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Absorbing External Knowledge for Innovation Success – Does the Recipe Work?

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Abstract

This paper examines empirically the theoretical relationship between external knowledge and innovation success. Special emphasis is posed on the effects that arise from various types of spillovers and how these effects are influenced by firm-specific absorptive capacities. The results of the microeconometric analysis based on German firm data on innovation suggest that firms can effectively use external R&D within their own innovation process, as long as they have access to the relevant knowledge flows and as long as they have built up sufficient absorptive capacities. Furthermore, the results stress the complementarity between own and foreign R&D. In contrast, lack of access to inter-industrial and international knowledge flows may result from informational barriers and ineffective inter-firm linkages.

JEL-Classification: O31, O32, O34, L13, L14**.**

I. Introduction

'We have installed listening posts abroad'. This was the reaction of Siemens-Chef Heinrich von Pierer during an interview in February 1999, when he was insinuated that his firm produces insufficient internal knowledge. According to him, innovative activities should not be confined on the knowledge produced inside the firm. He rather sees a crucial component of the recipe for innovative success in seeking for additional knowledge sources outside, for instance via cooperation with research institutes all over the world or via joint ventures with young and promising start-up firms in striving high-technology markets.

The example of Siemens reflects the ongoing discussion within the literature of innovation research and technological policy. Due to the public good characteristic of knowledge firms use knowledge without having to carry the costs of research and development (R&D). Thus, knowledge produced by one firm acts as an external effect on other firms, the so-called (technological) spillover effect. From a welfare point of view, spillovers are strictly positive. However, the threat for each firm that with its own research results it may even increase the market position of potential competitors this firm may be induced to invest less in R&D than is socially optimal. Technology policy then would come into place in order to internalise the R&D-reducing externality and thus, to generate sufficiently knowledge dissemination within the economy.

This internalisation argument in favour of an R&D-subsidy is based on the crucial assumption that external knowledge is used by other firms to the same degree that it is released by the knowledge producing firm. One additional reason for suboptimal diffusion of knowledge could be insufficient capacities on the part of the knowledge receiving firm, to absorb external knowledge. External knowledge may be to a high degree firm-specific knowledge, so that the costs of acquiring and using it would surpass the gains from it. These points would favour additional policy measures which aim at increasing the technology transfer between firms. To judge an adequate policy one first has to ask, whether firms are included in the (international) technology transfer, where information is exchanged via interpersonal contact and knowledge is transferred through investment and upstream-downstream relations. Given that firms are included in this technology transfer, one then has to ask whether these firms can use the external knowledge effectively in their own innovation process.

This analysis will review these questions by the help of a microeconometric analysis based on firm data on innovative activities. Thereby, special emphasis will be posed on the effects that arise from various types of spillovers and how these effects are influenced by firm-specific absorptive capacities. The analysis starts with a short introduction into the main theoretical aspects concerning spillover effects and absorptive capacities in chapter II. After elaborating on crucial methodological points in chapter III, the results of the microeconometric analysis will be presented in chapter IV. Chapter V will close with a final assessment of the role of technology transfer for firms and its consequences for technological policy.

II. Theoretical Considerations

1. Spillovers in Models of Patent Races

Spillovers arise whenever firms are not able to fully appropriate their research results, i.e., when the social return from research exceeds the private return. In recent studies of theoretical literature on innovation research, the effects of spillovers are analysed by models of patent races, due to the fact that – in reality – the innovation process is characterised by technological uncertainty. This technological uncertainty makes the aim to be innovative and thus the search for competitiveness a 'race' among competitors with time being a crucial component. In these setups, firms are simultaneously seeking for a particular innovation. All firms invest into R&D. However, assuming perfect patent protection only the firm who wins, i.e. the first firm succeeding in innovations, will reap the profits, while the others have losses due to the R&D they have been undertaking.

Reinganum (1989) explicitly models these realistic features. She assumes that firms may adjust the rate of knowledge accumulation to the progress of rivals which is characterised by the amount of time that has elapsed and by the firm's and the rivals knowledge stock. One can think of the model as follows: Two symmetric firms compete for an innovation, and every firm can influence its probability of innovation success by the choice of the appropriate R&D-investment. Additionally, both firms are informed about the technological progress of the rival. Thus, they act like Nash-players. From their information with respect to the rival's technological capacities, they can calculate the probability with which the rival firm succeeds in innovation. Given this probability, each firm decides on its own investment into R&D to maximise the expected payoff from innovation.

In the case of perfect patent protection, firms may overinvest into R&D in order to be first to innovate. This is especially the case with high competition on the research or the production stage. According to Reinganum (1989: 865), an increase in the number of firms will lead to overinvestment into R&D by each firm. Thus, increasing competition definitely will hasten innovations.

Whenever imperfect patent protection prevails however, the rate of knowledge accumulation may be suboptimal, and innovations may be delayed. Imperfect patent protection can take the form of simultaneous spillovers or ex post spillovers through imitation. In both cases, the underinvestment results from the fact that firms are not able to fully appropriate their R&D. In the case of imitation, this means that although the first firm who succeeds in its innovation will earn a high profit, another firm may still earn some profit, for instance by reverse engineering the winner's product and selling it at a lower price. In the case of simultaneous spillovers, the rival firm may benefit from the winner although the latter has perfect patent right on the innovation. There, underinvestment results in order to prevent knowledge spilling over to the competitor.

According to Reinganum (1989) however, spillovers do not necessarily prevent firms from investing into R&D. In contrast, as long as spillovers to the competitors are not too high, the possibility to use external knowledge may outweigh the external effect for the competitors[1]. Therefore, whether innovations will be hastened or delayed depends on the degree to which knowledge spills over to other firms and on the degree each firm can benefit from each other's knowledge.

2. Intra- Versus Inter-Industrial Spillovers

Therefore, there are two big 'ifs', which have to be fulfilled for external knowledge to be absorbed: First, firms have to have access to the relevant knowledge flows. This is equivalent to the question, to what degree knowledge actually spills over to other firms. Typically, firms are able to protect their knowledge to some degree by mechanism like patents or by the help of firm-specific mechanism like secrecy, time lead or long term contracts of qualified personnel. Thus, spillovers arise whenever firms are not able to fully protect their research results.

