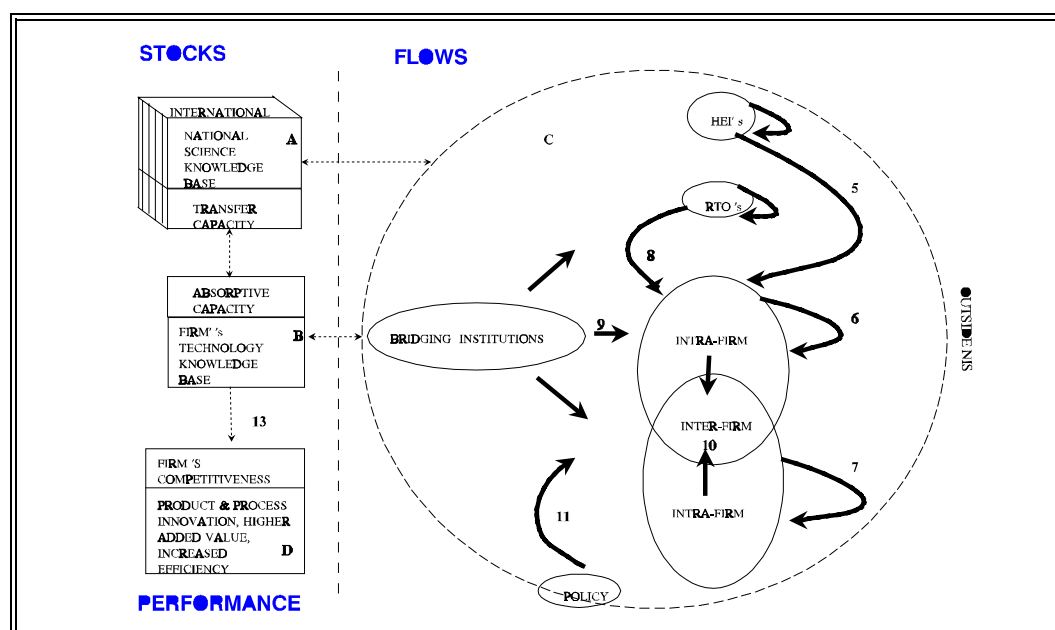
2.2 Conceptual framework

Theoretical notions as introduced briefly in the preceding section seems to indicate that innovation performance depends on many more factors than R&D efforts. Learning capabilities are a key feature in innovation and easy access to knowledge can improve this learning. Expenditure on R&D, scientific quotations and number of patents are not sufficient indicators for the effectiveness and dynamism of the NIS. How knowledge is exploited and used for new purposes cannot be measured by these traditional input and output indicators. Up to this moment there are hardly any satisfying examples of a dynamic assessment of the distribution power of nations, in

which the many often qualitative factors that determine the NIS and in particular its distribution power are integrated⁶.

We developed a conceptual framework that emphasizes this notion of distribution power (see figure 2.1). Before adopting this framework as a heuristic tool for a first attempt to systematically measure - using available datasets and statistics as much as possible - the distribution power of Dutch NIS in chapter 3, some key aspects of this framework are briefly introduced in the remainder of this section.

Figure 2.1. Conceptual framework



Knowledge bases, NIS and competitiveness

In figure 1 we basically make a distinction between knowledge bases, knowledge flows as they can be identified within the NIS and competitiveness.

Most of the information on both the national science knowledge base (box A) and firms technology knowledge base (Box B) typically has a static character. What is measured here are the number of R&D personnel/scientists in firms, Higher Education Institutions (HEIs), Research & Technological development Organisations (RTOs), students in relevant disciplines, patents, publications or R&D budgets, R&D intensities, etcetera. These are mainly input or output indicators that have no direct link to

⁶ One of the few is e.g. the IMD World Competitiveness Reports. However, the data used for "Science and Technology" are mostly the traditional ones like R&D expenditure, number of R&D personnel, intellectual property and R&D investments in key sectors and production technology.

processes of diffusion and competitiveness. They in the first place measure in a more or less static way the mere availability and magnitude of a certain knowledge base, more than the efficiency and effectiveness with which these bases are produced or the degree to which the resulting knowledge is actually disseminated, adopted and applied in products and services. There is no direct link between the magnitude of these knowledge bases and the distribution power of a NIS⁷ or competitiveness of firms (although one would expect at least a positive correlation between the two). For our purposes these bases are only interesting as far as it is to be expected that the higher these bases are, the higher the potential for diffusion is.

More interesting from a viewpoint of assessing distribution power is the throughput of knowledge within an NIS (represented by black arrows in circle C). Each arrow represents an exchange mechanism within a NIS that contributes to the dissemination of knowledge. Our prime aim of this pilot is to open up the black box of the NIS, to shed some light on these arrows within the circle and to point at some mechanisms at work that tend to be forgotten.

The link of A, B and C to firms' competitiveness (box D) clearly reflects the economic impact of the knowledge using activities on increasing firm's competitiveness. It would be interesting to see to what degree firm competitiveness is explained for by the distribution power of a NIS. It is expected that high distribution power of a NIS contribute to the competitiveness of firms reflected in improved factor productivity, share of (re)new(ed) products & services and production processes, higher added value, increased turnover and improved export performances. However, to assess carefully the linkage between A, B,C and D is probably one of the most difficult methodological issues to be solved. Although we started to collect existing data and statistics using this framework, we will concentrate on C as until most efforts that were already performed were aimed at A, B and D. Only after sufficient data (that could be coupled e.g. by using the same reference categories) are available on all four elements of the conceptual framework introduced here, it will be feasible to be more decisive about the linkages between A, B, C and D. In our view transfer capacity and absorptive capacity are some key notions here.

Transfer capacity and absorptive capacity

Distribution power should be seen from two perspectives. First, from the supply side it concerns the capability of knowledge creating agents to spread the results to potential users. This may be referred to as **transfer capacity**. Here the problem of

⁷ A complicating factor is that both science knowledge bases and technology knowledge bases develop in an international context. One could say that this is relevant from a diffusion point of view as the ability to tap off international stocks of scientific and technological knowledge is at least partly dependent on the availability of funds, well educated and trained personnel and R&D institutions. Investment in these knowledge bases may therefore be considered as a way to qualify for exchange of knowledge and (international) transfer of knowledge.

appropriation occurs since the agents want to benefit from their efforts. Alongside the spread of their innovation efforts in order to reap the economic benefits there has to be protection of their knowledge.

The second perspective is that of the capability of potential users of new knowledge or innovations to learn to access, acquire and implement the knowledge or technology. This is referred to as the **absorptive capacity**. The distinction between suppliers and users should not be used as a strict divide in different agents. A firm can be both a knowledge creator and user at the same time.

For both transfer and absorptive capacity a further differentiation of types of knowledge is needed as different types of knowledge may be disseminated in other ways depending on e.g. its degree of formalisation (codified versus tacit knowledge) and ownership status (publicly available knowledge versus privately owned knowledge). In the next section we will elaborate somewhat further on types of knowledge and knowledge carriers.

Types of knowledge and knowledge carriers

Knowledge and the way in which knowledge flows through a NIS can be characterised and categorised in quite a number of ways. What is important here is that scientific and technological knowledge⁸ is in no way a uniform product and various **types of knowledge** are subject to different regimes that limit or increase the potential for diffusion⁹. Important dimensions or variables that influence the propensity for knowledge to "flow" are e.g.:

⁸ Science and technological knowledge are increasingly interdependent as the worlds of science and technology converge. Differentiating between technological and scientific knowledge is increasingly difficult and artificial. However, technological knowledge is probably more likely to be appropriated, while scientific knowledge in principle is more freely disseminated. Specific mechanisms that come to mind for collecting data on the dissemination of scientific knowledge are: circulation of scientific publications, migration and temporary exchanges of scientists and attendance of scientific conferences.

⁹ These regimes are an important characteristic of a particular NIS. Differences in e.g. intellectual property systems, openness of universities for manufacturing and service companies, availability of information infrastructures, the number of collaborative R&D programmes funded by government, the amount of (secret) military research, the availability and use of apprenticeship systems, the mobility on the labour market to mention a few examples, are all factors that influence the way in which knowledge is disseminated in a NIS.

- generality/specificity of knowledge (generic technologies vs. firm specific technologies);
- vehicles or knowledge carriers (people, documents or equipments, materials & products);
- the tacitness or codification of knowledge (fully codified knowledge vs. highly individualised and completely 'tacit' forms of knowledge or 'know how') ;
- degree of disclosure (fully disclosed vs. fully restricted i.e. ranging from proprietary research communities as e.g. military research to open science communities);
- level of privateness (privately owned vs. publicly available).

Various attempts are known to develop typologies of technology flows, thus making a distinction between different types of technology flows (e.g. OECD, 1990). By way of example the typology as developed by the OECD is reproduced here¹⁰ (table 2.1). This typology illustrate the great many ways in which technologies and technological knowledge can be diffused.

In the first column, under the heading of 'vehicle', basically three categories of what we like to call **knowledge carriers** are identified:

- people/human resources (human embodied technology) e.g. science & technology personnel and students (learning by learning) and tacit knowledge incorporated in personnel (learning by doing e.g. on the job training);
- documents/written information (disembodied technology) e.g. scientific publications, patents, manuals, electronic databases;
- equipment, materials and products (equipment or capital embodied technology) e.g. high tech intermediate and capital goods.

In the second column referring to the generality or specificity of a certain technology a distinction is made between:

- general sectoral technology comprising technical information common to enterprises in the same industry;
- system-specific technology corresponds to knowledge developed by a firm in tackling a certain problem
- Firm-specific technology covers all the skills that the firm has developed through its activities or acquired through experience, but which cannot be ascribed to any one particular activity.

¹⁰ More recently, David & Foray (1995, p. 33) proposed a 'knowledge-product space' to differentiate between various types of economically relevant knowledge. They identified three dimension i.e. degree of codification; completeness of disclosure and ownership status.

Table 2.1. Flows by which technology is transmitted (slightly adapted from OECD, 1990, p. 15)

VEHICLE	GENERALITY/SPECIFICITY OF THE TECHNOLOGY			FLOW	COMMERCIAL AND CONTRACTUAL TRANSACTIONS
	General sector related	System specific	Firm specific		
I. PEOPLE	A	B	C	<ol style="list-style-type: none"> 1. Education and training (A) 2. Personal contacts (A, B, C) 3. Prof. mobility (A, B, C) 4. Tech. co-operation (A, B) 5. Tech. assistance between enterprises (B, C, F) 	<p>Official technical cooperation (1, 2, 4, 6, 7)</p> <p>Technical assistance agreements between enterprises (2, 5, 7, 8, 9, 10)</p>
II. DOCUMENTS/ WRITTEN INFORMATION Disclosed technology	D	E	F	<ol style="list-style-type: none"> 6. Congresses, seminars, conferences (D, E) 7. Tech. literature: patent periodicals and documentation (D, E) 	<p>Contracts with companies and engineering consultancies (8, 9, 10 and possibly 11, 12)</p> <p>Patents licences (5, 7, 8, 9, 10)</p>
Appropriated and/or secret technology	G	H	I	<ol style="list-style-type: none"> 8. Pre-feasibility and feasibility studies and projects (G, H, I) 9. Drawings, plans (G, H, I) 10. Detailed eng. drawings: rules & operat. proced. (F, G, H, I) 	<p>Equipments sales and purchases (5, 11)</p>
III. EQUIPMENT, MATERIALS & PRODUCTS	J	K	L	<ol style="list-style-type: none"> 11. Machines, equipment tools (J, K, L) 12. Turn-key plants (J, K, L) 	<p>Direct investment in subsidiaries/joint ventures (1, 2, 3, 5, 8, 9, 10, 11)</p>

From the last two categories it becomes clear that especially know how, the "body of knowledge and experience acquired for the application of a technique", is important and not something which can be transmitted as a ready made package.

The third and fourth column present some of the ways in which knowledge in practice is disseminated and distributed. From the fourth column it is clear that only part of the (sometimes combined) flows identified in column 3 take the form of a commercial or contractual transaction. This means that both contractual and non-contractual forms of technology flows should be kept in mind when dissemination of knowledge is concerned.

For the matter of this particular pilot and the aim of developing indicators it is important to look especially at the various knowledge carriers. The more traditional approach to diffusion looks mainly at equipment-embodied diffusion. Here a few industries are suppliers of technology-intensive goods and components to the downstream industries that can choose to buy them. There are early adopters who take the risk of using the new technologies before they have widely proven to have economic benefit. They create a 'critical mass', a gauge by which late adopters can judge the benefits of adoption. The discussion on the motives and conditions for adoption is summarised in the TEP report (OECD, 1992, p. 55-58). In short the real or perceived pressures of competition and the relative advantages of using competing technologies affect the pace of investment and adoption of new technologies. In this type of distribution of knowledge 'learning by using' is the major mechanism to improve innovative capacity. Pavitt's research (1984) has shown how sectoral patterns can explain differences in technical change. The relative importance of either knowledge creation or diffusion is not the same in every sector.

However, dis-embodied and human-embodied forms of diffusion are possibly as important as equipment -embodied forms of diffusion. There are for instance several mechanisms through which research information flows outside the originating firm: research personnel is the main one. The ease at which firms learn to absorb is also dependent on their own R&D efforts: it helps the firm to be in touch with available knowledge, reinforces the links with external sources of knowledge, in short 'learning by learning'. Another form of human-embodied knowledge flow is that between personnel of research institutions working with or within firms. Networks, both formal and informal are an important mechanism for firms to have access to publicly available knowledge. We can see that many of the flows of knowledge are human-embodied and dis-embodied diffusion and involve different learning mechanisms of the actors involved. This is what makes a systemic assessment of the distribution power of a national system so difficult because it also requires including many qualitative factors.

Potential role of intermediaries

To gap the bridge between the enormous resources of supply and the dense and varied population of users, intermediaries can play an important role. This role can be either to translate the problem of the user into a solution in terms of knowledge or technology, to match users with the appropriate technology available, or to increase awareness of the benefits of the use of certain technologies. This intermediary process is often referred to as technology transfer which plays a key role in the distribution power of the NIS. The various agents involved can be technology brokers, technology transfer centres, consultants, (semi-)public bodies such as the Dutch Innovation Centres. Industrial research centres, apart from creating knowledge, often play this intermediary role¹¹.

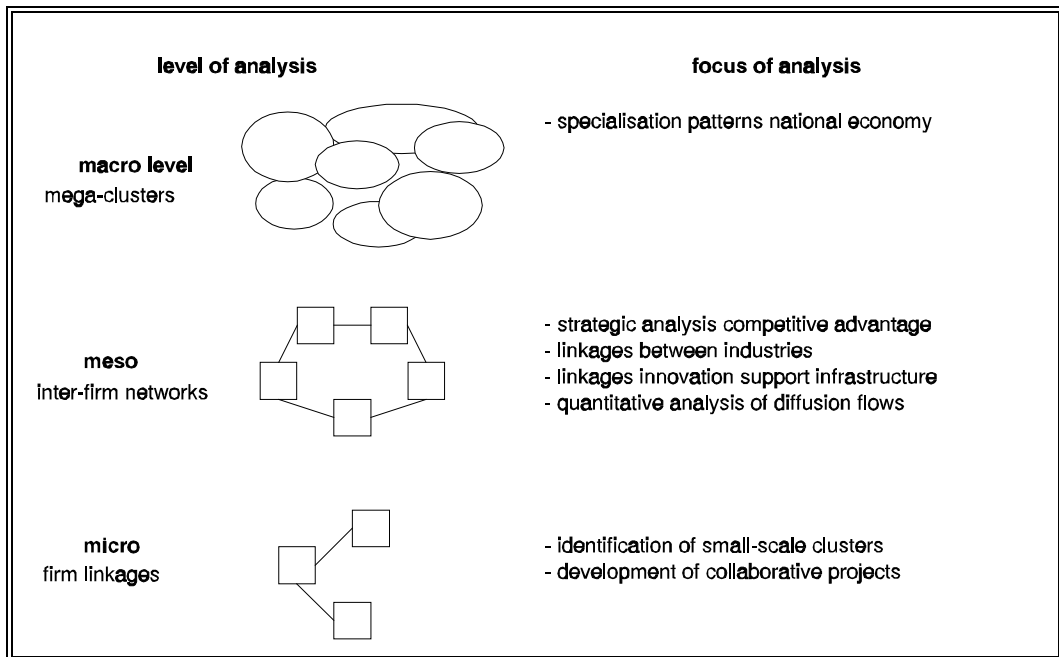
2.3 Clusters as reduced scale models

The conceptual model introduced above was originally developed to be applied at the aggregate (national) level. In practice this model might even be more suited for analyzing economic activities at a reduced scale i.e. at the level of clusters. Although clusters can be identified at various levels of aggregation (see figure 2.2), we confine ourselves here to the mega-cluster level. How these megaclusters were identified as well as the composition of the various megaclusters is illustrated in Annex IV.

