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Michael Rothgang

Sectoral Innovation Systems, Corporate Strategies, and Competitiveness of the German Economy in a Globalised World

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Abstract
The EU Barcelona target assumes a close causal relationship between corporate R&D, the competitiveness of business firms and the economic performance of industrial countries. Testing this hypothesis, this paper contrasts innovation and production activities in four research-intensive manufacturing sectors (chemicals and pharmaceuticals, motor vehicles, machinery, and electrical engineering). Starting point are observed long-term changes in worldwide value added of the manufacturing sector. The empirical analysis is based on a unique survey of R&D-intensive business firms in Germany and 50 personal interviews in large industrial companies. The results show that there is no simple connection between R&D and competitiveness. Moreover, the likely consequences of promoting R&D differ substantially between industries.

JEL Classification: L6, O23, R32

Keywords: Sectoral innovation systems, corporate R&D Strategies, chemicals and pharmaceuticals, machinery, electrical engineering, motor vehicles, bazaar effect

August 2008

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1. Introduction

In the political sphere, strong optimism prevails that the overall competitiveness of the European as well the German economy will be enhanced by increasing R&D expenditure, thereby generating additional growth and employment. Meeting in Barcelona in 2001, the European Council set the target of spending 3% of the GDP throughout the EU on research and development (R&D) by the year 2010. This resolution was formulated against the background of the Lisbon Strategy, to make the EU the most competitive knowledge-based economy in the world. This Barcelona target – how unrealistic it may be on the EU level – was adopted by many member states, among them Germany, as a national goal. In accordance to that target, the German federal government is aiming at investing 3% of German GDP in R&D by 2010.

Addressing a possibly declining competitiveness of European economies, and decreasing welfare and employment, the Barcelona target ties together three aspects of modern economic life which do partly interact: Firstly, it concerns the issue of national competitiveness which can be approximated by the share of value added in aggregate output and its development. Secondly, it touches upon the location and sourcing decisions of multinational firms and their effect on the development of industrial production activities in different regions. And thirdly, it emphasises the role of R&D activities for industrial competitiveness. These different aspects can be discussed by taking an encompassing view within the sectoral innovation systems approach (Breschi and Malerba 1997, Malerba 2002, 2004). This approach makes the mutual dependency between R&D and production activities explicit. To understand these complex relations, one needs to analyse (i) how value added is created in research-intensive business firms, (ii) how the regional allocation of value creation takes place and (iii) what role R&D and R&D location actually play for value added. All of these aspects of firm activities are not understood quite well yet.

This paper focuses on the hypothesis that an increase of R&D in the manufacturing sector leads to growing competitiveness of the German economy and faster growth of value added in the business sector. The empirical analysis is based on international statistics of production and value added and unique information from our own empirical investigations: These are based on 50 interviews with technology oriented business firms and on a recent survey on corporate and research strategies of technology intensive companies in Germany.[2]

The paper proceeds as follows: Section 2 presents some stylised facts about the world-wide allocation and long-term development of value added in the manufacturing sector and displays the data base for the study. Section 3 gives an overview of the factors which influence the development of value added. The evolution of corporate international production networks supporting the generation of value added are discussed prominently here, because they appear to be the main targets of the policy behind the Barcelona objective. In section 4, innovation and production activities in four sectoral innovation systems in the manufacturing sector (chemicals and pharmaceuticals, motor vehicles, machinery, and electrical engineering) and their interrelationship are analysed. Section 5 concludes.

2. Analysis of the Manufacturing Sector

2.1 Long-term Developments

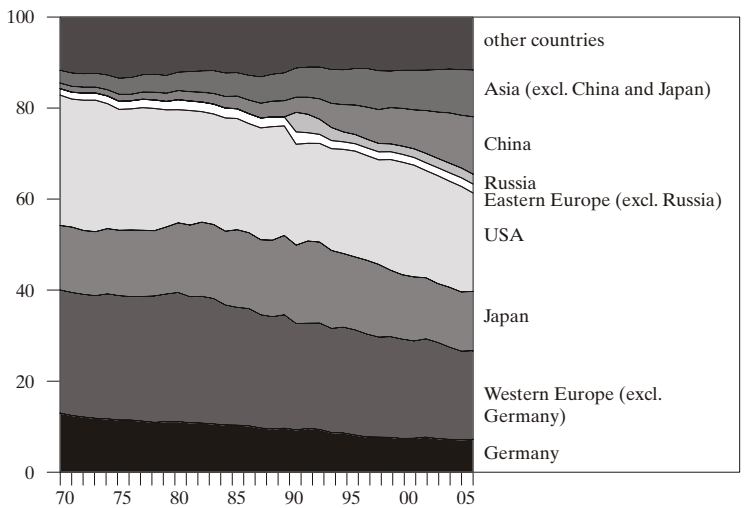
During the past decades, many observers have expressed their concern about a continuous decrease in the share of manufacturing in value added share in the industrialised countries and particularly in Germany. Dubbed the *bazaar effect* (Sinn 2004, 2005), the argument has been put forward that, in order to compete internationally, German companies are resorting to the

[2] This paper draws on results from a recent study of the RWI Essen in cooperation with Wissenschaftsstatistik GmbH, for the Ministry of Innovation, Science, Research and Technology of the State of North Rhine-Westphalia (RWI und SV Wissenschaftsstatistik 2007).

strategy of increasingly producing goods abroad. The central argument is that the remarkable growth in German exports is due to products that have been imported before, and thus does not reflect domestic production activities. Only administrative functions and maybe some central corporate functions like advertising, administration and design would remain in Germany. This argument was used to support the thesis of a decreasing international competitiveness of the German economy.