Furthermore, access to the necessary knowledge flows depends on the types of linkages between firms. With respect to the extent of spillovers and their effect on innovation or production of firms one has to distinguish between intra-industry spillovers in the sense of spillovers between firms acting on the same markets, and inter-industry spillovers in the sense of spillovers between firms which do not act as competitors, but rather complementary to each other. The crucial point determining the net effect of spillovers, is whether the markets where the different firms are acting are independent from or linked with each other. This is because of the relative importance of two counteracting effects of spillovers: the R&D-reducing externality as compared to the R&D-increasing productivity and the strategic spillover effect.

As long as firms compete with each other, i.e. as long as there are intra-industrial spillovers, firms will react to a lack of appropriability of knowledge by reducing their own R&D-investments. With high spillovers, this will even be the case despite otherwise strategic overinvestment in order to raise their own market shares at the costs of the competitors. In the case of inter-industrial spillovers this is not necessarily the case. In contrast, Peters (1999) emphasises that firms may even strategically increase R&D and thus induce spillovers to other firms in vertically linked markets where the output of one firms is a strategic complement for another. On the side of the knowledge receiving firm, the effect of spillovers is the same as in the case of intra-industrial spillovers: external knowledge leads to cost reduction, thus has a productivity effect on the receiving firm. However, on the side of the knowledge producing firm, there is – according to Peters (1999) - a strategic effect, which will be further on called 'spillback effect' due to the way it works: The upstream firm increases R&D in order to reduce the downstream firm's production costs. Increased production by the downstream firm may again induce higher demand for inputs produced by the upstream firm.

[1] This is even more the case whenever firms can use external knowledge from firms outside this model setup that do not compete, but are rather vertically linked with the firm under considerations. The respective effects are analysed in the next chapter.

However, no direct effect will arise whenever firms act on markets that are independent from each other[2]. The R&D-reducing effect does not arise since firms do not face the threat of competitors. The spillback effect does not arise, since the knowledge produced by the upstream firm is of no use for the downstream firm. At least, the spillback effect will not be sufficiently high to make firms induce strategical vertical spillovers.

Innovations are a function of the rate of knowledge accumulation, or like Peters (1999) calls it the effective R&D-investments. These effective R&D -investments z_i are determined by the internal R&D-investments and the external R&D from spillovers:

$$z_i = R_i + R_k + R_l \text{ , for i=1,..,n, l= 1,..,L.} \tag{1}$$

In more detail this can be written similar to Cohen and Levinthal (1989)[3]:

$$z_i = r_{ik} + \theta\left(\sum_{j \neq i} r_{jk} + \sum_j \sum_{l \neq k} r_{jl}\right). \tag{2}$$

The first term in equation (1) and (2) represents the internal R&D-investment of firm *i* in sector *k*. The second terms represents the spillovers. Intra-industrial spillovers R_k are represented by the sum of R&D invested by the firms *j* other than the firm *i* within the same sector *k*, multiplied by the degree to which these R&D-investments are public for the firm *i*, the spillover parameter θ. Inter-industrial spillovers R_l are represented by the sum of R&D-investments of all firms within the various sectors *l*, other than the sector *k* of the firm under consideration, again multiplied by the spillover parameter θ.

In consequence to the considerations above, the overall effect of spillovers on the rate of knowledge accumulation- and thus on innovations - depend on the relative effect of each type of spillovers. According to Peters (1999), the effective R&D-investment may increase in the case of linked markets. Then inter-industrial spillovers are high enough such that their positive, i.e. R&D-increasing productivity and spillback effects more than outweigh the negative, i.e. R&D-reducing external effect of intra-industrial spillovers. The ideal case for innovations thus would be high inter-industrial spillovers in the absence of intra-industrial spillovers.

3. Absorptive Capacity

Spillovers represent an external effect for other firms by increasing their productivity without having to carry the costs of own R&D. However, firms will only use external knowledge as long as the transfer of or the exchange of knowledge results in non-negative net-returns. This may not be fulfilled due to two reasons. First of all, knowledge transfer is not costless. Whether firms are able to effectively use external knowledge dependends on their capacities to absorb external knowledge, i.e. –according to Cohen and Levinthal (1989: 569) to 'identify, assimilate and exploit knowledge from the environment'. Given that cooks have the same recipes does not mean that they are

2 This holds true as long as one regards the bilateral linkages. Spillover effects of both forms, will arise, whenever the downstream or upstream firms are linked again outwards.

3 In contrast to Cohen and Levinthal, the analysis at hand focusses on spillovers between firms only.

able to cook a good soufflé. It is like Nelson (1992:181) point it the ‘tacit individual and organisational skills acquired in the course of learning how to make that recipe work’. According to him, these include primarily skills required to read the information given in patents or other documents, and skills due to and built up for learning by doing and learning by learning.

Second, external R&D may not be seen as complete substitutes to own R&D. Cohen and Levinthal (1989) emphasise the double role of R&D. On the one hand, R&D-investment serves as a direct input in the innovation process. On the other hand, it serves to build up the capacity to effectively use external results. Thus, with increasing spillovers from other firms, firms also have the incentive to invest more in own R&D[4].

Therefore, there is an additional parameter to be considered in equation (1) representing the absorptive capacity of the firm: γ_i, such that equation (1) changes to:

$$z_i = r_{ik} + \gamma_i \theta \left(\sum_{j \neq i} r_{jk} + \sum_j \sum_{l \neq k} r_{jl} \right), \text{ for i=1,..,n, l= 1,..,L.} \qquad (2)$$

Thereby, the firm specific character of absorptive capacities is represented by the index *i*, in contrast to the for firm *i* given parameter of spillovers.

Whether there will result such a positive net effect from spillovers and thus for innovation, will be tested on the ground of a logistic regression model, by using internal R&D and the various forms of spillovers as explanatory variables. Thereby, from the theoretical considerations it may be expected that spillovers will play a main role in the innovation process for those firms who on the one hand, are net receiver of knowledge such that there is only little relevance for the R&D-reducing externality effect, and on the other hand, for firms who are sufficiently linked with each other such that they can gain from the productivity and the so called spillback effect form R&D. Additionally, it may be expected that the role of absorptive capacity is justified, which should show up firstly, in an innovation increasing effect from spillovers, given that firms are able to absorb external knowledge. Seondly, this should show up in an increasing rate of return from own R&D, which indicates the complementarity between own and foreign R&D.

III. The Procedure

As a consequence to the crucial role of the individual firm the influence of spillovers and asorptive capcities will be analysed with an miroeconometric analysis based on firm-data on innovation activities. The data was obtained from a survey of German firms, undertaken by the Centre for European Economic Research in Mannheim (MIP 1993, 1994). Special concern lays thereby on data with respect to the firms’ innovation success, their R&D-investment, the effectiveness of various mechanism to protect research results and on various channels of information and knowledge transfer.