A shared basic characteristic of clusters is that different categories of businesses - that are mostly (at least statistically) part of different branches of industry - are linked to each other in a value adding production chain or value system sharing and diffusing technological as well as other forms of knowledge. Using clusters as a 'reduced scale model', offers a more precise insight in the crucial flows of knowledge in the economy of a NIS as they focus on the element of linkages and interaction between the main actors in the system. Experience shows that for each industry these can be different. As Porter already pointed out the determining factors of competitive advantage, or in other words the crucial factors in the national innovation system, are different for each sector or cluster. For a particular sector fundamental research can be crucial for new breakthroughs in product development, for the other it can be the close co-maker relationship with their clients. The level of aggregation of the analyses on the national level does not reveal these differences.

¹¹ Bessant and Rush (1995) illustrate the wide variety of 'bridge building' consultancies and their contributions to technology transfer. They conclude that their role is no longer a linear one of passing information from suppliers to users, but "... a flexible resource capable of filling the interstices within the overall innovation system."

Figure 2.2. The cluster approaches at different levels of analysis



Megaclusters (or otherwise branches of industry) will be our reference categories if feasible in chapter 3, when we will attempt to identify some of the knowledge flows between the various actors identified in box c of the conceptual framework with available empirical data. This will not only create a shared dimension for comparisons, but will also illustrate that distribution power and the nature of knowledge flows differ considerably between the various clusters.

3. Diffusion flows within the Dutch NIS

3.1 Introduction

Starting from the framework developed in section 2.2 (figure 2.1) we will report in this chapter on our attempt to measure distribution power of the Dutch NIS. In doing this we mainly focus on indicators characterising the mechanisms and dynamics within the Dutch NIS (C in figure 2.1, see further figures 3.1 and 3.2). Most of the indicators on especially the science knowledge base (Box A in figure 2.1) and to a lesser degree firms' technology knowledge base (Box B in figure 2.1) and competitiveness (D in figure 2.1) are well covered in existing studies and statistics. We will mainly reproduce some important indicators on A, B and D in Annex I. In our opinion these so called mainstream indicators are less informative unless you do link them to the dynamic diffusion processes or knowledge flows in a NIS and measure the effectiveness of related mechanisms.

We made a first selection out of the qualitative and quantitative indicators that are available at this moment. Apart from statistics provided by the Dutch Central Statistical office, we could dispose of the micro-data of the 1992 Dutch Innovation Survey as performed by Kleinknecht c.s.¹². These micro-data gave us the opportunity to assess, at least partly, some of the diffusion flows at the level of mega-clusters¹³.

We are aware of the fact that more indicators are needed to come to a well grounded judgement on the distribution power of the Dutch NIS. The aim of our efforts is to see whether it is feasible in the first place to collect and structure indicators using the notion of distribution power and the conceptual framework as developed in the preceding chapter. Secondly, this exercise should help us in identifying gaps and flows in available statistical material and the indicators that were developed using available data.

¹² Also referred to as SEO-data or SEO-survey.

¹³ As the definitions used in the surveys as performed by CBS and Kleinknecht differ sometimes, one should be extremely careful on comparing figures drawn from these two sources.

Figure 3.1. Knowledge throughput and relevant mechanisms in Dutch NIS

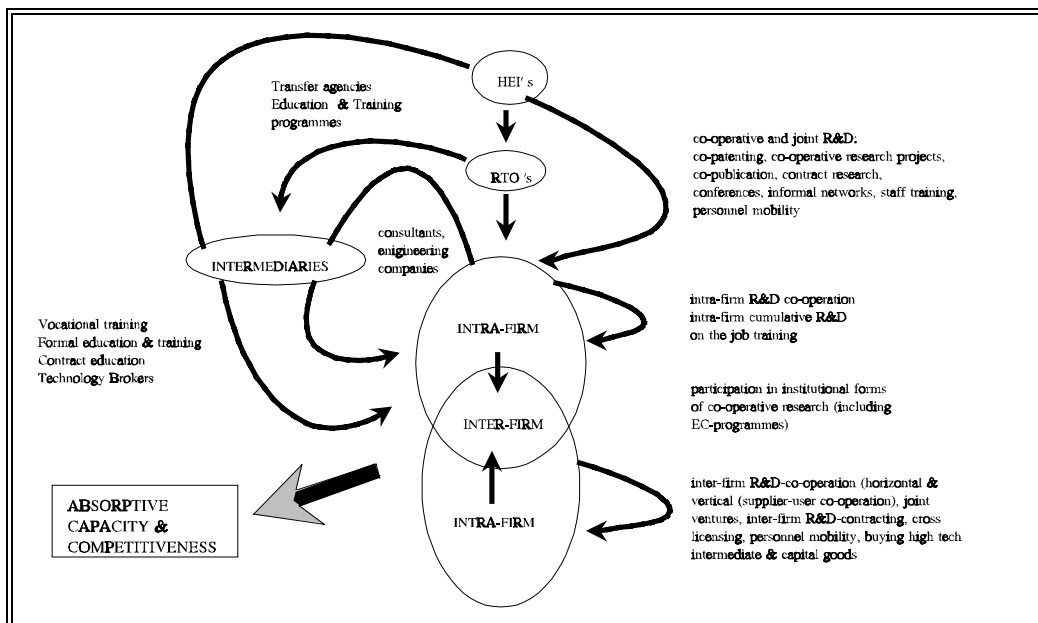
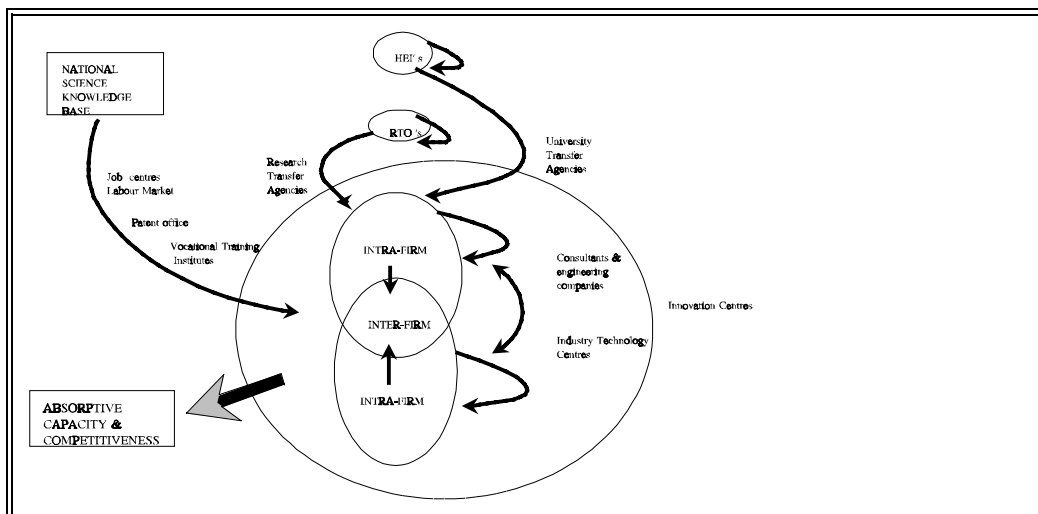


Figure 3.2. Knowledge throughput and relevant bridging institutions



In the following sections we will subsequently discuss the exchange of knowledge between important elements of the Dutch NIS. In section 3.2 we will first start with a brief overview of the Dutch R&D structure.

3.2 R&D-structure for the Dutch national innovation system

In 1992 gross domestic expenditure on R&D in the Netherlands accounted to *f* 10,5 billion, 1,87% of GDP (down from 2,22% in 1988). In 1992 about 52% of gross domestic expenditure on R&D in the Netherlands was made by the business sector (down from 60% in 1988). The share of the Higher Education sector rose from 20,7% in 1988 to 25,7% in 1992. Government sector (including governmental expenditures on RTOs) increased from 17,2% in 1988 to 19,6% in 1992.

In 1992 over 66 thousand employees (FTE) were involved in R&D in the Netherlands. Roughly speaking that is 10 out of 1000 persons of the total National Labour Force. Higher educated staff accounts for approximately 30% of the total R&D-staff. Business enterprises employ approximately 40% of the total R&D-researchers in the Netherlands. Since 1990 the annual growth rate of R&D personnel in the Netherlands is somewhat diminishing. More details are presented in table A1, A2 and A3 of the statistical annex.

The Dutch R&D structure can be best introduced by presenting sources and destination of R&D-financing (exact and natural sciences) as recorded by the Dutch Central Bureau of Statistics. The main outcomes are represented in figure 3.3 and figure 3.4, a more detailed table is presented in the statistical annex (table C0.1, Annex I). In this table financial flows in exact and natural sciences between the actors of the NIS (including intermediate payments), the national government and international flows are included.

Figure 3.3 and 3.4 reveal that R&D in the business sector is mainly financed by own resources. The same figures also indicate that about 90% of HEIs' R&D expenditures are publicly financed. According to the R&D-statistics the importance of HEIs in contract research in exact and natural sciences is very low (only *f* 52 million, or 8% of the total available R&D-funds). Other figures, derived from analysis of the universities' annual reports, suggest that contract research performed by universities is far more important as a source of funding¹⁴. In 1991 universities reported a total income out of contract research and education of *f* 831 million (contract research for government agencies included), accounting for about 16% of the total universities' income (see also section 3.4). The Rots' R&D financing structure is mixed. Government is also the major source of funding for Rots. Most striking is probably that financial flows between the various Rots seem to be more important compared with Rots contract research for firms. On average most of the R&D-resources (about 95%) in R&D-organisations are used for intra-mural R&D-activities.

¹⁴ No data are available on the contract research and contract education as performed by the institution for Higher Professional Education. However, there are indications that the role of these institutions on especially knowledge diffusion is considerable.

Figure 3.4 represents flows of R&D-financing by sources and destination in more detail. The most bulky financial flows consists of intra-firm R&D-financing (f 5,6 billion) and R&D performed by HEIs (f 1,6 billion) and Rots (f 1,6 billion) publicly financed. On average about 85% of firms' R&D resources are used for intra-mural R&D-activities. By far the most important flows take place within and between firms. The share of business expenditure on R&D (BERD) financed by government decreased from 13,2% in 1988 to 7,2% in 1992. The percentage of BERD financed by the industry itself increased in the same period from 83,7% in 1988 to 89, 1% in 1992 (see table B.2 Annex I).

International funding of R&D play a minor role in the Netherlands; less than 2% of the total R&D-expenditures in the Netherlands is 'imported'. In the business sector the percentage of business enterprise expenditure on R&D financed by foreign companies or organisations rose from 2,6% in 1988 to 3,1% in 1992. Compared to other EU-countries this is low. Funding of R&D abroad with funds that originate in the Netherlands is more important than R&D funding provided by foreign companies or organisations.

Figures on the Technological Balance of Payments point at a high degree of "imported and exported knowledge" for the Netherlands (table C10.6, Annex I). Similar, but more detailed indications can be derived from the study of Bulthuis et al. on international transfer of technological knowledge (table C10.7, Annex I). They concentrated on licence agreements on technological knowledge; both licences based on patents and licences based on "know how". These agreements can differ considerably in terms of duration and type of knowledge transfer¹⁵.

Expenditures on international licence agreements increased annually with nearly 10% on average in the period 1982-1989 and rose to 0,49% of GDP in 1989. Income out of international licence agreements rose over the same period on average 8,8% per annum to 0,25% of GDP in 1989 (Bulthuis et al., 1991, p. 24; p. 38).

Chemical industry, metal/electronics and foods/tobacco are the most important branches of industry as regard expenditures on licence agreements, with services as a runner-up. Regarding income from international licence agreements the chemical industry and the metals/electonics sector dominate the scene.

¹⁵ The way in which the international transfer of technological knowledge is registered, the categories included and by whom, differs considerably per country. Therefore careful interpretation of these figures is required. For the Dutch data as registered by the Dutch Central Bank both underestimations (only financial transaction are included as well as the most important non-financial transaction as registered and estimated by the Dutch Central Bank) as overestimations (financial contributions of subsidiaries to the R&D expenditures of the mother company) are possible (Bulthuis et al., 1991, p. 22).

Purchase of knowledge is dominated by intra-concern transactions of Dutch subsidiaries of foreign (mother-)firms. According to Bulthuis et al. these firms appear to hardly use technological knowledge that is available in the Netherlands and transfer of technological knowledge (at least in the form of licence agreements) is fairly limited (Bulthuis et al., 1991, p. 76). Income from international licence agreements can for about 45% be attributed to intra-concern flow of knowledge. However, this figure is nearly 100% for the small group of large Dutch multinationals, that dominate the Dutch R&D infrastructure.

The negative balance in 1988 and 1989 as regards the international trade in licence agreements on technological knowledge for the Netherlands, can for nearly 80% be attributed to the negative balance for intra-concern flows of technological knowledge.