The indicator which reflects the development of international competitiveness in the most accurate manner, is gross value added. Gross value added is calculated by subtracting the sum of all intermediate input values (energy, materials, and services) from gross production. It measures the sum of the values that have been created by the firms in an industry within a period of time (the industry-related contribution to GDP). The statistical office of the United Nations has published internationally comparable data for the development of world-wide value added for the manufacturing sector in about 200 countries since 1970. The data show (Figure 1) that in the year 2005 still the major part of world-wide value added fell upon the industrial countries in Western Europe, the USA and Japan (altogether 68 %). Therefore, it seems that these industrial countries were very well able to succeed in international competition. In contrast, already 27% of total value added fell upon the countries in Asia (excl. Japan), Eastern Europe and Russia. In 1970, their share had been 5%, and in 1990 already 16.7%.

Share of Worldwide Value Added in Manufacturing
1970 to 2005; in %



Source: United Nations Statistical Division, own calculations.

Figure 1: Share of Worldwide Value Added in Manufacturing[3]

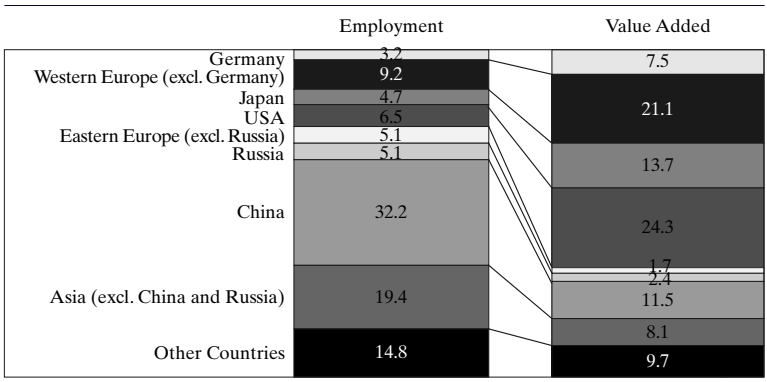
The development appears to be somehow less favourable for Germany and Western Europe as a whole than for the USA. The share in value added of Germany has continuously declined

[3] Value creation was calculated from the growth of real value added in national currency. The per annum values in US-Dollars were calculated using the growth factors in order to eliminate effects of variations in currency exchange rates (exchange rate in June 2005: 1,21 $ per €). Because no data were available for India, this country is excluded from our calculations.

during the last decades and has almost halved over the entire period since 1970, from 13% in the year 1970 to 9.3% in 1990 and 7.2% in 2005. The USA also experienced a reduction in their share of total value added from 28.6% in the year 1970 to 22.2% in 1990. Since then, the global share in value added has stayed approximately constant at 21.6% in 2005. The share of total value added for Japan has developed more favourably than for Western Europe. After an increase from 14.2 to 17.2% between 1970 and 1990, the economic crisis since the end of the 1990s was associated with a decrease to 13% of total world value added in the year 2005. This share is only marginally smaller than in the year 1970.

Also the comparison between shares in total employment and value added reveals some interesting facts (Figure 2).[4] First of all, the relative weights of industrialised and industrializing countries interchange: Only 23.4% of total manufacturing employment accrues to the industrialised countries, while in China alone, 32.2% of all world-wide employees in manufacturing are working today. More than half of total manufacturing employment is allocated to Asia as a whole. This is not a surprise because manufacturing productivity is considerably higher in the industrialised countries.

Share of Employment an Value Added in Manufacturing
in % of all countries



Source: UN Statistical Division, own calculations. – The basic population included data for 117 countries.

Figure 2: Share of Employment and Value Added in Manufacturing

The comparison between the industrialised countries, especially Germany and the USA, is striking. While Germany produces 7.5% of total value added by employing 3.2% of the total personnel, the USA produce more than three times the German value added (24.3%) by employing only double the personnel (6.5%). Altogether, not merely the absolute decrease in the share in global value added for Germany but the unfavourable situation with respect to labour productivity in comparison to the USA deserves an explanation.

Another indicator that reveals differences in industry structure, especially the relevance of intermediate inputs for output in that industry, is the share of value added in gross production.

[4] This table was produced for a somewhat smaller sample of countries (117 against more than 200 for value added alone) for which both data on value added and employment were available. However, this difference does not affect the general results because the countries that were excluded from Figure 2 are rather small and therefore unimportant in respect to total employment. The only exception is India for which both no data on employment and on value added have been available.

Figure 3 compares the shares of value added in gross production in Germany and the US for the large sectors in manufacturing. It becomes very clear that the small share of value added in production is not at all a phenomenon that only applies to Germany. On the contrary, the share of value added in production has been definitely higher in Germany in electrical engineering and the motor vehicles sector during the 1970s. However, the decrease in the value added share in Germany in the 1980s and 1990s has led to a convergence of the value added shares in both countries.