[4] For the empirical results, the model setup of Cantner and Pyka (1997) has to be mentioned: He assumes that spillovers increase the effectiveness of own R&D for the probability that later innovations will be succesful. This is done by introducing weights for the effect of R&D, with the weight dependend on the capacity of firms to absorb knowledge from spillovers. This setup will then be applied to the test of the complementarity between internal and external R&D.

Additionally, aggregate R&D-data was used to analyse the volume of spillovers from abroad and the technological linkages between industries both within Germany and abroad.

In the theoretical model just described the interesting variable is the probability π_i that a firm succeeds in his innovation today, given that it has not yet succeeded the periods before. This innovation success then is determined by the rate of knowledge accumulation by the firm, which can be represented by the sum of internal R&D-investments and the spillovers. [5]. Thus, the general estimation equation can be written like before:

$$\pi_i = F\left[r_{ik} + \gamma_i \theta\left(\sum_{j \neq i} r_{jk} + \sum_j \sum_{l \neq k} r_{jl}\right)\right]. \quad (4)$$

Assuming $F(z_i)$ as a logistic distribution in z_i, e.g., in the form $F(z_i) = 1/\left(1+e^{-z_i}\right)$, dividing it by its inverse probability *(1-F(z_i))*, and taking logs of this ratio results in:

$$\ln \frac{\pi_i}{1-\pi_i} = z_i = r_{ik} + \gamma_i \theta\left(\sum_{j \neq i} r_{jk} + \sum_j \sum_{l \neq k} r_{jl}\right). \quad (5)$$

Equation (5) directly represents the estimation equation of the logistic regression model used in the analysis[6].

1. Measuring Innovation Success

Our analysis estimates innovation success by the frequency with which firms have achieved product and/or process innovation in the previous year. There are basically two reasons for the choice of this indicator: First, it represents the most appropriate indicator to test models of patent races. It is therefore concerned with the direct probability of innovation success, rather than an indirect measure like productivity growth or profits, which have been used in the empirical litersture[7]. The direct variable influenced by internal and external knowledge is the conditional probability with which a firm has succeeded in innovations given this was not the case before. In the Mannheim Innovation Panel (MIP) however, firms have only been asked whether they have been innovative during the previous three years. In order to restrict the probability to the last year, the frequency of success has been calculated under the condition that the same firm had planned innovations the year before. Thus, a measure has been derived that comes very close to the theoretical probability.

Second, the reason not to choose the share of new products in total turnover, representing the market success of product innovation, and the question whether process innovations have led to cost reductions – despite their appeal as indicator for innovation success, ahve been data problems. Empirical studies, e.g. Geroski (1995) have shown

5 This results from assuming the knowledge needed to succeed to be exponentially distributed

6 According to Reinganum (1989) the function of the hazard rate ($F(z_i)$) has to be a twice differentiable, strictly increasing function, which is zero for zero z_i, and which is also zero for z_i going to infinity. Assuming logistic distribution, this is fulfilled.

7 See here for instance Jaffé (1986), Coe and Helpman (1995).

that one to three years are needed from the time of investment into R&D to the launching of a new product on the market. However, no data has been available to test longer time lags needed to take into account a period covering research and development, diffusion and launching of the product on the market. Nevertheless, to take into account the time necessary to develop the innovation a time lag of one period between R&D-input and innovation output has been assumed.

2. Internal Versus External Knowledge – Measuring Spillovers

Our analysis chooses the R&D-intensity, i.e. R&D-expenditures in relation to turnover as general indicator for innovation input[8]. The use of a flow variable - R&D-investment – instead of a stock variable -the capital stock- is in accordance with the theoretical model. There, the main variable, the probability for success at time t, dependends only on the contemporaneous rate of accumulation. This rate of accumulation of knowledge is equivalent to the R&D-expenditures invested during this period[9].

The distinction between external and internal knowledge for the empirical anylsis is based on the definition of appropriability. As long as firms are able to fully protect their research results, they can appropriate the returns from their research. Therefore, they can pass on some of the costs of research by selling the product, or by royalty fees in the case of licensing arrangements. From the side of the receiving firm, the knowledge then becomes internal, since it pays for the research done by the other firm. This is equivalent with defining external in the sense of external to the market, and thus with spillovers. Accordingly, internal knowledge is composed of first, the R&D undertaken by the firm for its own use, second, the acquired knowledge from different firms via market interactions, e.g. via contractual arrangements, third, R&D that may have been undertaken as contractual research for another firm and finally, R&D which has been undertaken in order to acquire external knowledge, i.e. the R&D undertaken in order to build up absorptive capacities.

Firm-specific spillover parameters were calculated on the basis of the survey data concerning the effectiveness of various protection mechanisms. These were legal mechanisms like patent rights, or firm specific mechanisms like secrecy, time lead or long-term contracts for qualified personnel. Firms were asked to judge the effectiveness of these different mechanisms on a scale ranging from 1, i.e. not effective at all, to 5, i.e. very effective. Recoding the scale, such that effectiveness of 1 is equal to a spillover parameter of 100%, effectiveness of 2 to spillovers of 75%, and so on, results in some

8 Until the date of submission, the analysis has been calculated only on the ground of the anonymous data. However, the procedure to make the data anonymous, is such that statistical estimations are not biased in comparison to estimations on the ground of the true data. Therefore, despite this procedure, sectoral R&D-intensities can be calculated by setting the sum of R&D-expenditures in relation to the sum of turnover within the same sector. With respect to the choice of R&D-intensities instead of absolute R&D-expenditures, however, see also OECD (1996).

9 Furthermore, it is due to the data constraints mentioned above. It does not make very much sense to calculate an R&D-capital stock from data for only two periods.

spillover parameter, between 0 and 1, similar to the spillover parameter used in the theoretical model. At the outset, these spillover parameters were calculated for each firm separately. The firm-specific spillover parameters were then applied to intra-industrial spillovers. However, in the case of inter-industrial and international spillovers, it was necessary to calculate additional industry-specific spillover parameters and one overall parameter respectively, in order to be able to calculate the aggregate spillover-pools.