Figure 3.3. R&D financing by sources 1991 (CBS, 1993)

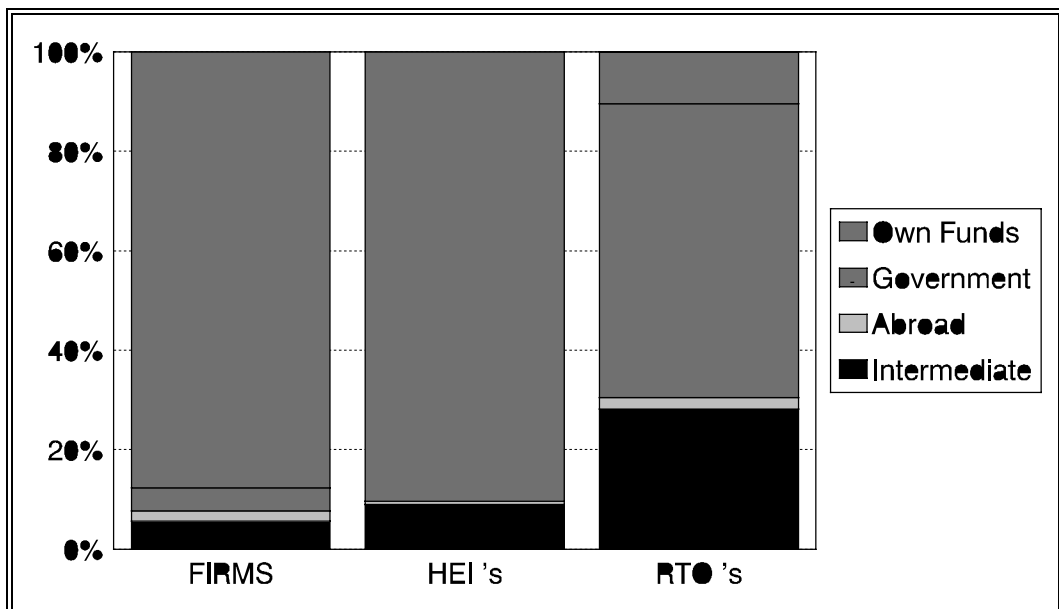
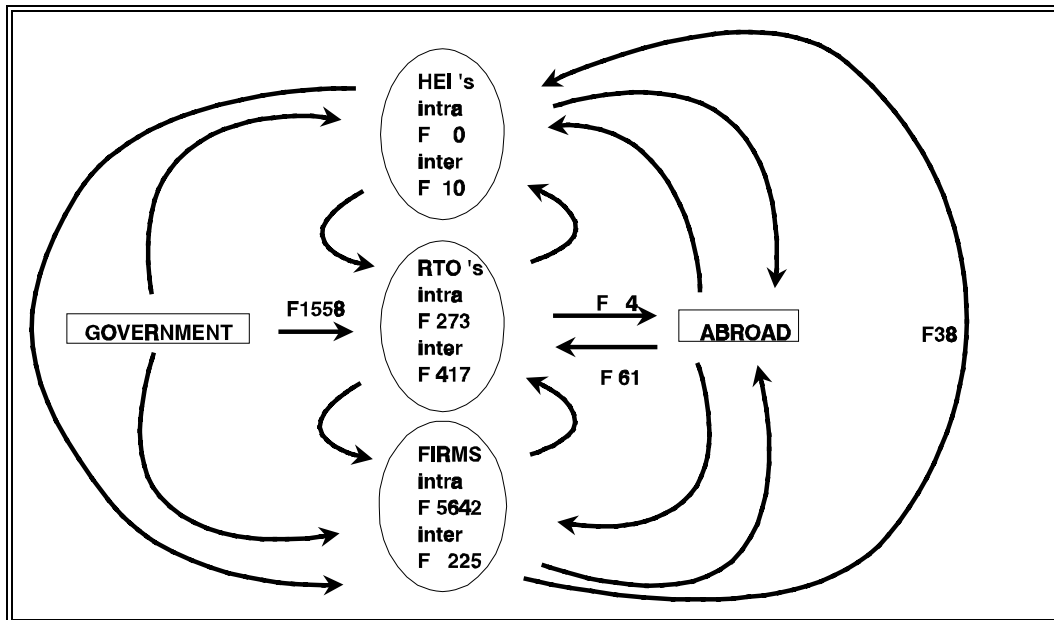


Figure 3.4. R &D financing by source and destinations in 1991 in mln. guilders (CBS, 1993)



3.3 Diffusion and technology transfer in the business sector

In the preceding section it appeared that the business sector is the single most important category, both as a source of and as a destination for R&D funding. The degree to which firms are successful in and capable of diffusing knowledge, within individual firms as well as between firms, is crucial for the distribution power of the Dutch NIS as a whole. In sub-section 3.3.1. we will first briefly characterize the R&D structure in the business sector. We will further attempt to assess firms' technology base and absorptive capacity, not in the least because these are important for especially intra-firm knowledge exchange. In sub-section 3.3.3 we will subsequently discuss some of the mechanisms in which the exchange of knowledge between firms are important e.g R&D cooperation and the use of external information sources. In two separate sub-sections we finally report on two methods that were developed to estimate the exchange of some specific types of knowledge between clusters: Intermediate Innovation Flows (section 3.3.4.) and Intercluster R&D Flows (3.3.5).

3.3.1 R&D structure in the business sector

Recent CBS-figures show a decline in R&D-expenditures in the business sector between 1989 and 1993, primarily due to a decrease in R&D-efforts of large

companies (more than 1000 employees). According to the CBS figures, R&D-efforts of SMEs (50 to 500 employees) have increased in the same period. It should be noted that official R&D statistics tend to underestimate small scale and informal R&D in SMEs (Kleinknecht et al., 1991)¹⁶. In 1993 the metal products and the chemical industries account for about 76% of all R&D-expenditures in the Netherlands (CBS, R&D Statistics 1993, 1995)

If we subsequently look at the level of clusters and sectors we can observe important differences in R&D efforts and the degree to which these are outsourced or not. Figure 3.5 and 3.6 indicate how the total R&D costs are distributed over the various clusters and the percentage of R&D per individual cluster that is outsourced. It appears that R&D intensive clusters such as the chemical industry and the Metal-Electro cluster outsource only a small part of their R&D. In general less R&D intensive clusters seem to outsource a much larger part of their R&D.

¹⁶ For that reason data should be interpreted very carefully.

Figure 3.5/3.6. Total R&D costs per cluster in 1992 as a % of all R&D costs (top) and outsourced R&D in 1992 as a % of total R&D costs by cluster (Source: SEO 1992/STB 1995)

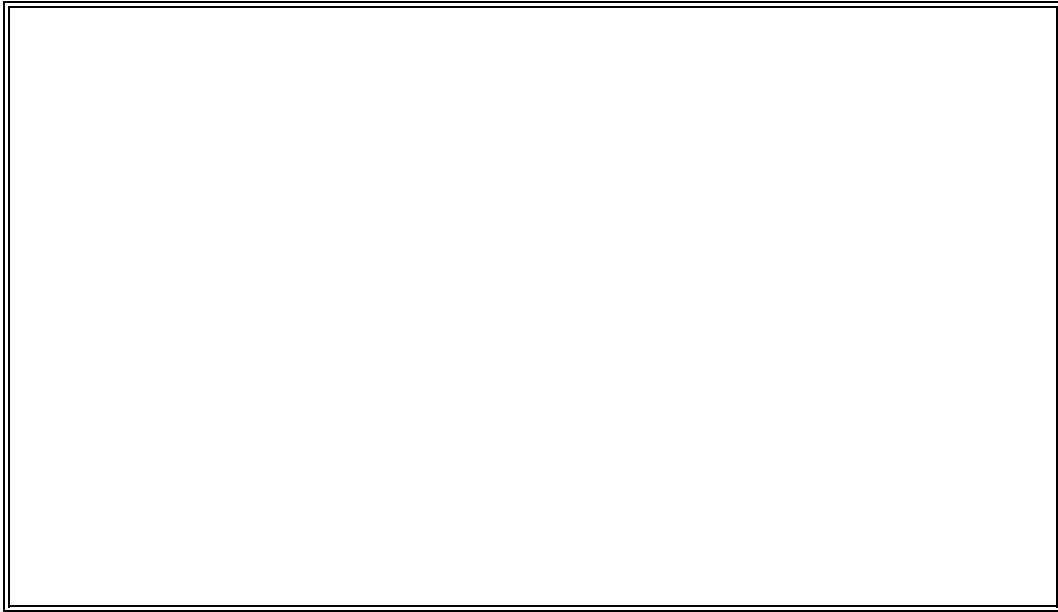
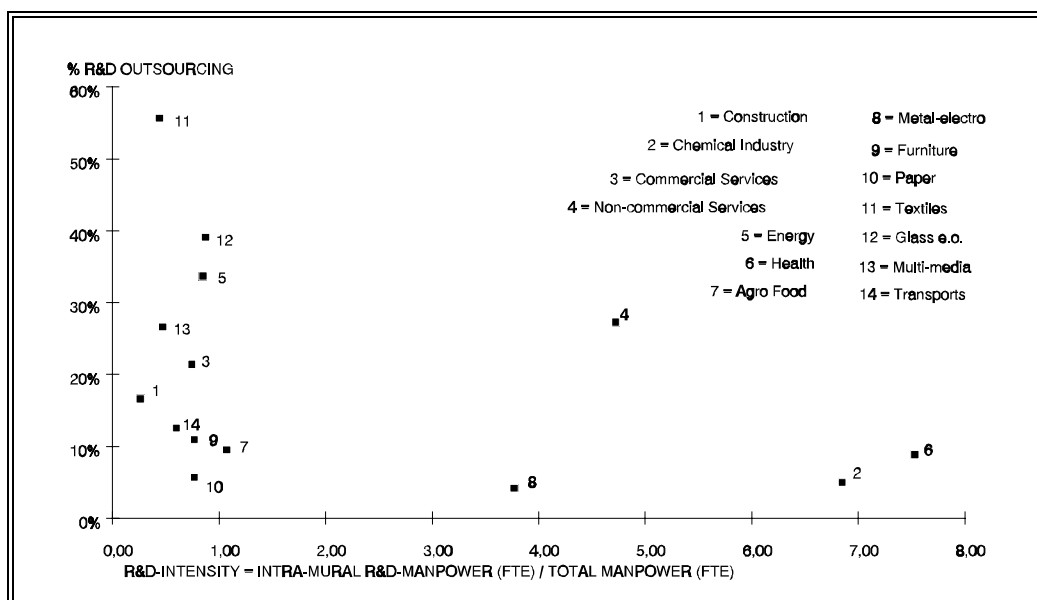


Figure 3.7 presents some key figures as well. Chemical Industry, Health, Non-Commercial services, as well as the manufacturers of Metal & Electro-Technical products can be characterized as economic clusters with a high R&D-intensity (see also Table B.5, Annex I). Most of these clusters combine a high degree of intra-mural R&D-intensity with a low level of R&D-outsourcing. The only exception to this pattern is the non-commercial services cluster, containing (semi-) public research organisations (with high R&D-levels) as well as different types of government agencies (with high levels of R&D-outsourcing). General speaking *low level R&D-intensity clusters* (Construction, Textiles and Multi-media) seem to *compensate low level intramural R&D-efforts with high levels of R&D-outsourcing*¹⁷.

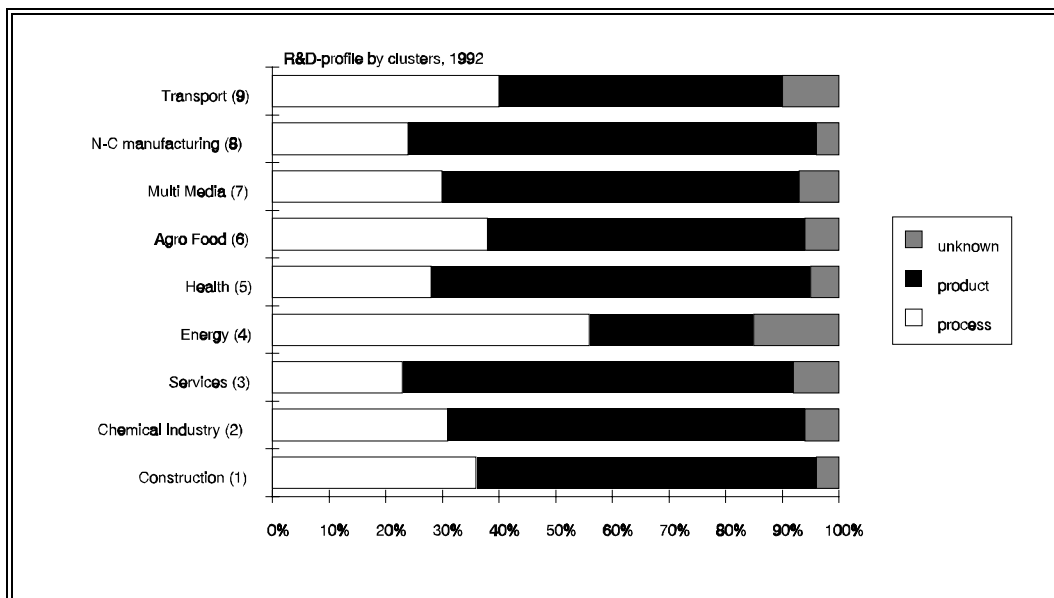
Figure 3.7. R&D-intensity and R&D outsourcing by clusters, 1992 (SEO/STB)



Another characteristic is the division of R&D expenditures over process innovation or product innovation. It is estimated that about 60% of the total R&D-investments made in the business sector are aimed at product renewal, while slightly more than 30% is aimed at process innovations (CBS, R&D Statistics 1993, 1995). Similar figures can be obtained from the SEO-data as shown in figure 3.8

¹⁷ This outcome also illustrates the limitations of traditional R&D-indicators and stresses the importance of the interactionistic approach of the NIS-analysis.

Figure 3.8. R&D directed to product and process innovation by clusters, 1992
(Source: STB, 1995/data: SEO,1994)



There are also important differences between clusters in technology fields of their R&D-activities (for more details see figure B.7, Annex I). For instance: R&D-expenditures in the Construction Cluster, Chemical Industries and Metal and Electrotechnical Cluster are mostly directed towards research on new materials and components. The Commercial Services Cluster, as well as the Multi-media and the Transport Cluster strongly direct their R&D-efforts towards the field of information technology. The Energy cluster as well as the Petroleum industry concentrate R&D on Research in Environmental and Energy Technology. Most of the Health clusters R&D is directed towards medical technology applications (SEO 1994/STB 1995).

3.3.2 Firms' technology base and absorptive capacity

The firm' technology base and absorptive capacity consists of human resources, materials, equipment & written information, the availability of which can only be assessed by using a great many number of different indicators. Although some indicators are presented here, other indicators still need to be added as firms' technology bases and their capacity to learn, absorb and distribute knowledge both within a firm and between firms are important for the distribution power of the Dutch NIS.

The total number of R&D personnel is fairly stable the last few years and accounted to 66.610 FTE in 1992 (CBS-figures, see Table A.3, Annex I). Apart from HEIs and RTOs, where more than half of the total number of R&D personnel is employed, about 30.000 FTE are employed by business enterprises, mainly the Metal industry, Chemical industry and to a lesser extent Foods, drinks and tobacco industry and Business services (for details see Table B.1, Annex I). Again we should be careful in interpreting these data as these CBS figures probably underestimate the number of R&D personnel. Kleinknecht c.s. estimated that the number of R&D-personnel accounted to nearly 50.000 FTE in 1992. Compared with CBS R&D statistics Dutch innovation survey data cover more extensively SMEs and include all service branches of industry¹⁸.

Education and training of employees is one of the instruments improving the firms knowledge base and increasing its absorptive capacity (for more detailed figures see C6.2a/b/c/d, Annex I). In the period 1990-1993 annual training and education costs in the Dutch business sector increased 5%, primarily due to increased participation in training of employees working at small and medium sized firms. The participation rate of employees attending company training and education programmes is particularly high in the Transport sector, in the Energy sector as well as in Banking and Insurance sectors. Analysis based on the Dutch Innovation Survey have not indicated any correlation between R&D-intensity and distribution power of firms on the one hand and the employees' participation rate in attending company training and education programmes on the other hand.

Some scholars interpret apprenticeship agreements as a special type of technology transfer. A high level of apprenticeships is supposed to improve the firms' technology knowledge base and its absorptive capacity of (re)new(ed) knowledge. Table C6.3 (Annex I) presents the share of the labour volume contributed by employees with primary or secondary level apprenticeship agreements as published by Ramakers et al. (1994). In 1992 the share of primary level apprenticeships is high in the Metals and Electrical sector, the Food stuff sector and the Transport sector (about 4,5% of the total labour volume). The number of primary level apprenticeships have been declining since the end of the eighties due to a general reduction in number of students. The share of secondary level apprenticeships is particularly high in the Food processing and Metal-electrical industries. Not much can be said about the economic impact of these apprenticeships.

The number of national patent applications (Table B3, Annex I) increased during the period 1987-1992. The dependency ratio for the period 1987-1992 is rapidly growing.

¹⁸ SMEs in the CBS figures have between 50-500 employees, whereas in the Dutch innovation survey the cut-off point for SMEs was 10 employees. Further CBS did not include all services branches of industry.

This indicates that the relative number of patent applications of foreign enterprises in the Dutch economy is growing. The same holds true for other countries like Belgium, France, Germany, Spain, Great Britain and Japan. This implies a growing internationalization of patent production and exchange. For the Netherlands the patents' rate of diffusion of Dutch enterprises is increasing sharply. This indicates a high degree of effectiveness of these firms for this kind of technology transfer in an open and export-oriented economy like the Netherlands.