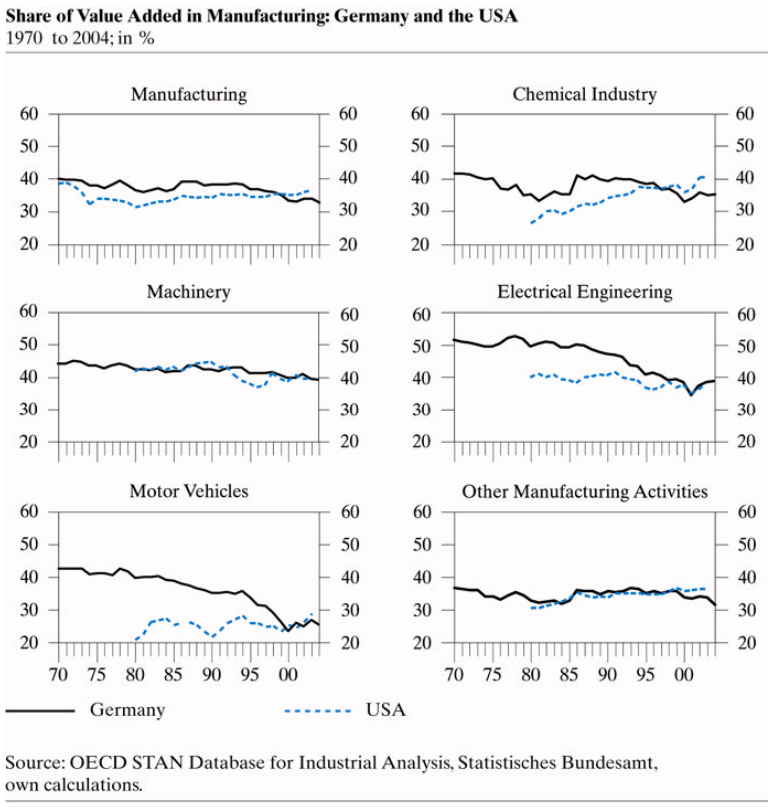


Figure 3: Share of Value Added in Manufacturing: Germany and the USA

2.2 Empirical Data Base

Apart from international statistics, the empirical basis for this study consists of two sources: A survey of R&D-performing firms in the manufacturing sector and interviews conducted with R&D managers of (mainly large) business firms. The survey was carried out in cooperation with SV Wissenschaftsstatistik. The questionnaire was attached to the recurring national R&D survey conducted every two years which mainly inquires the amount and structure of R&D expenditures in the economy based on the OECD Frascati Manual (OECD 2002). This regular survey does not ask about the R&D behaviour of business firms, though. Therefore, the additional questions in our part of the survey go well beyond the regular questionnaire. However, one advantage of combining both surveys was that we could focus on a representative sample from the firm population which is aimed at by the Barcelona target: those German business firms that conduct R&D. Therefore, we were able to learn about the factors determining the R&D activities in the economy in general.[5] This paper focuses on the relations between R&D activities and production.

Looking at the distribution of the response rate in respect to firm size, we see that medium-sized enterprises account for a large share of our sample (Table 1). Overall, 75.2% of the business firms in our sample are small and medium-sized enterprises according to the EU classification. They report a turnover of not more than 50 mill. € and less than 250 employees. Merely 50 of the business firms in our sample (9,8% of the analysable sample) either report more than 500 employees or a turnover of more than 500 mill. € or both. It appears that our sample shows a reasonably representative profile of research activities in all sectors in the economy. However, big firms regularly performing R&D are overrepresented.

Table 1

Distribution of the Survey Response by Company Size

	Number of firms	Share in %	Turnover	Number of employees
Micro	25	4.9	<2 mill. €	1 to 9
Small	136	26.8	2 – 10 mill.	10 to 49
Medium	221	43.5	10 – 50 mill.	50 to 249
Large	64	12.6	50-500 mill.	250 to 499
Very large	50	9.8	>=500 mill.	>=500

Source: Business survey of the Stifterverband Wissenschaftsstatistik and RWI Essen 2006. – A company has to fulfil both criteria in order to belong to the respective smaller company size. So, for instance, a company with a turnover of 5 mill. € but 100 employees will be classified as "medium".

At the same time, there appears to be a rather small number of very large firms with several R&D facilities in the total population of research-active business firms. A rather large share of the overall R&D activities in the German economy is represented by these firms. This is one reason why the expert interviews are so important for our study. They focus on research and production strategies of large companies in Germany. We selected the business firms according to their relevance for the research activities in the R&D intensive sectors of the German economy.

We conducted our interviews based on a standardised questionnaire.[6] The relevant contact persons were mostly the heads of the respective R&D departments, in some cases the responsible board members. The expert interviews were rather successful. Overall, 72 firms were chosen, of which only 22 declined an interview. Therefore, the success rate was 69%. Table 2 gives an overview of the allocation of the firms in respect to sectors of the economy. From the 50 interviews, 45 were with R&D-representatives in North Rhine-Westphalia. We interviewed eight foreign firms. Altogether, 12 firms have their headquarters located outside of

[5] The original questionnaire is reported in the appendix of the study (RWI / SV Wissenschaftsstatistik 2007).

[6] The questionnaire is also reported in the appendix of our study (RWI / SV Wissenschaftsstatistik 2007).

North Rhine-Westphalia. Three interviews were conducted as telephone interviews; one firm representative sent a written answer to our interview questionnaire.

Table 2

Expert Interviews in the Context of Sector-Related Case Studies: Distribution by Industry

Industry	Number of Firms
Chemicals/Pharmaceutics	12
Machinery	6
Motor vehicles	7
Electronics/Electrical engineering	8
Iron-Steel	5
Energy	2
Telecommunications	4
Software	2
Other research-active sectors	4
Total	50

3. Internationalisation of Production and Corporate Behaviour

3.1 Trends in International Production Systems

At the beginning of industrialisation, industrial production was primarily a local, regional or, perhaps, national affair. Production abroad was rather exceptional. Goods were typically produced in a company's home country and sold abroad via trade agencies. This changed slowly in the second half of the 19th century when the first German companies of the chemical industry and in electrical engineering were producing abroad in order to satisfy local demand there. Other industries followed, but the number of companies producing abroad was rather small in comparison to today. Especially after Word War I, there was an increase in foreign production, when a larger number of companies produced abroad with their own subsidiaries or even bought foreign firms (Jacob, Meyer 2006: 5 and Borsdorf 2007).