Table 1:
Sectoral Spillover – Parameter [10]

Textiles	Wood Products	Chemicals	Rubber Products	Ceramics	Metals	Steel	Machinery	Electro	Optical Instr.	Auto-mobiles	Service
0,604	0,792	0,471	0,479	0,594	0,604	0,542	0,458	0,500	0,479	0,438	0,821[a]

[a] Due to low number of observations.
Source: MIP 1993, 1994, own calculations.

From table 1 one can see that on average, the spillover effects are about 0,5 which is equivalent to the theoretical 'critical' parameter with respect to the effect of spillovers on R&D-investment, calculated by d'Aspremont and Jacquemin (1988).

Within theory, the criteria for distinction between intra- and inter-industrial spillovers is whether firms are acting within the same markets. In the empirical analysis however, the concept of the same market cannot be measured explicitly. Firms were only asked to which sector they belong, but not which products they produce within this sector. Therefore, for the empirics, spillovers are defined as intra-industrial as long as firms belong to the same sector, and inter-industrial, whenever this is not the case. Additionally, in order to take account of inter-firm linkages the degree to which knowledge spills over to various sectors was measured by a technology flow-matrix. This matrix gives information on how much of the knowledge produced within one sector can be used by another sector, and how much of the knowledge one sector can use results from different sectors.

intra-industrial spillovers

Starting point for the calculation of the potential intra-industrial spillovers were the aggregate intra-sectoral R&D-intensities, i.e., the sum of R&D in relation with the total turnover of all firms within one sector, but other than the firm under consideration. In order to represent the potential intra-industrial spillovers, these R&D-intensities have been calculated on the ground of the firm-specific spillovers, not the total R&D-expenditure. Not all of the knowledge of one sector is used within the same sector. This also to some degree reflects the existence of inter-firm linkages and contractual R&D. In order to take the pure intra-industry spillovers, each of these sectoral R&D-intensities has been multiplied by an intra-industry technology flow-parameter, resulting from the technology-flow matrix.

[10] A list of the sectors is given in the appendix.

inter-industrial spillovers

In contrast to the calculation of the intra-industrial spillovers, inter-industrial spillovers were calculated on the R&D-expenditures - weighted by the sectoral spillover parameter -of all sectors other than the sector under consideration. The degree to which firms are vertically or horizontally linked with each other, was then measured by the help of the technology flow matrix. It relates sectors according to the criteria how much of the R&D produced by one sector has been applied within another sector. This matrix therefore, differs from the usual technology flow matrices which are calculated on the basis of input-output matrices, since it does not assume that knowledge spills over to the same extent to which firms buy capital or inputs from other firms[11]. Additionally, technology can be transferred to other firms via several channels, such as investment for equipment, direct investment or joint ventures, or such as exchange of experience via personnel contacts, direct acquisition of research results, for example via outsourcing, or the employment of qualified personnel. In contrast to the input-output matrices, matrices on the basis of data to the shares of applied technology reflect these diverse channels[12].

Information regarding applied R&D was given by SV-Wissenschaftstatistik (1994). There, firms were asked to assign the products or processes for which they have undertaken R&D-investments to the sectors or subgroups where they were applied[13.] The data is complete concerning the sectors producing R&D and it is also comprehensive concerning the knowledge receiving sectors, including sectors like electronics and optical instruments, chemicals, automobiles and aircraft, machinery and services. Missing values have been calculated from technology flow matrices on the basis of input-output-matrices, given in Schnabl (1995: 53). In order to make these shares representative with the structure of the SV-Wissenschaftsstatistik, the values for the inter-sectoral technology flows have been assigned according to the structure of R&D-production in SV-Wissenschaftsstatistik.

Table A1 shows the resulting technology flow matrix. Generally, it supports earlier results on the basis of input-output matrices like the one in Schnabl (1995:53): R&D-intensive industries like electronics and automobiles and aircraft, are pretty much technologically autarch. They produce R&D to cover their own needs. In contrast, less R&D-intensive industries like wood products, steel, rubber products and ceramics are also low appliers of technology. In contrast to the input-output based technology

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[11] See here for example Krahmer and Wessels (1989), and Schnabl (1995) for the general procedure and the application for the German situation. For an alternative procedure to calculate technology flow matrices on the besis of patent data and a technology concordance scheme, applied to international spillovers see Verspagen (1997).

[12] According to OECD (1996:24) for instance, technology flow matrices on the basis of input-output-tables only reflect product innovation, while data with respect to applied technology also concern process innovations.

[13] This does not necessarily mean that knowledge flows out of the firm. However, it reflects more directly the link between research produced and research used, thus, it reflects more directly the technology and not the product-flow between sectors.

matrices, our result shows that more research-intensive industries not only posess high intra-industrial technology-flow-parameters, but technology from these industries again flows into high-tech industries.

international spillovers

Starting point for the calculation of the potential international spillover pool had been the aggregate R&D-intensities in the three main industrial regions, EU-other than Germany, USA and Japan. Due to the focus on spillovers from other firms, the relevant measure for R&D-expenditures here is the business enterprise R&D-expenditures (BERD)[14] given by the OECD-main science and technology indicators. In contrast to the R&D-intensities before, the R&D-expenditures are now set in relation to total GDP. Due to lack of better information, these R&D-intensities were multipied with an overall spillover parameter. This is thus based on the assumption that the degree to which knowledge spills over within Germany, is similar to the spillovers in other countries.

The degree to which knowledge actually spills over from foreign to domestic firms, was once again measured by the help of a technology flow matrix. Here, the matrix reflects the technology flow from abroad according to the amount German firms spent for an external technology service, e.g., direct R&D, patents and licenses, or data processing and engineering. Data was taken from Deutsche Bundesbank (1994 and 1998[15]) where the expenditures for technological services within the balance of payments are reported according to first, the industries that have acquired foreign technological services, second, the various forms of technological services, and third, the regions of origin. Missing shares have been calculated on the basis of the overall knowledge received by the sector under consideration, as it is given by the vertical sum of the national technology flow matrix. This - together with the general strategy of using technology flow indicators instead of input-output data - makes the resulting technology flow matrix comparable with the national technology flow matrix.

Table A2 gives the resulting international technology flow matrix. The results underline a strong technological interweavement between German and European firms, corresponding to the concentration of trade. However, confirming to expectations, R&D-intensive industries also strongly acquire technology from the USA. Additionally, like it was the case in the inter-industrial technology transfer, it is primarily the R&D-intensive industries which acquire to a high degree technology from abroad. The sectoral ranking of knowledge acquisition is similar to the sectoral ranking of internationalisation of R&D. According to Gerybadze et al. (1997: 36), leading sectors with concentration of R&D abroad are the pharmaceutical and agrochemical industry, followed by computer and consumer electronics, telecommunication and to a lower degree also the automobile-industry.