3.3.3 R&D-co-operation and external information flows

R&D-cooperation with other firms (suppliers, clients) and purchasing, selling and using intermediate products and capital goods produced by other firms (including competitors) are probably two of the most powerful ways to disseminate knowledge and technical know how within a NIS. In the NIS-framework it is supposed that high levels of interfirm (R&D) cooperation and a high diffusion rate of (re)new(ed) intermediate and capital goods and services contribute to a high diffusion capability of the NIS. Using the results of the Dutch Innovation Survey a very broad picture emerge as to the percentage of business enterprises with R&D cooperation in the Netherlands or abroad by type of partner at the level of clusters (see table C0.2, Annex I). Almost half of all firms were involved in some kind of R&D co-operation. Of course the patterns per cluster regarding the type of partner differs to a great extent. Nevertheless, R&D cooperation with clients, suppliers or other divisions within the same concern seem to be as important as R&D cooperation with HEIs and RTOs. However, these figures only give a very broad indication and leave much room for speculation. For instance neither the period, intensity and magnitude of the R&D cooperation are known, nor are the distribution between R&D cooperation with national or international partners and the fact whether R&D cooperation is a frequent well established phenomenon or a one-time experience¹⁹.

More than 40 out of 100 firms also use external information sources during the innovation process (see Table C0.3). Most firms gain access to external information by using informal networks, by buying specialized equipment, by hiring consultants or outsourcing R&D to public R&D-organisations.

Different economic activities ask for different forms of co-operation and information exchange. Some important differences between the various economic clusters can be observed. Clients and suppliers of materials and machinery are important external information sources to the firms in the Textiles cluster, as well as in the Transport

¹⁹ According to The World Competitiveness Report 1994 the degree of inter-firm technological co-operation in the Netherlands is on average. Dutch firms co-operate more than firms in Italy, France and the United Kingdom but less than firms in Japan, Switzerland and Sweden.

clusters; innovation in this cluster strongly depends on the activities of suppliers of materials, machinery and equipment. Engineering companies serve as an important external information source in the Construction sector. These engineering companies actually bridge the gap between the supply of knowledge in the national science knowledge base and the (specialized and generic) need for knowledge in the firm's technology base. Buying specialized equipment is a transfer mechanism most often used by clusters using high tech equipment in their production processes, like the Transport Cluster (Transport Equipment) and the Multi-Media cluster (Computers and other electronics). Almost all suppliers and research organisations in the Dutch Energy cluster co-operate; compared to other clusters, the Energy Cluster has the highest rate of information exchange. This can be explained by the public character of the goods and services provided, the need for co-operation using the public infrastructure, as well as the small number of suppliers involved.

Another indicator that illustrates the importance of interaction between NIS-actors refers to information sources used for innovation. In the Dutch Innovation Survey (1992) firms were asked to evaluate the importance of various information sources for their innovation performance. The results (see Table C0.5, Annex I), clearly points at the importance of user-supplier interactions, of intra- and inter-firm information exchange and of informal interactions between professionals. The information sources most frequently mentioned as very important or crucial for successful innovations were: intra-firm information, suppliers of material components and machinery, clients and competitors. About one third of the firms also considered professional meetings and exchanges and reading professional journals as important for successful innovation.

It is interesting to note that intermediate organisations like the Dutch Innovation Centres, the Regional Development Agencies, the Patent Offices, Public Research Organisations and Consultant Agencies, but also the universities and RTOs, only play a minor role in the information gathering process during the innovation process. Later on we will discuss the role of bridging institutions in more detail.

This result might point at a mismatch between the supply of knowledge generated in the public infrastructure and the needs of the private business sector. The public infrastructure consists of HEIs, RTOs and (some) intermediate organisations mostly financed out of public resources and strongly directed to the goals, needs and institutions of public agencies. On the other hand there is a mainly self-sufficient private sector, that mostly finances and performs R&D itself and does not often make use of the public infrastructure. This gives scope to an innovation policy that stimulates the interaction between firms and public infrastructure i.e. improving the transfer capacities of the public infrastructure as well as the absorptive capacity of firms.

Table C.05 (Annex I) further illustrates important differences between different kind of economic activities. For instance in the Construction Cluster engineering companies and specialized public Research Organisations play a major role as an external information source. In the Health Cluster intra-firm information sources are much more important for innovation than in other clusters due to the low number of highly specialized firms in this sector. On average HEIs (university hospitals) and professional meetings and journals are also more important information sources in the Health cluster compared with other clusters. Information provided by suppliers of materials and machinery, play a very important role for innovation in the Agro-Food Cluster (food processing machinery), in the Textile Cluster (specialized machinery) and in the Multi-Media Cluster (computers and communication instruments). This again illustrates the connection between type of economic activities and diffusion mechanisms used.

The outcomes of research on the impact of R&D-collaboration and technology transfer on innovation performance at branch of industry level are still ambiguous (Brouwer & Kleinknecht, 1996) and additional research is needed.

3.3.4 Diffusion of new products and services: Intermediate Innovation Flows

The range of diffusion of (re)new(ed) products and services in an economy can also be estimated by analyzing the intermediate use and supply of goods and services. New products produced in one cluster can be used in other sectors to improve the economic performance. In the NIS-framework buying and selling of (re)new(ed) goods and services is supposed to be an important diffusion mechanism. In this section we would like to discuss some first and tentative attempts to estimate the importance of these diffusion mechanisms for the various (mega-)clusters.

In the matrix displayed as table 3.1 some preliminary and tentative estimations are presented of intermediate innovation flows. The flows are estimated by calculating the share of new products in the inter- and intra-sectoral intermediate use of goods, using the Dutch Innovation Survey 1992 and the Dutch National Accounts as the main data sources. Columns represent the total use of new products per cluster, rows the total supply of new products per cluster²⁰.

Figure 3.9 presents the innovation spillover by cluster, referring to the share of new products that is used in other clusters than the clusters producing the new products. This figure illustrates the importance of intermediate embodied technology flows as a technology transfer mechanism. For instance: more than 80% of the new products and services used in the Transport Cluster, with a relatively low R&D-intensity, is

²⁰ Supplies of intermediary goods and services originating from abroad (imports) are included.

produced in other clusters (mainly Transport equipment and Communication services). The same holds true for new products produced in the Transport cluster: more than 80% is used in other clusters. The Energy cluster is also characterised by a low R&D-intensity combined with a high degree of forward and backward innovation spill over.

Table 3.1. Intermediate Innovation Flow Matrix, breakdown by clusters in f million, 1991

CLUSTER	Cons(1)	Chem (2)	Serv(3)	Ener(4)	Health (5)	Agro-f(6)	Media (7)	N-C man (8)	Transp(9)	new products
Construction (1)	9249	205	5118	101	215	281	175	925	777	17045
Chemical industry (2)	1200	6799	1612	157	184	1204	298	2473	837	14764
Services (3)	2075	1541	15466	628	1032	2513	1443	3903	1423	30024
Energy (4)	126	2740	690	2252	82	442	52	488	85	6958
Health (5)	0	149	252	1	1178	197	3	0	9	1791
Agro-food (6)	47	110	2321	2	296	20641	72	109	61	23660
Multi-Media (7)	28	53	1619	13	92	141	2254	201	76	4477
N-C manufacturing (8)	6057	1153	6044	649	573	2173	1340	19738	1355	39082
Transport (9)	195	110	2181	87	138	144	370	312	747	4283
Total										
use of new products	18977	12861	35304	3892	3789	27737	6007	28149	5370	142086
Innovation spill-over: *)										
forward	0,46	0,54	0,48	0,68	0,34	0,13	0,50	0,49	0,83	
backward	0,51	0,47	0,56	0,42	0,69	0,26	0,62	0,30	0,86	

Source: Preliminary and tentative estimations on the basis of Dutch National Accounts (NR-CBS) and the Dutch Innovation Survey 1992

*) Forward innovation spill-over is defined as the share of the supply of new products (row total) that is used in other clusters than the new products producing cluster. Backward innovation spill over is defined as the share of the use of new products (column total) produced in other clusters.

Figure 3.9. Embodied intermediate innovation flows by cluster in 1991 (Source: STB, 1995; data CBS 1993 and SEO 1994)



At the same time it is interesting to note that in particular the Agro-Food Cluster is in a way the opposite i.e. relatively independent of product innovations of other clusters. To a lesser degree the same holds true for the Health-Cluster that is in terms of innovation flows relatively independent of the economic activities in other clusters.

This outcome also illustrates some of the important limitations of traditional indicators on R&D and innovation. Low R&D-intensities simply do not tell us much about the level of innovativeness in a cluster. For low R&D-intensive sectors it is important to invest much in the effectiveness of their absorptive capacity. For instance: about 45% of the new intermediate products developed in the Construction cluster is used in other clusters; mainly in services related to the exploitation of and trade in real estate. In contrast almost all of the new products developed in the Agro-food cluster are used within the agro-food cluster (low innovation spill-over). The Energy and especially the Transport cluster can be characterised as clusters with a high innovation spill-over and a high diffusion rate of new products. Especially the chemical industry (petroleum industry) benefits from new products developed in the energy sector and the services cluster profits mostly from the new products developed in the transport cluster.

Another indicator often used to describe inter-firm embodied technology flows is the use of high tech products and services. In the Netherlands about a fourth part of the R&D-expenditures is used for the development of electric and electronic products (including computers and office machinery); that is almost 35 per cent of the R&D resources for product innovation. Diffusion rates for these kinds of products are very high (for details see Table C10.5). In 1993 about 78% of business firms were using computers and/or EDP personnel. It is expected that this rate of automation will increase to 81% in 1995. The rate of automation is (in 1993) low in Textiles Industries (67%), Banking (67%) and Agriculture and Fisheries (69%). Printing

and Publishing (94%), Chemicals, Petroleum and Plastics Processing industries (96%), Insurance Companies (99%) and Public Utility (99%) show high rates of automation.

3.3.5 Intercluster R&D flows

Another way of estimating technology flows in an economy is measuring the diffusion of R&D-efforts directed at developing new products and new production processes. We estimated R&D-diffusion on the basis of R&D-profiles of the different clusters (see figure 3.8). On the basis of these R&D-profiles we calculated a preliminary and tentative R&D-Flow Matrix. In this matrix rows indicate the investments in R&D per cluster and columns represent the benefits from R&D per cluster, which are not necessarily the result of R&D investments of the cluster itself (Table 3.2). The diagonal elements presents R&D-expenditures directed towards process innovations and are calculated by multiplying R&D-expenditures by the share of R&D-expenditures that are directed towards innovation of production processes. The non-diagonal elements indicate the diffusion of R&D-activities directed towards new products and are estimated by using the coefficients of the intermediate use of products and services (intra-cluster use excluded). It is assumed that the diffusion of R&D-expenditures follow the same pattern and structure as the value creating production chain in the economy.

In order to compare the investments in and benefits from R&D by clusters we have calculated a diffusion index.²¹ From this index a more precise picture of intercluster R&D flows develops. The index equals zero in case the amount of the production and use of R&D is exactly the same. In case the index has a positive value a cluster generates much more R&D than it "consumes" from other clusters. In that case a cluster can be characterised as a science-based R&D-cluster (Pavitt, 1984).²² When the index shows a negative value a cluster benefits much more from R&D-activities of other clusters compared with its own R&D-expenditures. In terms of Pavitt's taxonomy this type of cluster would be characterised as a supplier dominated R&D-cluster. The higher the absolute value of the index, the higher the degree of diffusion.

For the Netherlands the chemical industry cluster as well as the Non-continuous manufacturing cluster (mainly machinery, instruments, metal products and electro-technical products) can be characterised as science-based R&D-clusters. In this way the R&D diffusion-index can be used to characterise the R&D-profile of a group of economic sectors. For instance, the Construction Cluster is a highly R&D-consuming or dependent cluster and benefits considerably from the R&D-activities of the Non-continuous manufacturing cluster (especially machinery and instruments, metal products and electrotechnical industry). In contrast, the Chemical industry cluster spends much more money on the development of new products, used in other clusters (chemical basic products, production of artificial yarns and fibres, petroleum), than that it benefits from new products developed in other economic clusters. The same holds true for the Non-continuous manufacturing cluster, containing the electrotechnical industry, the manufacturers of instruments, machinery and transport equipment.

²¹ index = $\log(\text{R\&D-production divided by R\&D-use})$

²² Compare Pavitt's categories of technological linkages in: K. Pavitt, 1984.

Table 3.2. R&D-flows breakdown by clusters (in 100,000 guilders)

CLUSTER	Cons(1)	Chem (2)	Serv(3)	Ener(4)	Health (5)	Agro-f(6)	Media (7)	NC-man (8)	Transp(9)	SUM
Construction (1)	866		9	1119	23	77	19	13	83	196
Chemical industry (2)	1546	5749		4367	575	470	1070	267	2210	18544
Services (3)	3708	526	14079		1093	2000	1036	735	2488	27814
Energy (4)	30	116	237	723	40		46	8	57	35
Health (5)	0	267	2291	6	1239		524	6	1	4425
Agro-food (6)	39	24	1400	2	422		1226	27	33	3225
Multi-Media (7)	10	5	779	8	54		14	407	37	1355
NC-manufacturing (8)	6123	450	10849	2030	1540		842	384	8674	34493
Transport (9)	70	12	1276	63	118		28	60	71	2828
SUM	12392	7158	36397	4523	5960		4805	1907	13654	9586

DIFFUSION-INDEX*)

	-0,7	0,4	-0,1	-0,5	-0,1	-0,2	-0,1	0,4	-0,5
--	------	-----	------	------	------	------	------	-----	------

(Source: Preliminary and tentative estimations on the basis of Dutch National Accounts (NR-CBS) 1991 and the Dutch Innovation Survey 1992)

*) Index = log (row total / column total) = log (R&D-investment / R&D-benefits)

3.4 Diffusion and technology transfer from HEIs towards industry

Although HEIs are in the first place thought of as places for basic research and education, they may contribute considerably to the distribution power of national economies. As graduates (diffusion agents) start working in industry they will transfer knowledge and technological know how. HEIs are also in an increasing number of countries involved in performing contract R&D and contract training directly for industry.

Through mobility of well qualified graduates to industry and through performing contract research HEIs contribute to the distribution power of a national economy. However, it is not so much the existence of these links, as well as the efficiency/effectiveness of these links that influence the distribution power of a NIS.

According to CBS figures on R&D financing and destination the interaction between universities and firms²³, at least in terms of financing, is fairly limited (about f 38 million in 1991). Compared to other countries business financing of HEIs is very low (Ministry of Economic Affairs, 1994). In the Netherlands the degree of technological co-operation between firms and universities is about the average, higher than for instance in Belgium, France, Italy and the United Kingdom but somewhat lower than for example in Sweden, Japan and the United States.

On average only 9% of the firms consulted in the Dutch Innovation Survey considered universities to be very important or crucial for their innovation performances. The only exception is the Health cluster; about one out of three companies in the Health Cluster considers University Hospitals to be very important for innovation. About 50% of the firms in the Health cluster reports any form of co-operation with universities. On average about 17% of the firms in the Dutch Innovation Survey reports co-operation with universities. Co-operation between firms and universities is particularly high in the Health sector, the Transport Cluster, the Non-Commercial Services and in the Energy Cluster.

Bartels (1994) asked firms to evaluate the quality of different sources of external knowledge. Compared to non-profit research organisations, consultants and other firms, universities were most positively appreciated.

Business financing part-time professorships as well as Ph.D-scholarships can be considered as a special type of knowledge transfer. Bartels (1994) estimated the number of business financed part-time professorships to be about 265 and the number of Ph.D's about 173. This part of the university scientific personnel accounts to approximately 225 FTE (1,5% of scientific university staff).

The income from contract research and contract education of Dutch universities almost doubled in the period 1989-1992 from f 525 million in 1989 to f 958 million in 1992. The research capacity of Dutch universities based on contract research more than tripled (for details see tables C5.2 and figure C5.3, Annex I). In 1992 contract research and education accounted for 17% of the total universities' income and for almost 30% of the scientific personnel. There are no precise figures on the share of privately financed contract research at universities; the available statistics indicate a low level of privately financed contract research compared to other EU-countries. The high degree of co-operation between firms and universities in the Health Cluster also holds true for contract research at universities; medical research is the most important field of research in privately financed contract research (at 1987).