Today in all large segments of the manufacturing industry, production is strongly influenced by international and global firm activities. In the motor vehicle industry, about a dozen original equipment manufacturers (OEMs) exert strong influence on the global value chains which consist of hundreds of firms. In most machinery industries, a large share of the relevant production activities is divided up on a global scale by a few firms. The size of the firms competing internationally in these markets mostly depends on the respective overall size of the world market and the possibility to reduce costs by utilising economies of scale. While in branches with a substantial market volume also large firms exist, competition in smaller markets is mainly between smaller firms[7] .

In electronics, the prominent markets (especially in consumer electronics) are divided up by few large multinational firms. However, there are also many market segments where smaller firms compete. In the high-tech segments, both production and sales mainly take place in the industrialised countries. Remarkable differences in production structures also exist in the chemical and pharmaceutical industry. Scale intensive parts of these industries have been relocated to low-cost locations. In the pharmaceutical industry, to take one example, overall firm structure is still not very monopolistic. The number of firms that compete in the R&D intensive segment of the industry in developing new drugs is rather small and confined to the industrialised countries. Production of these new drugs mainly takes place in the high-income countries while other parts of production are often relocated to low-cost countries.

[7] They are mostly large firms in respect to the EU criterion for small and medium-sized enterprises.

Like from the beginning of international trade, arbitrage is the main motive for internationalisation of economic activities. However, the relevant parameters have changed and are still changing. The global reallocation of production that could be observed in the recent decades was driven by profit-oriented corporate activities, using new means of global arbitrage between purchasing, production and sales (Kenney, Florida 2004: xxii). However, strategic firm-level decisions do not only consist of location decisions in respect to production. Relevant decisions also encompass whether to produce or to outsource production and service generation.

The most notable aspect of the internationalisation of production are the production networks of very large firms, whereas also a considerable share of small and medium-sized firms possess international production facilities. Globally, there are less than 100 company groups which have succeeded in getting a dominant position in markets of large volume. In the mid-90s, for example, only 100 companies received one third of the world-wide stock of direct foreign investment, i.e. only 0.3% of the overall internationally active enterprises (United Nations 1996: 29). The internationalised companies have to choose nationally and worldwide where and which production and service activities as well as R&D activities will be carried out, and what components from where will be bought.

3.2 Factors Influencing Location of R&D and Production Activities

The factors determining R&D locations and their development do differ from those related to production. However, both spheres of firm level resource allocation are closely related to one another. Where R&D takes place is not independent from the location of production or of other firm level value creating activities.

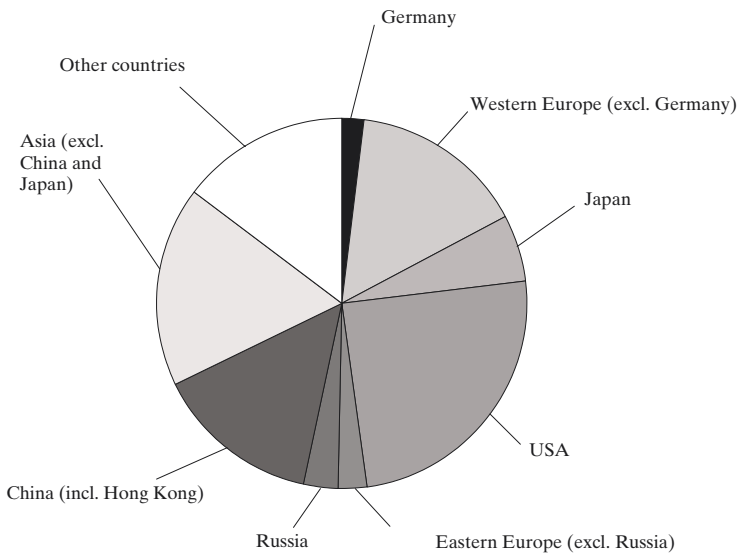
The two factors that advance the internationalisation of production activities in recent decades are market growth and cost savings. Of course, the differences in wage levels between industrialised and industrialising countries seem enormous at first sight. However, it has partly proven to be difficult to transform these into savings in production costs because lower wage levels correspond to lower levels of labour productivity. A considerable number of failures in establishing cost saving production facilities abroad document the problems arising with running production abroad. Altogether, especially large firms are rather successful in maintaining complex production networks that make use of the differences in factor prices.

Also the strategic decisions to be present in growing markets with an own production facility appears to be important for the internationalisation of production structures. In some important growth markets like China, firms are required to produce locally in order to be able to sell their products. But also other factors contribute to the necessity to be *in situ* with own production activities. Producing locally makes it easier to adapt products to the purchasers' needs. Also the image of a business firm can be increased by producing locally.

Figure 4 gives an overview of global GDP growth in the period from 2000 to 2005. The figure shows that opportunities to sell goods in the market increased both in the industrialised and the industrializing world. While high growth rates prevail in countries like China with a low initial level of GDP, absolute growth in GDP was comparable in the USA and Western Europe with lower growth rates but a higher wealth level.

Growth in distinctive markets strongly differs between the regions. In the fast growing Asian countries, growth rates of demand are especially high for capital goods and also some kinds of consumer goods (refrigerators, motor vehicles). In the USA and Western Europe, markets for these products remain static or grow slowly. New market opportunities arise in markets that e.g. develop from consumer preferences and perceived needs (e.g. mobile phones or DVD players in the recent years) or changing production processes and the reorganization of production processes and the related demand for new investment goods.

Distribution of GDP Growth
2000 to 2005; in %



Source: United Nations Statistical Division, Author's calculations.

Figure 4: Growth in GDP: 2000 to 2005

As the production activities, also firm-internal R&D structures have undergone extensive restructuring processes in the last decades. Especially the central R&D divisions of most large companies have been reorganised. This restructuring has also resulted in changing location patterns for R&D. Still, R&D activities are much less dispersed across space than production activities. Economies of scale are the most important cause that most small and medium-sized technology-oriented enterprises as well as the smaller among the large firms have one R&D location, usually at the headquarters of the respective firm. However, very large R&D-intensive firms that account for the predominant share of overall R&D activities usually have multiple R&D locations.