14 In order to make it comparable, the BERD in million current PPP $ has been used.

15 These include sectoral data for the year 1992.

3. Measuring Absorptive Capacity

Absorptive capacities like tacit skills and experience are a fundamental prerequisite for the effective use of external R&D. However, it is this tacitness which makes it impossible to directly measure it empirically. In this paper, we chose the diversity with which firms use various channels of knowledge acquisition as an indicator for absorptive capacity, due to several reasons: On the one hand it reflects the general interest of firms in or call it the openness for using external knowledge in addition to their internal R&D-efforts. On the other hand, this indicator can be interpreted in relation to the costs of knowledge transfer. As it was emphasised above, external knowledge is only used by each firm whenever it results in positive net returns. By choosing among a broad spectrum of transfer channels firms can select the least cost intensive channel to access specific external knowledge. Finally, related with the cost aspect of knowledge transfer, the diversity with which firms use various transfer channels also reflects experience in absorbing knowledge. This is due to the fact that it takes time and costs in order to build up and preserve the respective contacts. Firms with bad experience in using external knowledge may not invest heavily in these transfer channel, but may rather concentrate on own R&D-efforts.

Within the MIP, channels for knowledge transfer are licensing agreements, direct investment and joint ventures, as well as channels where knowledge is transferred directly via interpersonal communication like exchange of experience, consultancy services and employment of qualified personnel[16]. Additionally, firms had to state whether they used the channels within Germany or abroad. This made it possible to directly assign an indicator for absorptive capacities to national and international spillovers.

IV. Results

Table 1 gives the main results of our estimates. The results from the first regression serve to analyse the influence of the potential spillover pools in general and the specific role of absorptive capacity explicitly. By the help of the second regression the complementarity between internal and external R&D will be tested for. This will be done by looking at the interaction between internal R&D and the various external R&D-sources. Finally, the results from the third regression will give more detailed explanations, most of all with respect to the role of information flow.

The coefficients generally show the direction and the relative influence of each exogenous variable. Since the parameters of a logistic regression model can not be interpreted directly, elasticities have been calculated on the basis of the means of the influencing variables. In the table, the first elasticity results from an equation where all variables, the second elasticity where only the significant variables are included[17].

[16] This classification into ‚interpersonel communication‘ has been taken from Harabi (1995).

[17] For a detailed description of the logistic regression model see Krafft (1997). Elasticities have been calculated due to the scale-variance of the coefficients of a logistic regression model.

Table 2:
Spillovers and Innovation Success

	Regression 1			Regression 2			Regression 3		
Number of observations[a]	927			940			711		
Deviation[b]	88,421			90,394			81,87		
Correct Classification (in per cent)[c]	84,57			84,68			86,08		
Influencing Variables[d]	Coeff.[e]	Elasticity[f]		Coeff.	Elasticity		Coeff.	Elasticity	
		all	sign		all	sign		all	sign
Constant	2,055*	0,23	0,93	2,323*	0,18	0,69	3,359*	0,36	2,36
Internal R&D	0,002*	0,05	0,18	0,002*	0,03	0,13	0,003*	0,06	0,38
Spillovers -General									
Intra-industrial	0,015	0,10		0,013	0,06		0,017	0,11	
Inter-industrial	-0,399+	-0,13	-0,52	-0,370+	-0,08	-0,32	-0,668*	-0,21	-1,37
International	-0,466*	-0,21	-0,81	-0,456*	-0,14	-0,52	-0,727*	-0,30	-1,98
Spillovers-Absorption[g]									
Intra-industrial	0,002	0,11		0,006	0,09		0,004	0,14	
Inter-industrial	0,139	-0,09	-0,34	0,057+	-0,07	-0,27	-0,005+	-0,21	-1,38
International	0,078	-0,17	-0,68	0,103+	-0,11	-0,40	0,163+	-0,24	-1,54
Interaction[h]									
Internal-intra-industrial				0,000+	0,06	0,23	0,000+	0,08	0,55
Internal-inter-industrial				0,001+	0,05	0,18	0,001	0,06	
Internal-international				0,000	0,06		0,000+	0,13	0,82
Intensity of competition							0,333	0,03	0,03
Information Source									
Intra-industrial							-0,168	0,00	
Inter-industrial							0,089	0,00	
Impediments to Innovation									
Information							0,132	0,00	
Costs/Imitation							-0,036	0,00	
Regulation							-0,109	0,00	
Linkages							-0,118	0,00	
Finance							-0,107	0,00	

[a] Represents the number of firms for which information has been available, [b] represent the goodness of fit statistics. The deviation is the difference between the loglikelihood-function with only the constant included and the resulting loglikelihood, when the variables are included in the estimation equation. The estimations are the better, the lower this difference [see here also Fahrmeir et al. (1996:ch.2).] – [c] States the number of cases that have been correctly classified through the estimations. – [d] Additionally to the here mentioned variables industry-dummies have been included in the estimation. Most of them had no significant influence. [e] + denotes significant at the 10%, * denotes significance at the 5%-level. According to tests for heteroscedasticity, the regressors show no significant influence on the squared residuals of the original estimations. This has been tested by using a linear specification analogous to the test of White (see here Gujarati (1995:379). – [f] In order to compare the influences with each other, the elasticities on the basis of the coefficients have been calculated. The first elasticity (all) represents the elasticity, when all influencing variables are taken into account, the second represents the elasticity when only the significant values are taken into account. For further informations regarding the logit regression see Krafft (1997:631). [g] These elasticities represent the change in effectiveness of spillovers, given firms have above average absorptive capacities. [h] These elasticities represent the change in effectiveness of internal R&D, given firms can effectively absorb external knowledge.

Source: MIP 1993, 1994, SV-Wissenschaftstatistik (1994), Deutsche Bundesbank (1996, 1998), own calculations.

1. The Influence of Internal and External R&D in General

Conforming to expectations, internal R&D is the main determinant for innovation success. This can be seen from the coefficients in the second row of table 2. Internal R&D increases the probability of innovation success by between 0.13 and 0.38 percent. Additionally, the influence is always significant at the 5 percent-level, as indicated by the asterisk.