²³ Similar figures on the interaction of institutions for Higher Professional Education and firms were not identified, but are needed for a more complete picture on the interaction between firms and HEIs.

The share of co-publications of firms and HEIs can also be interpreted as a special type of knowledge and technology transfer. This kind of information exchange might have an impact on the use of knowledge in economic applications, but is quite difficult to measure a direct effect. Table C5.4 presents the share of co-publications of firms and HEIs, as recorded by CWTS Science Citation Index (1991-1992). Firms are involved in almost 3% of all publications in the exact and natural sciences.

It is interesting to note that co-publications between firms and researchers at HEIs as well as RTOs most often relate to disciplines or technology fields (materials sciences, chemical technology, mechanical engineering, civil technics, Chemistry, Physics and Pharmacology) that are particularly important for application in clusters with a high R&D-intensity and a high diffusion rate (Chemical industries, Health, Metal products and Machinery).

3.5 Diffusion and technology transfer from rtos towards industry

In some countries RTOs play a major role in creating and diffusing knowledge. Some of these institutions are more or less used as institutions aimed at creating (specialised) basic knowledge, others are more devoted to translating and transferring the available knowledge and technical expertise into practical products and services for certain groups of users. RTOs can work in a broad field of disciplines and industries or be more specialized at certain sectors or type of knowledge. Quite a few RTOs have a role in (further) educating R&D-personnel and therefore can develop into a pool of expertise which can more or less efficiently be diffused towards the national economy. However, the mere existence and availability of institutions and budgets is not decisive, especially the efficiency and effectiveness with which these RTOs function is important here. It is likely that the success with which the various RTOs operate differs between countries and between clusters/industries.

Through high levels of mobility of well qualified and experienced graduates from RTOs to industry, high levels of good quality contract research, scientific and technological knowledge and expertise is further disseminated and distribution power increased.

In the Netherlands RTOs are quite prominent part within the R&D infrastructure (at least financially) as can be observed from the various figures on R&D expenditures (see e.g. Table A.1, A2 and A3, Annex I). However, it is also noted that the role of RTOs as contract research organisation working for the private sector is limited. Table 3.3 presents some evidence on the share of both publicly and privately financed contract-research in the turnover of the single largest RTO i.e. TNO and a group of five major RTOs. The latter are the so called Large Technological Research Institutes. As a group these six RTOs had a joint turnover in 1993 of nearly f 1.2 billion. As regards contract research as a percentage of total turnover the picture differs for each of the six organizations. TNO scores are relatively low compared with especially WL, GD and MARIN, partly because some of the facilities (e.g. in the area of Defence and Health) function at least partly as governmental laboratories. An increasing share of the relatively large share of financing TNO receives from government, is earmarked and organised in research programmes.

However, the picture for the various clusters differs considerably. TNO e.g. is mentioned by 13% of business firms with R&D cooperation as a collaboration partner, but Energy, Chemical industry, Health and Agro-food clusters score well above this average (see Table CO.2, Annex I).

In the Construction Cluster as well as in the Energy Cluster the use of RTOs is more important for innovation performance than in other clusters, due to the technological specialisation of most of these RTOs. The research at the Centre for Energy Research in the Netherlands (ECN) for example is merely concentrated on Energy Technology and both Grondmechanica Delft (GD) and the Waterloopkundig Laboratorium (WL) are specialised in technologies that are primarily applied in the Construction Cluster.

A similar picture emerges if we take a look at the percentage of business enterprises using external sources of knowledge. 10% of the enterprises that are active in this respect mentioned outsourcing of R&D to public R&D institutions, with the same clusters showing above average scores. However, informal contacts (17%),

enlisting a consultancy firm (14%), purchase of specialised machinery (14%) and recruitment of qualified score better as external source of knowledge (see Table CO.3, Annex I).

Table 3.3. Total turnover, share of contract research in total turnover and publicly and privately financed contract research of TNO and the five Large technical Research Institutes in 1993 (Source: Ministry of Education, Culture and Sciences, 1995, p. 46, 49 and 50)

	<i>TNO</i>	<i>WL</i>	<i>GD</i>	<i>ECN</i>	<i>MARIN</i>	<i>NLR</i>
Total turnover (f million)	760	75	38	150	31	144
total contract research as % of total turnover	56%	87%	91%	60%	83%	70%
contract research commissioned by the public sector as a % of total turnover	18%	37%	46%	26%	12%	n.a.
contract research commissioned by private sector as a % of total turnover	38%	50%	45%	34%	71%	n.a.

If we consider the importance of the various information sources for innovation public laboratories score remarkably well (12%) compared to e.g. consultants (8%), HEIs (9%). However, suppliers of materials and components and machinery clients and competitors seem to be far more important. Again, the picture is different for each individual cluster (see Table CO.5, Annex I).

The share of co-publications between RTOs and firms is particularly high in chemical technology, materials sciences, civil technics, Chemistry, Physics and Pharmacology (Table C5.4, Annex I).

3.6 Diffusion and technology transfer through bridging institutions

Most of the actors that serve as bridging institutions are created to stimulate the process of diffusion and technology transfer. A well developed, efficient and effective infrastructure of bridging institutions may greatly enhance the distribution power of a national economy.

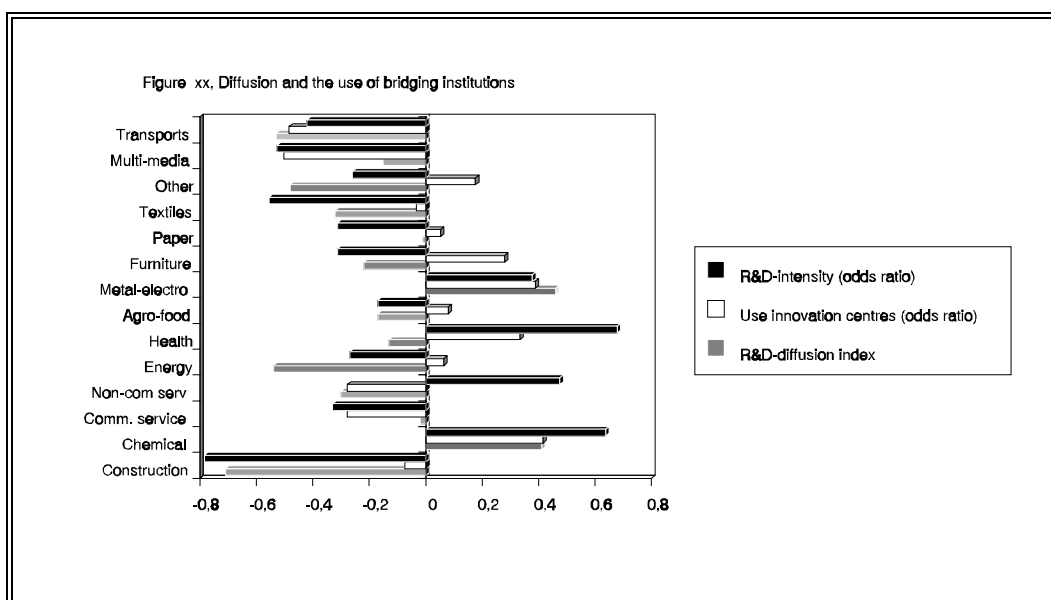
In section 3.3 we already discussed the minor role of bridging institutions like the Dutch Innovation Centres and the Regional Development Agencies in the information gathering process during the innovation process. In table CO.3 (Annex I) the most important findings are summarized. Consultants most often are used in the Construction Cluster (engineering companies). Patent agencies are mostly used by cluster with high R&D-intensities (Chemical industries, Health and parts of the non continuous manufacturing industries).

Especially striking is the relative low impact of the network of Dutch Innovation Centres. This network can be considered to be one of the most important policy instruments in the Netherlands directed towards diffusion. This is a network of 18 regional centres consulting SMEs regarding access to technological knowledge. Instead of developing technological expertise themselves, these centres may link firms and a wide range of innovation supporting (semi-) public organisations.

Figure 3.10 presents the use of the Dutch Innovation Centres by various clusters. On average about 7% of the firms actually uses the Dutch Innovation Centre Network. The figure shows the use of Dutch Innovation Centres (odds ratio), R&D-intensity (odds ratio) and the R&D-diffusion index.

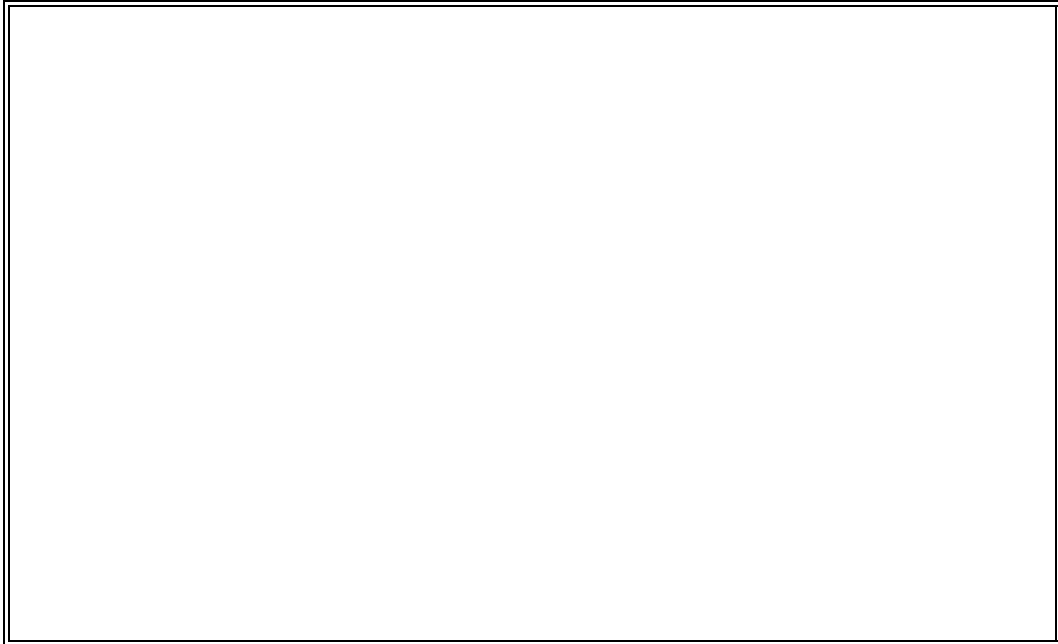
It is interesting to note that the use of Dutch Innovation Centres (IC) is particularly high in clusters with a high R&D-intensity and a positive value on the R&D-diffusion index: Chemical Industry (18%), Metal-Electro Industries (17%) and firms in the Health cluster (15%). The use of the Innovation Centres is rather low in clusters with low intra-mural R&D-levels and clusters that are highly dependent on supplying industries for their innovation performance (Multi-Media (2%) and Transport cluster (2%)). Successful innovations in this type of clusters strongly depend on specialized suppliers in other sectors (Computers, Electronics and Transport Equipment). This outcome suggests that the Dutch Innovation Centres have gained access to science- and technology based clusters with relatively high capacities in terms of transfer of technological knowledge. It might suggest that ICs have not yet succeeded in supporting more supplier dominated clusters on a wide scale.

Figure 3.10. Diffusion and the use of bridging institutions (Source: STB, 1995; data, SEO, 1994)



Although not always directly considered to be an intermediary bridging institution, but actually possibly one of the most successful ones in the Netherlands is the Technology Foundation (STW). This foundation, established in 1981 with the aim of financing technical scientific research at Dutch universities is financed by the ministries of Economic Affairs and Education, Culture and Sciences. University research groups can apply for financial support for high quality application-oriented research proposals. Already in its selection procedure for projects to be funded - a peer review/jury procedure - both scientific quality and potential for utilisation are taken into account. STW has a tradition of extensively evaluating the projects that were supported by STW. User-involvement thereby is an important criterion (see also figure C9.2, Annex I). In 1993 STW presented an evaluation-report ("utilisation report") in which a total of 123 research projects that started in 1981 and 1982 were evaluated. For the first time projects were evaluated on three criteria: the availability of tangible products, user-involvement and revenues from the project. All projects were ranked on these three criteria from 0 (failure) to C (successful). The results of this exercise are displayed in a three dimensional scheme (Figure 3.11). The magnitude of the spheres is an indication for the number of projects with the same score.

Figure 3.11. 10 years evaluation of 123 projects supported by STW on availability of a tangible product, user-involvement and revenues (Source: STW, 1993, p. 16)



3.7 Policies aimed at enhancing distribution power

Traditional indicators of the public sector involvement in science and technology focus on governmental R&D expenditures. Dutch public expenditures of the last five years in general in the Netherlands show a downward trend. This is reflected in the decreasing percentage of business enterprise expenditure on R&D financed by the government and in the negative growth rate of government budgets on R&D (see figure 3.12 and 3.13).

Figure 3.12. Percentage of BERD financed by government (Source: OECD Science and Technology Indicators 1995)

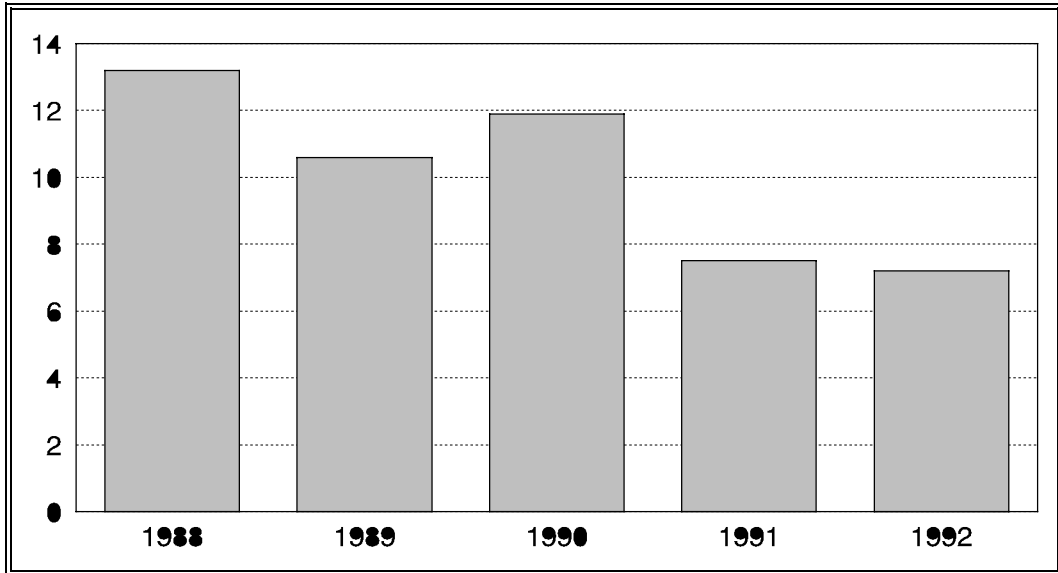
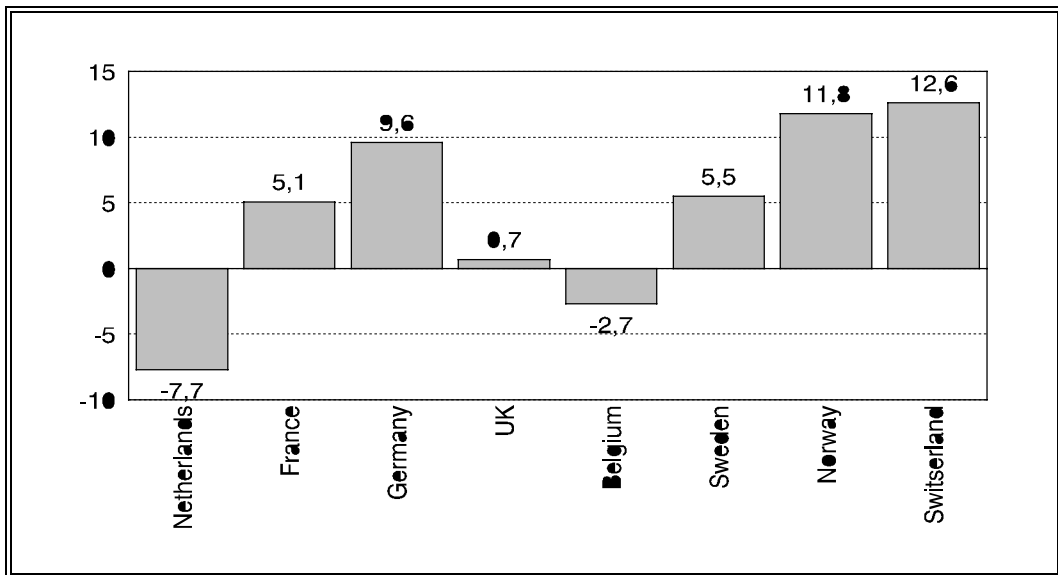


Figure 3.13. Growth in budgets for technology policy 1990-1993 in % (Source: Ministry of Economic Affairs, quoted from MERIT International Policy Survey 1993)



In this present NIS study we are looking at the distribution power of the system rather than the expenditures on knowledge creation. The distribution power of nations is highly dependent on the institutional infrastructure that can enhance the knowledge flows between the different actors in the national system of innovation. Public intervention plays an important role in shaping this institutional context.