With respect to international R&D locations, a comprehensive set of studies has been conducted (see e.g. Granstrand et al. 1993, Meyer-Krahmer et al. 1998, Edler/ Döhrn/ Rothgang 2003). Two main motives for the internationalisation of R&D are identified in this literature: Like for production activities, performing R&D in order to adapt to the respective national and regional markets' needs is the dominant motive. As a second motive, the literature has identified the need to participate from specialised knowledge (university knowledge, proximity to the R&D activities of other firms).

The production and R&D structures have developed with different speed: While it has proven to be easier to locate or relocate production activities, the relocation of R&D takes more the character of a long-term process.

3.3 Globalisation on the Value Chain in Automobile Production

Economic analysis of these trends is rather difficult. Because the developments are rather branch-specific, it seems worthwhile to focus on one branch of the economy which has been well documented in many industry studies: the automobile industry. The automobile industry features production bases in the industrial triad, in Europe, the USA, and in Japan. The industry is organized along the value creation chain with a dominant position of worldwide a few OEMs. The production process comprises the OEMs as well as numerous suppliers on different positions (1st tier, 2nd tier etc.) both in the automobile sector and from other industries like electronics, the metals and chemical industry.

Figure 5 displays the development of production value and value added in the motor vehicle industry in Germany. There has been a rapid increase in the production value since the beginning of the 1990s. While the real value of production has increased at a yearly growth rate of 6.6% from 1995 to 2004, real value added has merely increased by 2.4%. In the same time period, the share of value added in production has decreased by nearly 10 percentage points from 35.2 to 25.5%.

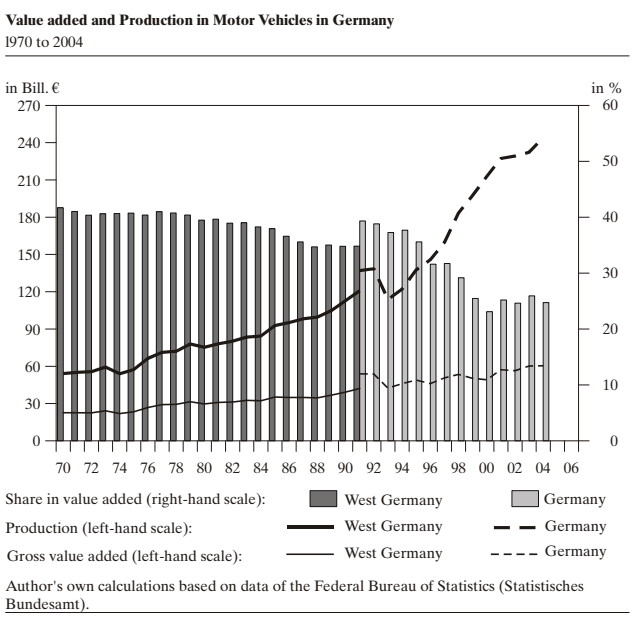
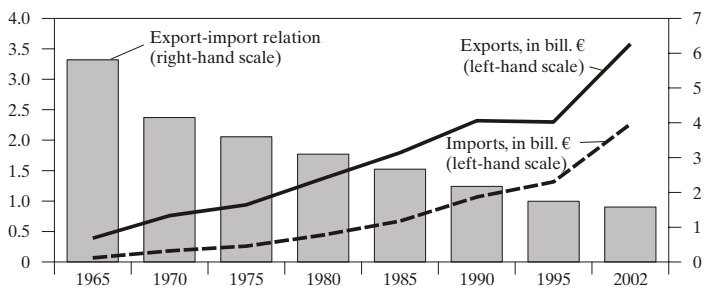


Figure 5: Value Added and Production in the Motor Vehicles Industry in Germany[8]

[8] Source: Statistisches Bundesamt, Volkswirtschaftliche Gesamtrechnungen, Fachserie 18, Reihe 1.4 und Fachserie 18, Reihe S.29; author's own calculations. Production and value added in real values calculated from chain indices of the manufacturing of motor vehicles and parts and accessories for motor vehicles, according to the Statistical Classification of Economic Activities WZ 2003. After 1991, the chain indices of production for Germany have been

This development is accompanied by a long-term reduction of the ratio between exports and imports in automobile parts since the 1960s (Figure 6). This ratio has been reduced from 5.8 in 1965 to 1.6 in 2002. This trend reflects long-term changes in the production activities in the motor vehicle industry. Parts of the value chain have moved to other regions, at first especially to Southern European countries like Spain or Portugal, lately to Eastern Europe.

Exports and Imports of Motor Vehicle Components
1965 to 2002; at constant prices



Author's own calculations based on data of the VDA (diff. years).

Figure 6: Exports and Imports of Motor Vehicle Components

Obviously, the patterns sketched out show some reflections of the "bazaar effect" as it has been discussed lately. However, as different studies show, this development has not been constrained to Germany or Europe. There has been a general, industry-wide trend to move parts of the value chain to low-cost locations, from the US to Mexico, from Central to Southern and Eastern Europe, and from Japan to locations on the Asian continent (Korea, Malaysia, China) (Sturgeon/ Florida 2004).

3.4 Value Creating Activities in Manufacturing Firms

The evolution in firm level location of value added has been accompanied by changes in the firm-internal structure of value creation activities. Based on data from the micro census in Germany, Table 3 splits up employment in manufacturing to different activities: production related activities, R&D, activities related to controlling, testing and other service activities.