Regarding the spillovers in general, i.e. without yet taking into account absorptive capacities, the results in table 2 indicate that firms can effectively use external R&D as long as it is produced within the own market or in markets which are linked with each other. According to theory, two counteracting effects may prevail from spillovers: the negative R&D-reducing externality and the positive productivity and so-called spillback effect. In table 2, intra-industrial spillovers exert a strong positive influence on the probability for innovations. The elasticities range between 0.06 and 0.11 percent. However, due to the empirical definition, these intra-industrial spillovers do not exactly correspond with the theoretical intra-industrial spillovers. Market linkages can prevail within the intra-industrial spillovers, or in inter-industrial spillovers, according to the linkages given by the technology-flow-parameters. Therefore, the strong, positive influence of intra-industrial spillovers on innovation success in table 2 has to be interpreted as positive productivity effect from vertically linked markets within the same sector.

Furthermore, table 2 shows significantly negative influences of inter-sectoral and international spillovers. This together with the positive intra-industrial effect indicates that firms are not sufficiently included in the external technology transfer. Statistically, this negative effect means that firms chose not to innovate in this period although they could have had access to spillover pools from other industries or from abroad. This can arise whenever firms did not have access to these spillovers. This presumption is supported by looking at the technology flow matrix in the appendix. There, one can see that there are no strong inter-sectoral technology-linkages. Except for sectors like rubber products, ceramics and to some degrees also optical instruments technology is primarily used in the same sector as it is produced. Therefore, it is not astonishing that the inter-industrial spillovers do not show positive influences on the innovation probability.

The same reasoning applies to the influence of international spillovers on innovations. Looking at the international technology flow matrix, one can see that it is only services and the R&D-intensive industries ADV/electronics, automobiles and aircraft which have high shares of acquisition of foreign technological services like R&D, patents or licensing, wheras not-R&D-intensive sectors like ceramics, metal products and steel only show very low intensities for knowledge acquisition from abroad.

2. The Influence of Absorptive Capacity

Negative influences of spillovers on innovation success may also result from low absorptive capacities on the part of the firm. However, according to the results in the block 'spillovers-absorption' in table 2, this is not the case. In contrast, confirming to the expectations from the theory, absorptive capacity raises the ability of firms to use external knowledge effectively in their own innovation process. The coefficient for every form of spillovers turns positive once the firm specific absorptive capacity is taken into account. As a consequence, given the absorptive capacities, the innovation elasticity from spillovers increases[18].This interpretation is not necessarily reversed by the fact that the change induced in the elasticity is very small. There are two aspects which have to be considered before:

Firstly, the seemingly low influence can be explained by a high variance across firms with respect to their absorptive capacities. The first column in table 3 shows the median values of the extent of diversity in channels of knowledge acquisition. The larger the values the more are firms involved in the technology transfer, thus the more firms are willing to implement external knowledge. The second column gives the means of the predicted frequencies with which firms are innovative, given the internal and the external R&D-sources. These are the estimated probabilities resulting from the logit regressions. Table 3 now shows that in industries that are characterised by a high absorptive capacity also high probabilities for innovation prevail. This is especially the case for automobiles and aircraft and for machinery and optical instruments. This result is additionally supported by the fact that just in the opposite case industries with only a limited involvement in the national or international technology transfer only have low probabilities for innovations.

[18] On the basis of the median values a dummy variable has been calculated with 1 reflecting above average use of transfer channels, and 0 reflecting low diversity respectively. Setting the dummy equal to one makes it possible to calculate the innvation elasticity of spillovers given that firms are sufficiently capable to absorb external R&D, compared to the elasticity, when this is not the case.

Table 3:
Knowledge Acquisition and Innovative Activities

	Absorptive Capacity		Estimated Probability of Innovation Success		
	Germany	International	Regression1	Regression2	Regression3
Textiles	2,00	1,00	0,698	0,701	0,719
Wood Prod.	0,00	0,00	0,786	0,765	0,795
Chemicals	9,00	8,00	0,871	0,866	0,903
Rubber Prod.	0,00	0,00	0,826	0,825	0,828
Ceramics	0,00	0,00	0,906	0,905	0,961
Metals	8,00	7,00	0,873	0,845	0,863
Steel	4,00	2,50	0,729	0,778	0,758
Machinery	8,00	8,00	0,933	0,933	0,933
ADV/Electro	8,00	8,00	0,797	0,796	0,832
Optical Instr.	8,00	7,00	0,932	0,933	0,917
Auto/Aircraft	10,00	8,00	0,901	0,899	0,923
Services	0,00	0,00	0,768	0,784	-[a]

[a] Due to low number of observations.

Source: MIP (1993, 1994), SV-Wissenschaftstatistik (1994), Deutsche Bundesbank (1994, 1998), own calculations.

Secondly, absorptive capacity increases the effectiveness of internal R&D. This can be seen fom the elasticities that are calculated on the basis of the interaction terms in table 2. These elasticities state how the use of external knowledge changes the rate of return from own R&D, given that firms can absorb external knowledge, i.e. their absorptive capacities are above average[19]. Especially the extent of the change in these elasticities speaks in favour of absorptive capacity. When only the significant variables are taken into account, 'absorbed' intra-industrial R&D increases the rate of return from own R&D by 10 percentage points from 0.13 to 0.23 percent, or from 0.38 to 0.55 percent when the influence of spillovers on innovation is controlled by informational variables. Compared to this, the interaction effect does not change the low influence of inter-industrial spillovers on innovation. These effects can be explained by the fact that knowledge can easily be transferred between firms with similar technological capacities.

In the case of international spillovers and internal R&D, the effectiveness of own R&D also increases when international knowledge flows can be absorbed. This is interesting, since international spillovers had no positive influence before. This result may primarily be explained by the cost aspect of knowledge transfer. Acquiring knowledge from abroad is connected with high costs like investments into the setup of plants or research laboratories, or with more indirect costs like informational barriers. Empirical studies have shown that infomation very easily is gathered through local or regional channels, whereas transborder information flow, e.g. in the form of

[19] This is thus equivalent with the test for complementarity like it has been modelled in Cantner and Pyka(1997). See also page 6 in this paper.

cooperations, are less prevailing[20]. The interaction effect of internal and international external R&D thus indicate that those firms who managed to overcome these burdens, may gain enormously. This speaks in favour of the results from Cohen and Levinthal (1989) that the higher is the external knowledge to be absorbed, the more internal R&D is invested in order to build up absorptive capacities.

These last considerations elucidate that the extent, the costs and the direction of inter-firm information flows is of crucial importance for the influence of spillovers on innovation activities. As a consequence, this gives further support for the presumption that low influences of inter-industrial spillovers on innovations is due to insufficient or ineffective inter-firm linkages.