The institutional infrastructure that influences the distribution power includes:

- intermediary organisations between technology suppliers and users;
- intermediary organisations between firms or groups of firms for exchange of innovation experiences (technological, managerial) and collective action;
- public support activities for diffusion (support programmes/centres for application of technologies, for technology transfer, tacit knowledge flows, demonstration activities);
- the system of vocational education where tacit knowledge between firms and education institutes is exchanged.

This section discusses the role of Dutch innovation policy and its instruments regarding the diffusion capability. The general trend in national innovation policies is one moving away from a focus on generation of new knowledge to one of the diffusion of applied knowledge and technologies in the economy.

Data on these institutional and policy oriented factors are mainly qualitative and descriptive in nature²⁴. The performance of a diffusion infrastructure, where networking and linkages for mutual learning are essential features, cannot be grasped by quantitative data such as the number of technology transfer agencies. Indicators for the diffusion orientation of public policy should therefore be used with some caution.

An assessment of the dominant orientation in innovation policies can be made after deciding what innovation support activities can be designated either directly or indirectly 'diffusion oriented'. We can divide policy instruments according to their primary objective into the following categories:

1. *generation of new knowledge*. Support (subsidy, fiscal arrangements) for research projects or research institutes; These support mechanisms are not oriented to diffusion but to increase the knowledge base of knowledge suppliers and firms with R&D facilities.

2. *support for intermediary organisations*. Setting up an infrastructure to support knowledge flows and linkages between firms and between firms and technology suppliers is an important mechanism to increase the distribution of knowledge. However an assessment of the quality of these infrastructures and their effect on competitiveness is a very difficult task. Some parts of this infrastructure are public, others are public-private partnerships or entirely private. An example of the latter are trade associations performing a role in upgrading their member firms through knowledge exchange. As we are discussing the role of public policy in this section, the focus is on public and public-private partnerships.

3. *diffusion oriented instruments*. Under these support mechanisms we understand policy programmes with diffusion or technology transfer as an immediate objective. This could be encouraging the flow of tacit knowledge, innovation management practices, demonstration projects, the application of particular technologies by firms or consumers.

²⁴ The key sources of available data can be found in:

- Regular innovation policy reviews and White Papers from the responsible Ministries (Ministry of Economic Affairs, Competing with Knowledge(1993), Knowledge in Action (1995);
- Evaluation studies on particular diffusion oriented instruments or support services (BEA, Evaluatie Innovatiecentra; Limpens, Technology Demonstration and Application Centres);
- Studies on innovation policy with particular interest in diffusion (Bureau Bartels, 1995).

For the purpose of this study we will focus on initiatives taken in the second and third category. A listing of policy initiatives oriented to diffusion and distribution of knowledge compared to the generation of new knowledge, allows an assessment of the degree of commitment. Included are those initiatives with a clear diffusion oriented character. Of course there are programmes with a mixture of both generating new knowledge and supporting its diffusion. An example of the latter is the Subsidieregeling Programmatische Bedrijfsgerichte Technologiestimulering (PBTS), a subsidy instrument for thematic, firm-related technology. Within this instrument both research projects and demonstration projects can be subsidised. In those cases that diffusion is not an objective in itself but a last phase in an essentially R&D oriented setting a policy programme is not included in the overview.

Since 1991 the Ministry of Economic Affairs, the government agency responsible for innovation policy, had the following programmes that can be designated as diffusion oriented:

Support for intermediary organisations

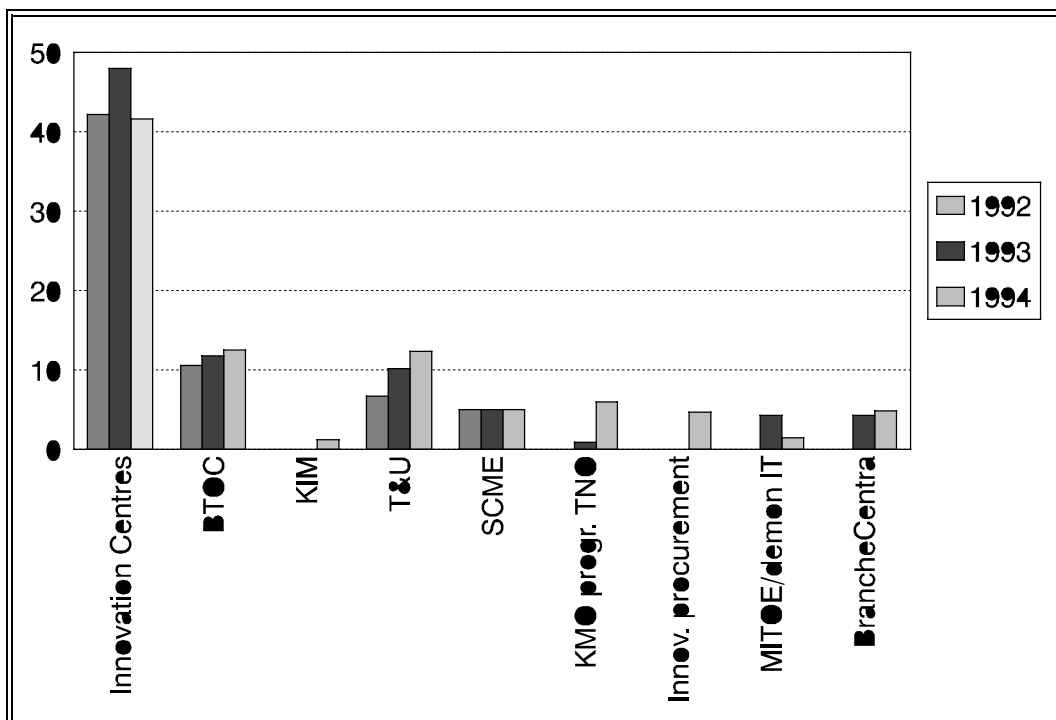
- Innovation Centres (Network); This is a network of 18 regional centres consulting SMEs regarding access to technological knowledge, improving quality and so forth. Instead of developing technological expertise themselves, these centres form a linkage mechanism between firms and the wide range of innovation support structures.

Diffusion oriented instruments

- Research for collectivities (BTOC): f 10 million in 1991 and f 11,8 in 1993
- KIM - Kennisdragers in het Midden en Kleinbedrijf (Tacit-knowledge carriers in SMEs): a programme which subsidises SMEs (< 50) to employ a university graduate for at least one year.
- T&U - Toeleveren en Uitbesteden (Contractor - Suppliers Scheme): stimulating relations between contractors and suppliers and with the objective to upgrade the suppliers.
- TNO-SME programme: to enhance diffusion of technological knowledge to SMEs. Budgets: f 2,8 million in 1994 and 1995.

Figure 3.14 shows the budgets allocated to these diffusion oriented policy instruments:

Figure 15. *Innovation policy instruments focusing on the distributive power (Source: various reports from the Ministry of Economic Affairs)*



The graph shows a wide scope of initiatives and actions with a diffusion oriented character. However if we compare these budgets with total expenditures for innovation related policy by the Ministry of Economic Affairs the share is relatively small. For 1993 for example, the total innovation policy budget was 920,4 million of which approximately 75 million can be earmarked as diffusion oriented (Dutch Ministry of Economic Affairs, 1993).

In the recent years of Dutch innovation policy three policy issues have been central themes in the debate:

- the decreasing R&D expenditures in firms;
- the unsatisfactory interaction between the S&T infrastructure and industry;

- the Information Super Highway.

In a 1995 White paper it was announced that R&D support would shift towards clusters of firms and knowledge centres rather than individual firms or research centres²⁵. The philosophy behind this is the promotion of increased collaboration amongst firms and between firms and technology suppliers. Such an approach acknowledges the importance of networking and interfirm linkages as a vehicle for the diffusion of knowledge. The design of this policy in terms of measures is still to be defined in details.

Thus summarising we can conclude that there is a clear trend towards more diffusion oriented national innovation policies, however in terms of allocated budgets, the balance is still in favour of research related support aimed at generating new knowledge rather than its distribution.

3.8 Diffusion power and firm' competitiveness

This link reflects the economic impact of the knowledge using activities, increasing firms' competitiveness (improving factor productivity, increasing share of (re)new(ed) products and services, introducing new production processes, creating higher added value, increasing turnover and improving export performance). However, a firm' technology knowledge base and absorptive capacity is only one of the factors that affects a firm' competitiveness. It would be interesting to see to what degree firm competitiveness is explained for by the distribution power of a NIS.

A high distribution power of a NIS is thought of as contributing to the competitiveness of firms reflected in improved factor productivity, share of (re)new(ed) products & services and production processes, higher added value, increased turnover and improved export performances. Linking the various forms of knowledge diffusion within a NIS on the one hand and their economic impact in terms of competitiveness, innovation, export performance and profitability on the other hand, however, is one of the most difficult methodological issues to solve in the NIS-project²⁶. Assessing this correlation needs econometric research on high quality data bases. Although some economic variables at the level of clusters are included in Annex I (table D1 and D2), this methodological issue has not been solved in this pilot study.

As indicated in section 3.3.3. the outcomes of research on the impact of R&D-collaboration and technology transfer on innovation performance at branche of industry level are still ambiguous (Brouwer & Kleinknecht, 1996).

Recent work of Kleinknecht (1995) based on CIS-data illustrates that Dutch firms not only perform badly on R&D-input indicators but also on R&D-output-indicators, notably with respect to products new to the sector (i.e products not earlier introduced by competitors). Percentages of firms which sell these products, as well as the shares in firms' total sales of these products are lower than in other countries.

²⁵ White Paper Knowledge in Action, Ministry of Economic Affairs, Ministry of Education Culture and Science and Ministry of Agriculture and Fisheries, 1995.

²⁶ Recent work of CBS (van Leeuwen & Nieuwenhuizen) based on analysis of micro-data for example indicates a correlation between R&D-efforts and firms' productivity.

4. Evaluation and conclusions

4.1 Introduction

In research and policy there is a growing need for information on the impact of knowledge diffusion and technology transfer on the economic performance of national economies. Not only the investments made in the production of new knowledge, but also improving the distribution and use of the existing knowledge base might contribute considerably to competitiveness and economic growth. This explorative study aims at testing the robustness and operationalising the notion of distribution power of NIS, as originally designed by the OECD. This report presents the results of a first attempt to map and measure diffusion and the distribution power of NIS. This is a challenging, but also an ambitious task. Therefore this pilot study for the Netherlands does not provide final answers to the questions raised in the OECD-project.

Apart from our critical appraisal of the usefulness of the notion of distribution power and the conceptual framework based on this notion, we hope this study points at some promising avenues for both innovation researchers as well as technology policy-makers.

In the following sections we formulate some conclusions regarding the usefulness of the concepts proposed (4.2) and the possibilities to empirically cover the notion of distribution power for the Dutch case (4.3). We further point at a selection of indicators that would be helpful in measuring distribution power (4.4). Finally we formulate some tentative policy implications (4.5).

4.2 Concepts and methodological issues

The notion of distribution power refers to the accessibility and dissemination of scientific and technological knowledge throughout an economy. This is an important complement to studies analyzing the impact of generating new knowledge on nations' economic performance. However, actually measuring such a broad concept proves to be an ambitious and difficult task. We developed a heuristic conceptual framework in which we:

- concentrated on scientific and technological knowledge;
- differentiated between knowledge stocks (i.e. international science knowledge base, firms technology knowledge base) and knowledge flows between actors within the NIS,
- related knowledge flows within the NIS to competitiveness;
- emphasized knowledge flows between formal knowledge producing **and using** agents (HEIs, RTOs, firms) as well as the role of bridging institutions and policy-making;
- differentiated between three categories of knowledge carriers i.e. human-embodied, disembodied and material-embodied knowledge flows.

As we have already noted above the concept of distribution power in a NIS correctly points at some issues which have probably been too long neglected by innovation researchers, statisticians and policy-makers alike, that is the importance of diffusion for competitiveness and economic growth. We used both the notion of distribution power as well as the conceptual framework to systematically map the available data and statistics, using clusters as much as feasible as a reference category. In our actual analysis of the data and indicators that were available, we clearly focused on the knowledge distribution in a NIS (box C, figure 2.1) and on the interactions between knowledge using and knowledge producing agents.

Apart from practical difficulties to collect all the data and indicators needed to assess the distribution power of a NIS, some methodological and conceptual bottlenecks and pitfalls problems were experienced. These will be dealt with first, before we will discuss in general terms the data and indicators used (section 4.3).

In the first place knowledge distribution is primarily related to flows of knowledge between various actors. The distribution power of a NIS is characterized by the effectiveness of these knowledge flows. However,

how knowledge distribution within one organisation or firm takes place, is hardly covered. At the same time it can be noted that in the Netherlands most of the R&D-activities are actually carried out within individual firms. The level to which knowledge within individual firms and organisations is distributed is probably as important as the exchange of knowledge between actors within a NIS. When measuring the distribution power of a NIS, both indicators on the exchange of knowledge between various actors as well as on the intra-firm knowledge transfer are needed.

Secondly, the causal relationship between the interactions in the NIS and performance indicators representing competitiveness is the most difficult methodological issue raised in this project. Developing indicators on knowledge flows within the NIS only makes sense if you can finally relate these figures to performance indicators. However, from a methodological-technical viewpoint this relationship is hard to isolate and requires high quality data sources that are not yet available. National competitiveness is influenced by a large number of factors.

We further experienced that some indicators as proposed in the OECD-framework are ambiguous. It is for instance hard to assess whether high levels of R&D cooperation by definition contributes to higher diffusion levels of knowledge. Similarly, one could question whether RTOs' research should preferably be complementary to R&D performed in the private sector or that some overlap is needed to ease the exchange of knowledge. The importance of private consultancies and technical engineering could be explained as a welcome addition to knowledge exchange initiated by RTOs or HEIs, or as a sign that these type of actors do not function well. These type of causal links need to be researched more thoroughly first, or at least some hypotheses formulated, before new data are collected on a large scale.

Another problem that is probably inherent to exploratory research is the risk of collecting all sorts of data, without much sense of direction. In practice there are indeed numerous ways to distribute knowledge. However, although this limited selectivity in collecting data and indicators might be necessary in a first pilot phase, eventually a selection of indicators and possibly even the construction of a composed diffusion index is needed.