The data show different interesting details: Firstly, the work of a considerable share of overall employees in manufacturing (53.6%) is not directly related to manufacturing. Further 7.1% are engaged in R&D and design activities. This share is considerably larger than the share of R&D personnel that is reported in the official data (3.8 %, not displayed in the table). However, the delineation of R&D in the official Frascati manual is definitely stricter than the one used by the micro census. Anyhow, the share of overall employment that goes to R&D is considerably small.

When looking at the sectoral data, we see first of all that still more than half of employees in the motor vehicle sector perform production-related activities. These are considerably less in the electrical engineering and in the chemical sector. In 'Office, accounting & computing machinery', only 21.7% of all employees in Germany do production-related activities.

made available by the Federal Bureau of Statistics on demand. The share in value added is based on real terms: the values for West Germany in prices of 1991, those for Germany in prices of 2000.

Table 3

Employment Shares in Business Firms of the Manufacturing Industry Related to Occupation, 2004

Industrial Sector		Production related	Service-related[1]	Measurement, testing	Research, design, construction
		Employment share, , in %			
24	Chemical Industry	31.2	48.4	11.1	9.3
27, 28	Metals	62.7	29.9	3.7	3.7
29	Machinery	49.5	35.7	3.7	11.1
30-33	Electical Engineering	38.4	41.4	7.1	13.1
30	Office, accounting & computing machinery	21.7	48.4	6.1	23.8
31	Electrical machinery & apparatus, nec	43.3	37.6	7.4	11.7
32	Radio, TV, communication equipment	35.5	40.4	8.1	15.9
33	Medical, precision & optical instrum.; watches & clocks	39.0	44.9	6.2	9.9
34, 35	Motor vehicles, incl. other transport equipment	50.3	32.9	6.7	10.0
34	Motor vehicles, trailers and semi-trailers	51.4	32.3	6.7	9.6
35	Other transport equipment	43.8	36.2	7.1	12.9
	Other manufacturing	42.0	52.0	2.8	3.2
	Total manufacturing	46.4	41.8	4.8	7.1

Own projections based on the micro census 2004. [1]Other than measurement / testing or research / design / construction.

The data show that production activities obviously represent merely one (often a minor part) of the value creating activities of manufacturing firms in Germany. Changes in the structure in value creation in Germany among others reflect structural changes within the respective sectors or changes in the division of labour between different national and international locations within a sector. The following section tries to get closer to understanding what happens within individual firms and business sectors in respect to value creation.

4. Sectoral Innovation, Production and Value Added Systems

4.1. The Sectoral Innovation and Production Systems

When looking at the four large research-intensive sectors in manufacturing (chemicals and pharmaceuticals, motor vehicles, machinery, electrical engineering), we find different characteristic patterns of production and R&D activities. The results from our interviews show that these patterns differ not only between the four sectors, but also within these sectors diverse characteristics of R&D and production activities can be distinguished (Schedule 1).

The *machinery sector* consists of several sub-branches which are rather different in respect to market volume. Only firms in the large sub-branches can make extensive use of economies of scale in production. In these branches, we can find large firms. In many other branches, smaller firms compete on mostly global markets.[9] Most of these markets changed in respect to the ever increasing importance of the growing Asian markets, partly also those in Eastern Europe which have become more and more important for many branches of the machinery sector. At the same time, the competitiveness of the individual firms strongly depends on the firm internal knowledge base which usually has developed through many decades in the past. R&D activities are mostly located near the headquarters, in some cases when firms operate in different divisions, close to the headquarters of the respective division.

The *electrical engineering sector* consists of quite different sub-sectors where both the conditions in respect to production and R&D activities differ. In most of the "older" branches which have developed in the second half of the 19th century, conditions in respect to both production and R&D are quite similar to parts of the machinery sector. Although obviously

[9] Of course, there is no economic criterion against which the delineation between SMEs and large companies can be tested. In the "large" markets, firms like Siemens or MAN do often dominate production activities.

many of the successful German companies in the electronic sector produce for these markets, they represented a minority in our sample. Production activities in these branches have partly been transferred to low-cost countries. This is the case especially with products that cannot generate a high value added. The knowledge base of these firms has been developed over a long time period and R&D is often held close to the company headquarters. As is the case for machinery, Asian countries have developed as new competitors.

Sector	**Machinery**	**Electrical engineering**	**Chemistry, pharmaceuticals**	**Motor vehicles manufacturing**
	Production activities			
Branch characteristics	Many different sub-sectors	Older/ newer sub-sectors	Chemistry: multiple markets; pharmaceuticals: market for itself	Value added chain
Market segments with economies of scale	Large sub-sectors	Consumer electronics markets; others	Chemistry: commodities; pharmaceuticals: generic drugs	both in motor vehicle manufacturing and in parts
Production networks; location of production	Partly local, partly in low cost regions/ near the market	Different in respect to branches; often cost minimising production systems; high-tech branches: often secondary role of production costs	Different: importance of cost factors esp. for commodities, generic drugs;	Increasing importance of production costs;
	R&D			
Characteristics	Cumulative; important role of tacit knowledge	Different: partly science-driven (newer branches); partly tacit knowledge	Different: process innovations (commodity chemicals); science and "idea" driven (specialty chemistry; new pharmaceutical drugs)	Improving parts of the system "automobile"; also: international coordination of different R&D teams
Location	Mostly: few locations, at headquarters	"older" branches: close to headquarters; new high-tech branches: international R&D, close to university research	Commodity chemicals: close to production; pharmaceuticals/ speciality chemicals: high-tech research partly in-house, partly in close cooperation with universities/ new ventures	Still mainly national, but internationalising – cost saving becoming more important

Schedule 1
Sector Characteristics in Respect to Production and R&D

Partly different conditions prevail in the typically new branches that produce electronic devices. Here, we find also differences between consumer electronics, small firms in high-tech segments, as well as the electronics suppliers for motor vehicle manufacturing which are parts of the respective value chain. In the large markets in consumer electronics, international production systems have developed most rapidly. Even firms have developed that specialise on

production for brand firms (e. g. in mobile phones). Only a small fraction of production still takes place in the industrialised countries, while still a large fraction of value added is created there, mainly in R&D, design, and other service activities.