3. Spillovers, Absorptive Capacity and Innovations - Revisited

With respect to the intra-industrial spillovers, the result suggest that although there are signs for an R&D-reducing externality, this may be more than outweighed by the productivity effect in linked markets. An indicator for the external effect can be seen by looking at the effect of the various information sources. These sources can be roughly classified into intra-industrial information channels like competitors and customers and inter-industrial channels according to upstream and downstream linkages[21]. Table 2 shows that intra-industrial information imposes a negative influence on innovations. This is especially noticeable since -by including these additional variables into the estimation equation- the coefficient of intra-industrial spillovers increases. The respective innovation elasticity rises to some 0.4 percent. Statistically, this may be due to the fact that innovating firms do not see competitors and customer as relevant information source. In contrast, it can be interpreted that firms fear knowledge flowing out to competitors. In this case, intra-industrial spillovers are to be interpreted as R&D-reducing externality. However, the increasingly positive coefficient of intra-industry spillovers itself speaks for the productivity and spillback effect from spillovers in linked markets.

An additional argument for the presumption that firms do not judge the externality effect that high can be found in the effect that the intensity of competition exerts on innovations. In the theoretical model above, increasing competition will hasten innovations as long as there is perfect patent protection. When spillovers prevail however, Reinganum (1989: 866) comes to the result that an increase in the number of competitors will reduce the incentive to invest into R&D and thus will delay innovation. Table 2 shows that firms succeeded in innovations although (or because) they were faced with increased competiton during the previous years. This together with the still positive effect of the absorption-term supports the presumption that firms are net receiver of knowledge and can absorb knowledge from technologically related firms.

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20 Almeida and Kogut (1997) for example emphasise the importance of face to face contacts, e.g. in the pub next to the firms. According to Koschatzky, firms even do not cooperate with foreign firms, although they are regionally located closely to each other.

21 In Table A3 the results of the factor analysis of information sources are given.

With respect to the inter-industrial spillovers however, incorporating the additional variables reinforce the results from above: There is no evidence for a productivity enhancing inter-industrial spillover effect, since markets are not sufficiently linked with each other. On the one hand, inter-industrial information positively influences the probability for innovations. That is, firms who do see suppliers of materials and equipment as important source for information are also innovative. However, this effect is not significant, indicating that these firms are rather the minority. In contrast, including this information variable into the estimation even reduces the effect of inter-industrial spillovers. This result is supported by the influence of impediments to innovation. As a part of the survey, firms have been asked where they see main problems for innovation[22]. The negative influence of the 'linkages'-variable then indicates that firms which suffer from low innovative activity from the side of the customers or the suppliers are not innovative. Thus, the prerequisite for strategically induced spillover is not given.

However, looking at the interaction term suggests that whenever firms have sufficient absorptive capacities these informational problems may be overcome. The strong positive common influence of internal and external R&D on innovations may be interpreted as that firms who do have access to inter-industrial knowledge flows and additionally have sufficient absorptive capacities can increase the effectiveness of own R&D by 17 percentage points from 0.38 to 0.55 percent. With respect to the international spillovers, the effect is even stronger: there, the innovation elasticity of internal R&D rises by 44 percentage points. This again supports the role of absorptive capacities, but also the double role of internal R&D.

V. Conclusion

The empirical results show that firms can effectively use external R&D within their own innovation process, given that they have access to the relevant knowledge flows. This is the case as long as firms have access to external R&D which is produced within the own market or in markets which are linked to it. Within the same industry, firms may even be seen as net receiver of external knowledge. Although there is some evidence for an R&D reducing and thus innovation delaying externality effect from spillovers, there is more evidence for a positive productivity and 'spillback'-effect from spillovers. Additionally, this is especially the case whenever firms have built up sufficient capacities to absorb external R&D within the own innovation process. Furthermore, absorptive capacities raise the effectiveness of internal R&D for the innovation process. Therefore, the results stress the complementarity between own and foreign R&D.

The empirical results suggest however, that innovation may be delayed due to insufficient access to inter-industrial or international knowledge flows. This can be seen

[22] As it was expected, these impediments can be adequately classified into few subgroups. The respective results of the factor analysis are given in Table A4.

from a strong positive influence from intra-industrial spillovers as compared to negative influences from inter-industrial and international spillovers. On the one hand, this may result from the fact that technology flows are concentrated within the own sector and by the fact that only R&D-intensive industries show a strong outward orientation towards international technology transfer. On the other hand, innovations were hampered when inter-industrial sources for information were not judged as relevant or when firms suffered from low innovativeness on the part of vertically linked firms.

With respect to technology policy, this insufficient involvement of firms into the inter-industrial and international technology transfer combined with the important role that technology transfer could have on innovations, given that firms have built up absorptive capacities, could in general speak in favour of technology measures which aim at increasing the technology transfer between firms. However, these results reflect the fact that the market works efficiently. A most remarkable proof is that, given that internal and external R&D are used complementary to each other, and given that firms have sufficient absorptive capacities, firms can even exploit inter-industrial and intersectoral spillover effects. This supports the presumption that firms will use external knowledge effectively and thus will invest into the absorptive capacities whenever they expect gains from international technology transfer. As a consequence, if technology policy is still desired, it should be designed as neutral as possible and aim at measures to reduce informational barriers, rather than directly influence the technology transfer.

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Appendix:

Table A1

Technology Flow Matrix - Germany

Technology flow parameter: R&D which is produced by sector *i* and applied by sector *j*												
	Textiles	Wood Prod.	Chemic als	Rubber Prod.	Ceramic s	Metals	Steel	Machin ery	Electro	Optical Instr.	Auto/Ai rcr.	Services
Textiles	0,8088	0,1527	0,0103	0,0006	0,0005	0,0018	0,0031	0,0042	0,0074	0,0005	0,0101	0,0000
Wood	0,2612	0,6702	0,0216	0,0013	0,0010	0,0033	0,0066	0,0120	0,0214	0,0015	0,0000	0,0000
Chemicals	0,0153	0,0167	0,7507	0,0215	0,0158	0,0061	0,0091	0,0012	0,0293	0,0020	0,0018	0,1305
Rubber	0,0865	0,0905	0,0458	0,6658	0,0357	0,0138	0,0205	0,0016	0,0016	0,0000	0,0908	0,0000
Ceramics	0,0652	0,0286	0,5924	0,0368	0,1220	0,0104	0,0155	0,0076	0,0501	0,0031	0,0685	0,0000
Metals	0,0152	0,0079	0,0209	0,0013	0,0009	0,7480	0,0665	0,0104	0,0077	0,0113	0,0128	0,0969
Steel	0,0093	0,0048	0,0099	0,0006	0,0004	0,0031	0,5125	0,3493	0,0132	0,0004	0,0002	0,0955
Machinery	0,0057	0,0029	0,0013	0,0004	0,0003	0,0019	0,1167	0,8232	0,0213	0,0035	0,0186	0,0001
ADV/Elect	0,0097	0,0087	0,0001	0,0007	0,0005	0,0041	0,0177	0,0188	0,8656	0,0121	0,0534	0,0060
Optical	0,0095	0,0086	0,0225	0,0007	0,0005	0,0040	0,0174	0,0199	0,0461	0,7938	0,0769	0,0000
Auto/Aircr	0,0003	0,0002	0,0003	0,0000	0,0000	0,0001	0,0061	0,0111	0,0004	0,0000	0,9510	0,0304
Services	0,0320	0,0032	0,0000	0,0037	0,0003	0,0212	0,0210	0,0000	0,0013	0,0017	0,0000	0,8828

Source: SV-Wissenschaftstatistik (1994), Schnabl (1995), own calculations.

Table A2:
Technology Flow Matrix – International

Technological services acquired by sectors						
	Expenditures		Country of Origin			
	in Mio DM	in percent	EU	Japan	USA	Total
Textiles	960,43	0,0608	0,0299	0,0010	0,0217	0,0526
Wood Prod.	316,17	0,0200	0,0098	0,0003	0,0072	0,0173
Chemicals	2343,00	0,1484	0,0729	0,0024	0,0530	0,1284
Rubber Prod.	314,85	0,0199	0,0098	0,0003	0,0071	0,0172
Ceramics	116,45	0,0074	0,0036	0,0001	0,0026	0,0064
Metals	38,68	0,0024	0,0012	0,0000	0,0009	0,0021
Steel	129,32	0,0082	0,0040	0,0001	0,0029	0,0071
Machinery	535,00	0,0339	0,0167	0,0006	0,0121	0,0293
ADV/Electro	4788,00	0,3032	0,1490	0,0050	0,1083	0,2623
Optical Instr.	128,00	0,0081	0,0040	0,0001	0,0029	0,0070
Auto/Aircraft	2086,00	0,1321	0,0649	0,0022	0,0472	0,1143
Services	4036,00	0,2556	0,1256	0,0042	0,0913	0,2211
Total	15.792,00		7.762,00	259,00	5.643,00	15.792,00

Source: Deutsche Bundesbank (1994, 1998), own calculations

Table A3:
Results of the Factor Analysis ‘Sources for Information’

	Sources for Information[a]:	
	Intra-industrial	Inter-industrial
Competitors	0,389	
Fairs	0,734	
Conferences/Journals	0,604	
Suppliers of inputs/materials		0,518
Suppliers of equipment		0,819
Customers	0,327	

[a] Extraction Method: Maximum Likelihood. Rotation Method: Varimax with Kaiser Normalisation; eigenvalues > 1,2 (according to the scree plot)

Source: Mannheim Innovation Panel (1993), own calculations.

Table A4:
Results of the Factor Analysis 'Impediments for Information'

Impediments	Factors: Impediments for Innovation[a]				
	Information	Costs/ Imitation	Regulation	Linkages	Finance
High risks		0,5172			
Impediments within the firm	0,3829				
Lack of info about technology level	0,6647				
Lack of info marketing	0,7235				
Lack of info external know-how	0,7940				
Lack of cooperation with firms	0,5890				
Lack of cooperation - universities	0,5539				
Restrictive regulations			0,8259		
Bureaucracy			0,8179		
Lack of tax incentives			0,4671		
Lack of innovation customers				0,6882	
Control of innovation costs		0,4971			
Lack of innovation suppliers				0,6964	
Market not yet mature				0,4776	
Lack of firm capital					0,9048
Lack of outside capital					0,7444
High costs of innovation		0,8183			
Amortisation of costs		0,7988			
Imitation		0,4682			
Lack of qualified personnel	0,3448				

[a] Extraction Method: Maximum Likelihood. Rotation Method: Varimax with Kaiser Normalisation.

Source: Mannheim Innovation Panel (1993), own calculations.

Table A5:
Classification of Industries:

Terminology in the text	Industry according to WZ 93 and NACE-Rev.1	2 digits accord. to WZ 93	ISIC-Classif[a]
Mining	Mining, minerals, energy and water supply	10-14, 40, 41	0
Food Products/ Textiles	Food manufacturing, Tobacco manufactures, textiles and wearing apparel	15, 16, 17, 18, 19	0
Wood Products	Manufacture of wood and paper products, printing and publishing; manufacture of furniture, jewellery, music instruments, sporting goods and manufacturing industries not classified elsewhere (n.e.c.)	20, 21, 22.2, 22.3, 36	0
Chemicals	Chemical industry; mineral oil processing, manufacture of coal	24, 23	1 0
Rubber Products	Manufacture of rubber and plastics	25	0
Ceramics	Manufacture of glass, pottery and earthenware	26	0
Metal Products	Manufacture of fabricated metal products	27	0
Steel Processing	Iron and steel basic industries	28	0
Machinery	Manufacture of machinery, weapons; electrical appliances and houseware n.e.c.	29	1
Electronics	Manufacture of office, computing and accounting machinery, radio, television and communication equipment Manufacture of electricity distribution and control apparatus etc.	30, 32 31	2 1
Precision/ Optical Instruments	Manufacture of medical appliances, appliances for measuring, checking etc., Optical instruments, photographic equipment	33	2 1
Automobiles/ Aircraft	Manufacture of aircraft and spacecraft, Manufacture of motor vehicles, parts and accessoires, Manufacture of transport equipment, n.e.c.,	35.3 34, 35.2	2 1 0
Construction	Construction	45.2	0
Services[b]	Data processing a. database, research and development, technical, physical a. chemical services, Architecture- a. engineering, Recycling, metal waste and scrap	72, 73; 74.3, 74.2 90	2 1 0

[a] ISIC-Classification, '0' represents non R&D-intensive industries, '1': high-level technology, '2': R&D-intensive industries. – [b] Classification following the ISIC/SITC-Classification.

Source: MIP (1993, 1994).