In this project we mainly focused on available data and statistics, while to answer the questions as posed in the NIS-project requires a combination of quantitative indicators and qualitative analysis (to describe the processes at work). Up till now the quantification has been emphasized, but we think that a more balanced combination of quantitative indicators and qualitative information is needed to answer these questions.

4.3 Data and indicators

Distribution power cannot be measured directly. Most of the available sources are not designed for measuring distribution power and quite a lot of data are still collected within the traditional framework of the linear model e.g. R&D statistics, patents and bibliometric data. This implies that most data and indicators were available on the available knowledge bases (Box A and B, figure 2.1) and on economic performance in general (Box D, figure 2.1). As expected, we experienced that 'throughput' data and indicators on processes of knowledge exchange were less well established.

Nevertheless, on some linkages interesting material is available, mostly from the Dutch Statistical Office and from the Dutch CIS-survey as performed by Kleinknecht cum suis. Regarding the type of knowledge carriers that were less well covered we found that especially on human-embodied knowledge flows data and indicators are missing almost completely. Data on disembodied and material embodied knowledge flows are available to a greater extent. A more detailed overview of the data collected is included in the statistical annex (Annex I)

On knowledge distribution practices in the *business sectors* most data were available. Matrices on intermediate innovation flows and intercluster R&D flows seems promising to differentiate in the way technology and scientific knowledge is distributed in and between the various mega-clusters. However, we

should be careful to interpret this flows. In general most indicators are still very R&D based. More information on especially human-embodied knowledge flows are needed.

Data on knowledge distribution practices in which *HEIs* and/or *RTOs* are involved are less well established, partly because accounting and reporting of these sectors is more troublesome. For the information that was available (especially the importance of HEIs and RTOs for innovation performance of business firms), the picture differs considerably for the various mega-clusters. Different economic activities and different production chains seem to rely on different (mixtures of) mechanisms for the diffusion of scientific and technological knowledge. For assessing the role of HEIs and RTOs we had to rely on more traditional input-output data, mainly measuring material-embodied knowledge flows. More information on human-embodied and disembodied technology flows would have been helpful here.

Information on processes of knowledge distribution in which *bridging institutions* are involved is relatively scarce. An interesting outcome is that the activities of Dutch Innovation Centres, particularly established to promote diffusion of scientific and technological knowledge, seem to be aimed more at especially science and technology based clusters. STW has developed some interesting ways to measure user-involvement. Although some data were available, the variety of bridging institutes and bridging practices is much more extensive than reported here. We especially consider some of the professional services like engineering companies and business consultants to be an important category of agents along which knowledge is distributed. If we are to relate the activities of the bridging institutions to their contribution to innovation performances and finally competitiveness, we need to a better insight into the effectiveness of these institutions.

Regarding the *role of policy-making* in knowledge distribution we concluded that although the approach adopted in technology policy seem to suggest a clear trend towards more diffusion oriented innovation policies, this trend has not yet resulted in change of the budgets allocated, the balance still is in favour of research related support aimed at generating new knowledge, rather than its distribution.

There clearly are some considerable gaps in the available statistical data. These are for instance no or hardly any data available on relevant themes such as mobility of R&D personnel; importance of interaction between users and producers; importance of the property right system; participation in standardisation activities and the degree to which the university knowledge base is used by business firms. Identifying regular statistics on the themes like the specific (Dutch) advantages in transfer and engineering sciences; research cooperation within firms; learning taking place in relations between HEIs and firms and finally R&D cooperation and other forms of cooperation between universities and industry, proved to be difficult as well. At best some irregular statistics or case study material was available.

A more detailed overview of the zones in which data and indicators are clearly lacking as well as themes and topics that are not well covered in neither research nor statistics we refer to annexes II and III.

4.4 Selection of indicators

Although available data and statistics are limited, quite a few indicators were collected (see Annex I). However, to keep the task of measuring distribution power manageable a more limited set of indicators that measure distribution power is needed. In Box 4.1 and box 4.2 a selection of indicators that were collected during this pilot are represented. Most of these indicators are already available, although not all at the level of clusters. The quality of these indicators was discussed during a national expert meeting in which 9 experts from various organisations participated (for details see Annex V).

The participating experts were also asked to come up with some new indicators to measure aspects of distribution power. In total 16 new proposals were added to the selection made by the TNO-team. Some of them are shown in box 4.3.

Not all of these added 'indicators' are yet well operationalised, but they at least give an indication of the sort of indicators that we should think of when trying to assess quantitatively the notion of distribution power.

These three rather diverse sets of indicators (Boxes 4-1, 4.2 and 4.3) were subsequently combined in one longlist of 37 indicators. After having discussed the individual indicators the experts were asked to rate the indicators on quality (using a 10-point scale). Indicators with the highest scores would be most suited to measure (aspects of) distribution power. The top-15 is given in Box 4.4. The outcome is not representative, but indicate that indicators on R&D cooperation between the various actors as well as mobility indicators score quite well. Participation in formal R&D networks also scores well. Indicators 10-15 are somewhat diffuse.

Finally experts were asked to indicate which of the indicators included in this top-15 were most suited to be included in a module on diffusion of the questionnaire of the Dutch Statistical Office. Here measurability is the argument to give an indicator a high score. Although the ranking is somewhat different it is remarkable to see that the top-8 (bold, number in brackets indicating the ranking on this question) more or less resembles the ranking on quality of the indicators.

**BOX 4.1: MEASURING KNOWLEDGE FLOWS BETWEEN ACTORS:
SELECTION AS PROPOSED BY TNO ON THE EXPERT
MEETING**

- * *Overall indicators*
 - Percentage of business enterprises with R&D cooperation in the Netherlands or abroad
 - Percentage of business enterprises using external sources of knowledge
 - Outsourced R&D as a percentage of total R&D costs
 - Importance of various information sources for innovation
- * *Intrafirm knowledge flow indicators*
 - Percentage of business enterprises with intrafirm R&D cooperation in the Netherlands or abroad
 - Percentage of personnel that attended company or external training programmes in 1992
- * *Interfirm knowledge flow indicators*
 - Percentage of business enterprises with interfirm R&D cooperation
 - Intermediate Innovation Flow matrix
 - R&D flows matrix, breakdown
 - Technology Balance of Payments
- * *HEIs - firms knowledge flow indicators*
 - Percentage of business enterprises with R&D cooperation with HEIs
 - Income from privately financed contract research at Dutch universities
 - Mobility of R&D personnel from HEIs towards industry
- * *RTOs - firms knowledge flow indicators*
 - Percentage of business enterprises with R&D cooperation with RTOs
 - Income from privately financed contract research at Dutch RTOs
 - Mobility of R&D personnel from RTOs towards industry

BOX 4.2: MEASURING THE ROLE OF BRIDGING INSTITUTION AND POLICY-MAKING ON THE DISTRIBUTION OF KNOWLEDGE: SELECTION AS PROPOSED BY TNO ON THE EXPERT MEETING

- * *Indicators on the role of bridging institutions*
 - Percentage of business enterprises with R&D cooperation induced by bridging institutions
 - Use of various categories of bridging institutions by firms
- * *Indicators on the role of governmental policies*
 - Percentage of business enterprise expenditure on R&D financed by government
 - Budgets allocated to diffusion oriented policy instruments
 - Effectiveness of various diffusion oriented policy instruments

BOX 4.3: SOME OF THE INDICATORS SUGGESTED DURING THE EXPERT MEETING

- * Percentage of turnover generated with innovative products (new for the enterprise/new for the branche of industry; questions in CIS-survey)
- * Inflow/outflow of engineers in business enterprises, especially SMEs (source/destination)
- * Percentage of R&D personnel active in mixed project teams (i.e. including non-R&D personnel)
- * Use of CAD/CAM in industry (or other specified high tech equipment)
- * Match between fields of knowledge covered by HEIs and fields of knowledge covered by industry
- * Participation of HEIs and firms in joint formal R&D networks
- * Match between fields of knowledge covered by RTOs and fields of knowledge covered by industry
- * Number of successful (R&D) partnerships arranged by bridging institutions

BOX 4.4: INDICATIVE SELECTION OF USEFUL INDICATORS FOR MEASURING DISTRIBUTION POWER

- 1. Percentage of business enterprises with R&D cooperation with HEIs (2)**
- 2. Percentage of business enterprises with R&D cooperation with RTOs (5)**
- 3. Mobility of R&D personnel from RTOs towards industry (6)**
- 4. Percentage of business enterprises with R&D cooperation in the Netherlands or abroad (1)**
- 5. Mobility of R&D personnel from HEIs towards industry (4)**
- 6. Participation in collective formal R&D networks (new) (7)**
- 7. Inflow/outflow of engineers in business enterprises, especially SMEs (new) (3)**
8. Percentage of business enterprises with interfirm R&D cooperation
- 9. Importance of various information sources for innovation (8)**
10. Income from privately financed contract research at Dutch universities
11. R&D flows matrix, breakdown
12. Technology balance of payments
13. Match of fields of knowledge covered by RTOs and fields of knowledge covered by firms (new)
14. Income from privately financed contract research at Dutch RTOs
15. Budgets allocated to diffusion oriented policy instruments

4.5 Policy implications

This explorative study clearly focused on identifying and analyzing a set of relevant indicators to assess the distribution power of the Dutch NIS. We concentrated on identifying indicators that could measure the exchange of scientific and technological knowledge between (groups of) actors and institutions. Apart from a limited availability of data and indicators on some of the linkages or for some of the knowledge carriers identified, we had to cope with some severe conceptual problems (see section 4.2). Probably the most problematic one is how to relate the characteristics of the knowledge flows between actors in the NIS, indicating strengths and weaknesses in the distribution power, to performance or competitiveness indicators. Competitiveness is influenced by numerous factors and isolating the influence of diffusion on competitiveness raises quite complex methodological and practical questions. Solving these questions goes far beyond the purpose and possibilities of this study. As a consequence the central empirical question i.e. the relation between distribution power of NIS and competitiveness cannot be answered yet.

Nevertheless, some policy implications that might prove to be helpful can be pointed out.

In the first place it should be noted that the approach as adopted in this study starts from the assumption that distribution power is mainly influenced by the exchange of knowledge between different types of actors, while abstracting more or less from the exchange of knowledge within individual organisations. Technology policies aimed at increasing the distribution power therefore should also explicitly take into account the way in which knowledge is distributed and used within individual companies (knowledge management)

Secondly, it can be concluded that the way and degree to which scientific and technological knowledge is diffused, differs greatly for the various mega-clusters identified. The cluster perspective revealed the importance of inter-industry flows of knowledge. There are indications that we can discern between knowledge generating clusters, knowledge adopting clusters and more self sufficient clusters. This means that apart from R&D efforts of the various clusters themselves, the ability to profit from R&D performed in other clusters (absorptive capacity) is an important factor contributing to competitiveness. Therefore, also in policy-making this absorptive capacity of clusters and individual firms should be paid attention to.

Further, it can be observed that, although in recent science and technology policy-making the attention for strengthening the links between the public knowledge infrastructure (HEIs and RTOs) and industry has increased, the notion of transfer capacity might help to systematically score these institutions on their ability to distribute more effectively and efficiently the knowledge they dispose of.

In a similar vein the effectiveness of bridging institutions and best practices in technology transfer need to be assessed, i.e. to what degree are they successful in stimulating knowledge exchange between the various actors.

Another clear policy relevant outcome of this pilot study is that on some issues there obviously is a need to collect new data and possibly develop some new policy-initiatives. This is most clearly the case for human mobility, R&D cooperation and formal R&D networks. Some indicators were identified on these topics and they could possibly be included in the next innovation survey, preferably in a separate distribution power or diffusion module. Moreover, linking the Dutch Innovation Survey to the National Accounts (Technology Module in the National Accounts) should importantly increase the possibilities for analyzing and answering the questions raised in this project. After some key indicators have been defined, it is worth to consider developing a composite diffusion index. Especially policy initiatives aimed at stimulating the mobility of R&D personnel could prove to be a very effective way to stimulate knowledge diffusion.

BOX 4.5: THEMES AND TOPICS ON WHICH MORE INSIGHT IS NEEDED

- * Role and importance of transfer sciences
- * Intensity and specialisation of HEIs and RTOs patenting activities
- * Accessibility and ability to use (inter)national science knowledge base (e.g. availability of electronic infrastructures)
- * Professional careers of R&D personnel
- * Number and technological specialisation of university related research institutions primarily working for industry
- * Temporal exchanges and mixed research positions of R&D personnel
- * Use of consultants and technical engineering firms in R&D-activities
- * Role of bridging institutions and policy-making in building formal and informal R&D networks
- * Mobility of R&D-personnel between companies
- * Participation in national and international standardisation activities

A more extensive overview of themes and topics that require more attention in both research and policy-making is included in Annex III.

Literature

Adviesraad voor het Wetenschaps- en technologiebeleid, *Technici en onderzoekers: kwaliteit en kwantiteit*, AWT-advies nr. 11, Den Haag, 1992

Adviesraad voor het Wetenschaps- en technologiebeleid, *Technologiebeleid en economische structuur*, AWT-advies nr. 16, 1994

Algemene Rekenkamer, *Derde-geldstroomactiviteiten bij universiteiten*, Tweede Kamer, vergaderjaar 1994-1995, 24 100, nrs. 1-2, 's-Gravenhage, 1995

Archibugi, D., P. Cohendet, A. Kristensen & K.A. Schäffer, *Evaluation of the Community Innovation Survey (CIS) - Phase I*, DG XIII EIMS, EIMS Publication no. 11, Luxembourg, 1995

Archibugi, D & M. Panta, *The technological specialization of advanced countries. A report to the EEC on international science and technology activities*, Kluwer Academic Publishers and the Commission of the European Communities, Dordrecht, Luxembourg, 1992

Berendsen, H., *De arbeidsmarkt voor onderzoekers 1990-2010*, Ministerie van Economische Zaken/Researchcentrum voor onderwijs en arbeidsmarkt, BTE-studie 13, Maastricht, 1991

Bessant, J. & H. Rush, *Building bridges for innovation: the role of consultants in technology transfer*, *Research Policy* 24, pp. 97-114, 1995

- Bianchi, P., Lee Miller, *Systems of innovation and the EC policy making approach*, paper for the workshop Systems of Innovation (Sprint/Fast), Bologna 5-6 October 1992
- Boekholt, P. *Clusters in de metaalektro*, in: D. Jacobs & A.P. de Man, *Clusters en Concurrentiekracht, Naar een nieuwe praktijk in het Nederlandse bedrijfsleven?*, Alphen aan den Rijn, 1995
- Boekholt, P., *The European Community and innovation policy: reorienting towards diffusion*, Thesis University of Aston/STB-TNO, Birmingham, 1994a
- Boekholt, P. *Methodology to identify regional clusters of firms and their needs*, presentation for the RITTS workshop, CEC, Luxembourg, 30-31 May 1994b
- Boekholt, P., Fahrenkrog, G., Jacobs D., Howells, J., *Clusters and Networks of Innovative SMEs*, Background paper for the Policy Forum Workshop, Luxembourg, CEC DG XIII, SPRINT/EIMS, December 1993
- Brouwer, E. & A. Kleinknecht (1996), Firm size, small business presence and sales of innovative products: a micro econometric analysis, in: *Small Business Economics* (to be published)
- Brouwer, E. en A.H. Kleinknecht, *Innovatie in de Nederlandse Industrie en Dienstverlening (1992)*, Ministerie van Economische Zaken/STB-TNO, BTE-studie 27, Den Haag, 1994
- Brouwer, E. en A.H. Kleinknecht, *Technologie en de Nederlandse concurrentiepositie. Een onderzoek op micro- en meso-niveau*, Ministerie van Economische Zaken, BTE-studie 23, Den Haag, 1991
- Buck Consultants International, *Evaluatie Universitaire transferpunten*, Nijmegen, 1988
- Bulthuis, R., Morsink, R.L.A. en J.A. Velt, *Internationale overdracht van technologische kennis. De positie van Nederland*, BTE-studie 11, Ministerie van Economische Zaken, Den Haag, 1991
- Bureau Bartels, *R&D netwerken van Nederlandse bedrijven*, Utrecht/Assen. Onderzoek uitgevoerd in opdracht van het Ministerie van Economische Zaken, Utrecht/Assen, 1994
- Butter, F.A.G. den & F.J. Wollmer, *Endogenising technical progress in the Netherlands*, BTE-studie no. 22, Ministerie van Economische Zaken, Den Haag, 1993
- Caniëls, M. en B. Verspagen, 'R&D-intensiteit bij bedrijven: hoopvol of zorgwekkend?', *Economische Statistische Berichten*, 7/10/1992, pp. 978-979
- Cainarca, G. C., Colombo, M. G. & S. Mariotti, An evolutionary pattern of innovation diffusion. The case of flexible automation, *Research Policy* 18, 1989, no. 2, April, pp.59-86
- CBS, various regular and irregular statistics
- Commissie Bedrijfsleven - TNO, *Kennis van Zaken. Voorwaarden voor een effectief functioneren van TNO*, 1995
- David, P.A. & D. Foray, Accessing and expanding the science and technology knowledge base, in *STI Review*, no. 16, 1995, pp. 14-68
- Davies, S., *The diffusion of process innovations*, Cambridge University Press, 1979