Totally different conditions prevail in small high-tech segments of the electronics industry. Two of the electronics firms in our sample belong to that segment. These segments which are often closely related to university research are characterised by a large share production activity in the industrialised countries. Business firms from developing countries do not belong to the competitors. Also the main markets for the products of these firms are in the industrialised world.

Differences in respect to research and production also prevail in the sub-branches of the *chemical and pharmaceutical industry*. The chemical industry as such consists of different sub-sectors. Some of them – especially *commodity chemicals* which are characterised by large volume production processes – make extensive use of economies of scale. In these sub-branches, an intense cost competition takes place, which privileges industrialising countries as location for production, where environmental obligations are less strict than in industrialised countries. These parts of the industry are not rather research intensive, R&D being dominated by process innovations in close relation to production. Other parts of the chemical industry, like speciality chemicals, are more research intensive. Especially more advanced and complicated production processes in these branches are still mostly located in the industrialised countries. Still, there are high-tech segments in the chemical industry, which develop mainly in the industrialised countries in close relationship to the relevant markets. Both research and production activities in these segments are located in the industrialised countries.

Having developed together with the chemical industry originally, the *pharmaceutical industry* has separated itself from the chemical industry in the last decades. The industry consists of different segments, partly producing in industrialising countries because of production costs and the necessity to be close to the market. Again, the research intensive high-tech segment of the industry is located in industrialised countries. In this part of the industry, however, mere production of drugs only comprises a small fraction of all value added creation (with small volumes of substances produced totally). Other activities like research, drug testing, advertising, and distribution activities appear to make up a sizable share of industry activities.

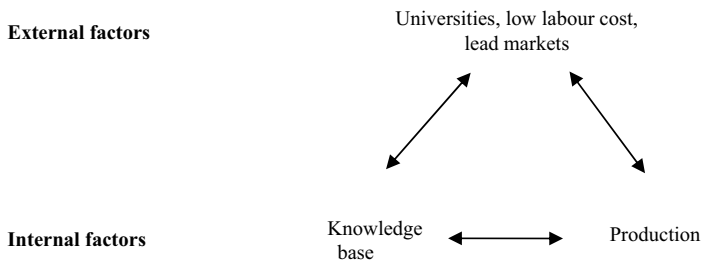
Pharmaceutics appears to be a sector where search for new knowledge dominates the development of R&D locations. However, there are obviously different firm strategies in respect to R&D. While some firms strongly focus on developing the own R&D capacity, others do rely more on external sources. Also being present at important research locations (like in the US for German firms) is one motive for choosing R&D locations.

The production system in the *motor vehicle industry* has been discussed in length in section 3.3 of this paper. Important R&D activities are conducted both by the OEMs and the suppliers. The OEMs and also large suppliers perform part of their R&D with the aim to understand future trends in the relevant markets. The main share of R&D activities with respect to personnel employed is focused on the development of new models. The internationalisation of automobile production through mergers and acquisitions also lead to the necessity to coordinate international teams in several locations. Thus, the development of R&D locations has led the industry to partly overcome restrictions in R&D cooperation.

4.2 The Interaction of Sectoral Innovation and Production Systems

This section discusses the question, how and to what extent R&D activities could influence long-term trends in value added. One hypothesis could be that by improving local conditions for R&D, production activities and jobs could be kept in the country. Of course, there is no simple answer to that question. The distribution of firm level production and R&D activities and value added in general at one moment in time is the result of a sequence of past decisions on changing extent and location of firm activities (or leaving them unchanged). Also past decisions to acquire other firms have an effect on the distribution of firm level activities.

In general, the location of R&D could be influenced by a combination of internal and external factors (Schedule 2). Firm external factors would relate to the necessity to be close to university research and important lead markets. Internal factors would encompass either a close proximity to production or to the firm-internal knowledge base (central functions like corporate management and marketing).



Schedule 2
Factors Determining the Location of R&D in Business Firms

In our questionnaire, we **asked** about factors that determine the location decisions for R&D. Three pre-formulated answers were related to co-location of R&D and production facilities (together with production, together with production plants in "lead markets", and at existing production facilities in low-cost locations). One answer was related to R&D locations not depending on production, where the company's knowledge is available (close to other R&D activities or to central functions). The remaining two given answers asked for the relevance of factors not depending on production (in the vicinity of universities or research institutions, not depending on production and with low labour costs).