- Dijk, A., J. Frankfort, T. Horn en K. Vos, *Wetenschaps- en Technologiebeleid in Nederland*, DSWO Press, Leiden, 1993
- Dosi, G., Technological Paradigms and Technological Trajectories: A suggested interpretation of the determinants and directions of technical change, *Research Policy*, vol. 11, 1982, no. 3, pp. 147-162
- Dosi, G., Ch. Freeman, R. Nelson, G. Silverberg & L. Soete, *Technical change and Economic Theory*, London: Pinter Publishers, 1988
- Engelsman, E.C. en A.F.J. van Raan, *Nederland in de moderne technologie: een positiebepaling op basis van octrooien*, Ministerie van Economische Zaken, BTE-studie 5, Den Haag, 1990
- Ergas, H., *Does Technology Policy Matter?*, CEPS Papers No. 29, Brussels: Centre for European Policy Studies, 1986
- European Commission, *The European Report on Science and Technology Indicators 1994*, DG XIII, Luxembourg, 1994
- Faasse, P., *Basis data on postgraduate research training*, Amsterdam. Koninklijke Academie voor Wetenschappen, 1993
- Freeman, Ch., Formal Scientific and Technical Institutions in the National System of Innovation, In: Lundvall, B-Å, *National Systems of Innovation, Towards a Theory of Innovation and Interactive Learning*, Pinter Publishers, London, 1992
- Freeman, Ch., *Technology policy and economic performance, Lessons from Japan*; SPRU, Pinter Publishers, London, 1987
- Freeman, Ch., *The economics of Industrial Innovation, London*: Pinter publishers, 1982
- Freeman, Ch. & C. Perez, *The diffusion of Technical Innovations and Changes of Techno-economic Paradigm*, Paper presented for the Conference on Innovation Diffusion, Ca' Dolfin, Dorsoduro 3825/E, Venice, 17-22 March, 1986
- Fruytier, B., K. ten Have en V. Timmerhuis, *Personele mobiliteit en kennistransfer. Een terreinverkenning in opdracht van het Ministerie van Economische Zaken ten behoeve van de oprichting van een mobiliteitsbureau voor R&D laboratoria, universiteiten en onderzoeksinstituten*. Rapport IVA, Tilburg, 1994
- Geurts, T., H. Mieras en J. van Steen, *TWIN. Technologie- en wetenschapsindicatoren*, Ministerie van Onderwijs en Wetenschappen/Ministerie van Economische Zaken, Zoetermeer/Den Haag, 1991
- Holland, C., *Technologiebeleid in de regio. Een inventarisatie voor het Ministerie van Economische Zaken*, Consultium, juni 1994
- Horn, T.C.M. en T. Langendorff, *Science and technology indicators 1991*, Achtergrondstudie Adviesraad voor Wetenschap en Technologie nr. 1, 1991
- Huisman, H, R. van der Meijden, F. Prakke, *The impact of EC R&D policy in the Netherlands, industrial participation*, STB/94/026, TNO Centre for Technology and Policy Studies, Apeldoorn, 1994
- IMD, *The World Competitiveness Report 1994*, Lausanne, 1994

- IMD, *The World Competitiveness Report 1993*, Lausanne, 1993
- ING-bank, economisch Bureau, *Miljoenennota MKB*, Amsterdam, 1994
- Innovatie Centrum Netwerk, Centraal Kantoor, beschrijving KIM-regeling
- Jacobs, D. & A.P. de Man, *Clusters en Concurrentiekracht*, Naar een nieuwe praktijk in het Nederlandse bedrijfsleven?, Samson, Alphen aan den Rijn, 1995a
- Jacobs, D. & A.P. de Man, Clusters, industriebeleid en ondernemingsstrategie, *Economisch Statistische Berichten*, 22/2/1995, 1995b
- Jacobs, D., P. Boekholt & W. Zegveld, *De economische kracht van Nederland*, Den Haag, SMO, 1990
- Jacobs, D., *The policy relevance of diffusion*, Ministerie van Economische Zaken/STB-TNO, BTE-studie 8, Den Haag, 1990
- Kleinknecht, A.H., *Innovatieve producten en R&D-samenwerking. Nederland vergeleken met vijf andere landen*, ESI-VU Amsterdam, Amsterdam, 1995
- Kleinknecht, A. & J.O.N. Reijnen, More evidence on the undercounting of R&D in small firms, in *Research Policy*, Vol. 20, 1991, pp. 579-587
- Kleinknecht, A., T.P. Poot & J.O.N. Reijnen, Formal and informal R&D and firm size: Survey results from the Netherlands, in: Z.I. Acs & D.B. Audretsch (eds.), *Innovation and technological change: an international comparison*, New York, 1991, p. 84-108
- Kleinknecht, A.H., J.O.N. Reijnen en J.J. Verweij, *Innovatie in de Nederlandse Industrie en Dienstverlening. Een enquête-onderzoek*, Ministerie van Economische Zaken/STB-TNO, BTE-studie 6, Den Haag, 1990
- Kline, S.J. & N. Rosenberg, An overview of innovation, In: Landau, Ralph, and Rosenberg, (eds), *The positive sum Strategy: Harnessing Technology for Economic Growth*, The National Academy Press, Washington D.C., 1986
- Krugman, P., *Geography and trade*, Leuven University Press & Cambridge Mass., MIT Press, Leuven, 1991
- Kuijper, J., W. van Dalen en B. Verspagen, *Het belang van de technische en natuurwetenschappen. Een inventarisatie*, Overlegcommissie verkenningen, Amsterdam, 1994
- Kuipers, S.K, R.L.A. Morsink en R.J. Mulder, Contouren van een kennisbeleid, in: *Economisch Statistische Berichten* 12/4/1995, 1995, pp. 353-357
- Limpens, I., Beelen, E., Verspagen, B.; *Technology policy in eight European countries: a comparison*, MERIT, Maastricht, 1992
- Limpens, I. en W. van Dalen, *Technology demonstration and application centres. The Netherlands*, TNO Centre for Technology and Policy Studies, december 1994
- Limpens, I. en Th.C.M. Weijers, *Het maatschappelijke draagvlak voor technologie. Een discussiestuk*, STB/94/004, STB Studiecentrum voor Technologie en Beleid, Apeldoorn, 1994
- Lundvall, B. A. (ed), *National Systems of Innovation, Towards a Theory of Innovation and Interactive Learning*, London: Pinter Publishers, 1992

- Lundvall, B.A., *Innovation as an interactive process: from User-producer interaction to the national system of innovation*, in: G. Dosi et al., *Technical change and economic theory*, London, Pinter Publishers, 1988
- Meijden, van der, R., H. Huisman, D. Jacobs en I. Limpens, *Kennisbronnen in het MKB. Een proefonderzoek over diffusiepatronen in drie sectoren*, STB-TNO, Apeldoorn, 1994
- Ministerie van Onderwijs en Wetenschappen, *Feiten en Cijfers 1993*, Zoetermeer 1993
- Ministerie van Onderwijs, Cultuur en Wetenschappen, *Feiten en Cijfers 1995*, Zoetermeer 1995
- Ministerie van Onderwijs en Wetenschappen, *Ontwerp Hoger Onderwijs en Onderzoek Plan 1994*, Zoetermeer, 1993
- Ministerie van Onderwijs en Wetenschappen, *Speur- en Ontwikkelingswerk in Nederland: Beleid, Financiering en Uitvoering*, Zoetermeer, 1992
- Ministry of Economic Affairs, *Indicators Science and Technology*, Technology Lecture 30/11/'94, Den Haag, 1994
- Minne, B., *Technologie en economie: de Nederlandse positie*, Research Memorandum no. 94, Centraal Planbureau, Den Haag, 1992
- Minne B., *Onderzoek, ontwikkeling en andere immateriële investeringen in Nederland*, CPB Onderzoeksmemorandum, Den Haag, 1995
- Moerdijk & van Oosten, *Uitbesteding van Research en Development door grote bedrijven in Nederland*, Rapport t.b.v. Ministerie van Economische Zaken, Mijdrecht, 1992
- Nasbeth, L. & G. F. Ray (eds.), *The diffusion of New Industrial Processes: An international study*, London: Cambridge University Press, 1974
- Nederlands Forum voor Techniek en Wetenschap, *Naar een betere benutting van kennis in de industrie*, 1994
- Nederlands Observatorium van Wetenschap en Technologie (NOWT), *Wetenschaps- en Technologie-indicatoren 1994*, MERIT/CWTS, Maastricht/Leiden, 1994
- Nelson, R. (ed.), *National Innovation Systems, A Comparative Analysis*, Oxford: Oxford University Press, 1993
- Nelson, R. R. & S.G. Winter, *An Evolutionary Theory of Economic Change*, Cambridge: Harvard University Press, 1982
- Nelson, R. R. & S.G. Winter, In search of Useful Theory of Innovation, *Research Policy*, 6, 1977, pp.36-76
- OECD working group on innovation and technology policy, *National Innovation Systems. Workplan for pilot case studies*, DSTI/STP/TIP (94)16/REV 1, Paris, 1995
- OECD, *Education at a glance*. OECD Indicators, Paris, 1995
- OECD, *Science and Technology Indicators*, Paris, 1994
- OECD, *Manual on the measurement of humana resources devoted to S&T* ("Canberra manual"), Paris, 1994

- OECD, *OECD proposed guidelines for collecting and interpreting technological innovation data* ("Oslo manual"), OECD, Paris, 1992
- OECD, *Technology and the Economy, The key relationships*, Paris, 1992
- OECD, *Technology and Productivity. The Challenge for economic policy*, TEP-programme, Paris, 1991
- OECD, *Proposed standard method of Compiling and Interpreting Technology Balance of Payments Data* ("TBP Manual"), Paris, 1990
- OECD, *TEP Background report*, Paris,
- Pavitt, K., Sectoral Patterns of technical change: Towards a taxonomy and a theory, *Research Policy* 13, 1984, pp. 343-373
- Peek, M.J.P.M. en J.A. van Dijken, *Groothandel en de diffusie van kapitaalgoederen*, Ministerie van Economische Zaken, BTE-studie 16, Den Haag, 1991.
- Porter, M., *The Competitive Advantage of Nations*, New York: Free Press, 1990
- Porter, M., *Competitive Advantage*, New York, Free Press, 1985
- Ramaekers, G.W.M. en J. Hoevenberg, *Technology indicators: population, labour and schooling. 1993 report*, Research Centre for Education and the Labour Market, University of Limburg, Maastricht, 1994
- Rosenberg, N., *Perspectives on technology*, Cambridge: Cambridge University Press, 1976
- Sakurai, N, G. Papaconstantinou & E. Ioannidis (1995), *The impact of R&D and technology diffusion on productivity growth: evidence for 10 OECD countries in the 1970s and 1980s*, Paper presented on the Effects of Advanced Technologies and Innovation Practices on Firm Performance: Evidence from Establishment and Firm Data, Washington 1-2 May, 1995
- Schaffers H. , *De Nederlandse kennisportfolio op het gebied van technische en natuurwetenschappen, rapport fase I*, rapportage tbv Overleg Commissie Verkenningen, TNO Studiecentrum voor Technologie en Beleid, 1995
- Scherer, F.M., Inter-industry Technology Flows and Productivity Measurement. In: *Review of Economics and Statistics*, 1982, pp. 627-634
- Schuyt, A. van der et al, *Publiek-private samenwerking in onderzoek*, Coopers & Lybrand en Consultium, Den Haag/Driebergen, 1994 (not public)
- SER, *Kennis en economie*, Rapport van de Commissie Economische Deskundigen over kennis en economie, nr. 4, Den Haag, 1995
- Slabbers, M. & B. Verspagen, *De Nederlandse Deelname aan Europese Framework Programmes, 1988-1994*. Rapportage voor het Ministerie van EZ op basis van de CORDIS-databank, MERIT, Maastricht, 1995.
- Slabbers, M. & B. Verspagen, *STEMMING 2. De Nederlandse technologische positie en de invloed van globalisering*, MERIT, Maastricht, 1994.

- Slabbers, M. & B. Verspagen, *STEMMING 1. Een beoordeling van de Nederlandse technologische positie op basis van kwantitatieve indicatoren*, MERIT, Maastricht, 1994.
- Smookler, J., *Invention and Economic Growth*. Cambridge, 1966
- Soete, L. & A. Arundel, *An integrated approach to European Innovation and Technology Diffusion Policy, A Maastricht Memorandum*, Brussels-Luxembourg: CEC, DG XIII, EUR 15090 EN, 1993
- Soete, L. en B. Verspagen, *METING 4: Convergentie en Divergentie in Technologie*, MERIT-rapport voor het Ministerie van Economische Zaken, Maastricht, 1992
- Soete, L. en B. Verspagen, *METING 3: Een overzicht uit de databank ter beoordeling van de Nederlandse Technologie- en Wetenschapspositie*, MERIT-rapport voor het Ministerie van Economische Zaken, Maastricht, 1992
- Stichting voor Economisch Onderzoek (UvA), *Innovatie in de Nederlandse industrie en dienstverlening (1992)*, BTE-studie 27, Ministerie van Economische Zaken, Den Haag, 1993
- STW, *Profiteren van Kennis. Balans van tien jaar STW-onderzoek. De utilisatie van STW-projecten die in 1981 en 1982 van start gingen*, 1993
- STW, annual report 1994, Utrecht, 1995
- Tilburg, J.J. van en C.M. Vorstman, *Ondernemen met technologie. Het ontstaan en de groei van nieuwe kennisintensieve bedrijven vanuit de Universiteit Twente*, Van der Meer & van Tilburg, maart 1994
- TNO, ECN, GD, MARIN, NLR, WL, *De waarde van kennis en technologie*, Den Haag, september 1994
- Verspagen, B., *Measuring inter-sectoral technology flows using a non-input-output based approach*, MERIT Research Memorandum 2/95-007, Maastricht, 1995
- Vrije Universiteit Amsterdam/FENEDEX, *Global Sourcing. Een onderzoek naar de verplaatsing van bedrijfsactiviteiten door Nederlandse bedrijven*, Amsterdam, 1994
- Vuorinen, P., *User-producer linkages in technological change*, Report from the Six Countries programme Conference on User-Producer relations in the innovation process, Espoo, Finland, November 26-27, 1992
- Wetenschapsbudget 1995*, Tweede Kamer der Staten-Generaal, vergaderjaar 1994-1995, 23965, nr.2
- Willems, E.J.T.A. en A. de Grip, *Jongeren en techniek. Studie- en beroepskeuzes, waardering en beeldvorming ten aanzien van techniek*, BTE-studie 26, Ministerie van Economische Zaken, Den Haag, 1994