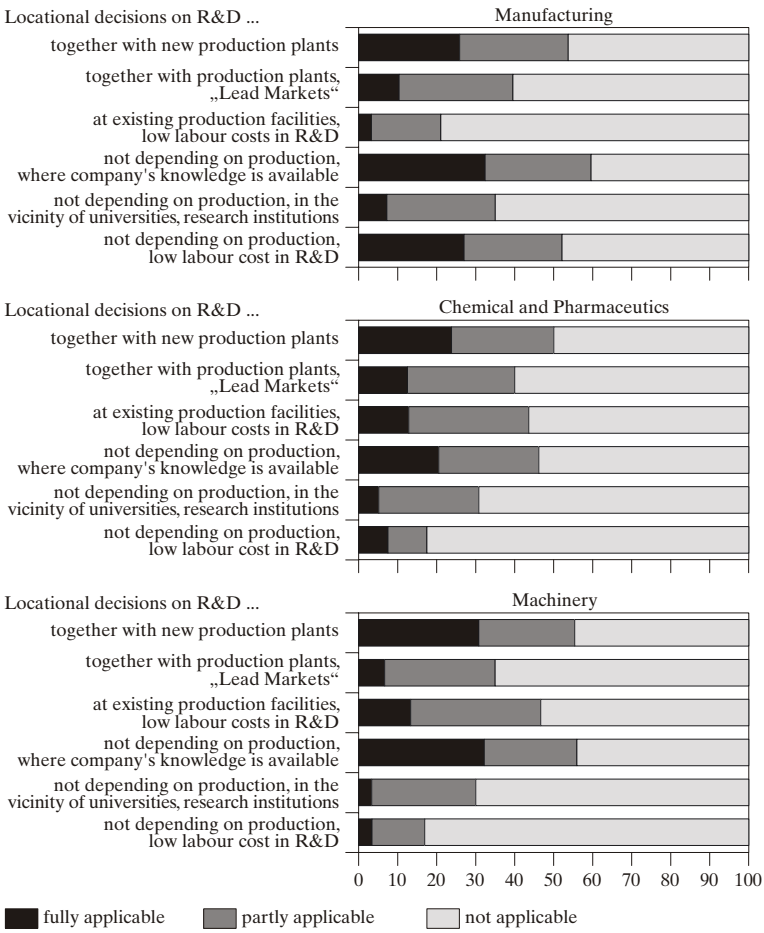
Figure 7 shows the responses of the companies of the overall manufacturing industry, chemical and pharmaceutical industry as well as in the machinery sector. The results from the expert interviews, which are mainly focused on very large companies of the industries in question, give additional information on how production and R&D locations are related in the sectors scrutinized. In general, the answers show that for manufacturing firms, both firm internal factors and external factors are relevant for R&D location decisions. Although spatial proximity between R&D and production is a relevant factor for location decisions, it seems that in many cases R&D location is chosen independent from production activities.

About one half of the companies in the *chemical and pharmaceutical industry* claimed making decisions on R&D locations together with production sites, an almost similar share (46.1% of companies) gives the answer that R&D locations would be chosen independently of production where knowledge about products and processes are available. At the same time, the common location of R&D and production at low-wage sites plays a role for 43.6% of the companies.

According to the results of our expert interviews, in the chemical and pharmaceutical industry, the relationship between production and research is highly dependent on the individual market segments. In the manufacturing of *commodity chemicals*, R&D occurs in connection with the production, also in its immediate vicinity. If production facilities are relocated abroad on a

larger scale, R&D capacities are relocated, too. In the different segments of the *pharmaceutical industry*, the relation between R&D and production varies. While there are drugs that can be produced in simple production processes at low-cost locations, the production of newer, more complex drugs takes place in high income countries. Also the production processes in this industry are on a small scale. Proximity of research and production is advantageous, but not necessary. Both possibilities (close proximity and distance) could be observed in the firms we interviewed.

Locational Decisions on R&D and Production:
Manufacturing, Chemicals and Pharmaceutics, Machinery
share of responses in %



Source: Survey of business enterprises of Stifterverband Wissenschaftsstatistik and RWI Essen 2006. - Manufacturing: 294 analysable questionnaires, Chemicals and Pharmaceutics: 42, Machinery: 65.

Figure 7: Location Decisions on R&D and Production: Manufacturing, Chemicals and Pharmaceutics, Machinery

The firms in the *machinery sector* obviously often locate their new R&D activities where there are already existing R&D locations; mostly close to the firm headquarters. Some 55.4% of the firms interviewed stressed, that new R&D activities would develop at already existing R&D locations. At the same time, the establishment of new R&D-teams often follows the implementation of low-cost production facilities. After all, 46.6% of the firms in our sample answered that this possibility applies for them.

In the branches of the machinery sector, with large *economies of scale* in production, location of production sites is chosen in order to optimise the production processes with respect to cost and market development. In a major part of these companies R&D as well as a significant share of production is taking place centrally in the same location, mostly in the vicinity of the headquarters. Also the spatial vicinity of production and research is often considered to be important. Sometimes it is also an explicit part of the corporate strategy that research and production are connected spatially with each other.

For the companies of the *electrical engineering and electronics industry* (Figure 8), the spatial vicinity between research and production plays on average a smaller role than in other branches in manufacturing. But still nearly one half of the companies (47.7%) answered that the vicinity between research and production is important to them. Also low R&D labour costs (whether dependent on or independent of production) are important for the R&D location decisions (in 55.4% of the companies in connection with production facilities in 33% of the companies without production). The vicinity to universities and universities of applied sciences plays an important role. Some 44.9% of the companies gave the answer that this is a relevant factor for R&D location decisions.

In the branch segments, we found different types of relationship between R&D and production. In the markets that are prone to intense cost competition, the immediate vicinity between research and production is not as close as in other sectors. Production is optimised independently from R&D facilities.[10] In the large volume markets (like mobile phones, consumer electronics), optimisation of the production (and supply) system with respect to costs is one of the overwhelming factors in competition. As soon as it is possible to produce the goods of the respective market in low-cost countries, all producers are forced to relocate production in order to be competitive. Partly, overall production is outsourced; others chose to keep production inside the firm. The firms that chose to do that produce merely their value added by doing design, advertising (creating a brand), and doing administration. However, they still have located most of their value creating activities in the high-wage countries.

In smaller high-tech segments (e.g. censors), production cost are of no overwhelming importance in competition. The companies aspire to an immediate spatial vicinity of research and production in order to facilitate a tight interchange of information.[11] Therefore, in these high-tech market segments, production is often still on high-wage locations. The relocation to low-wage sites is of no importance.

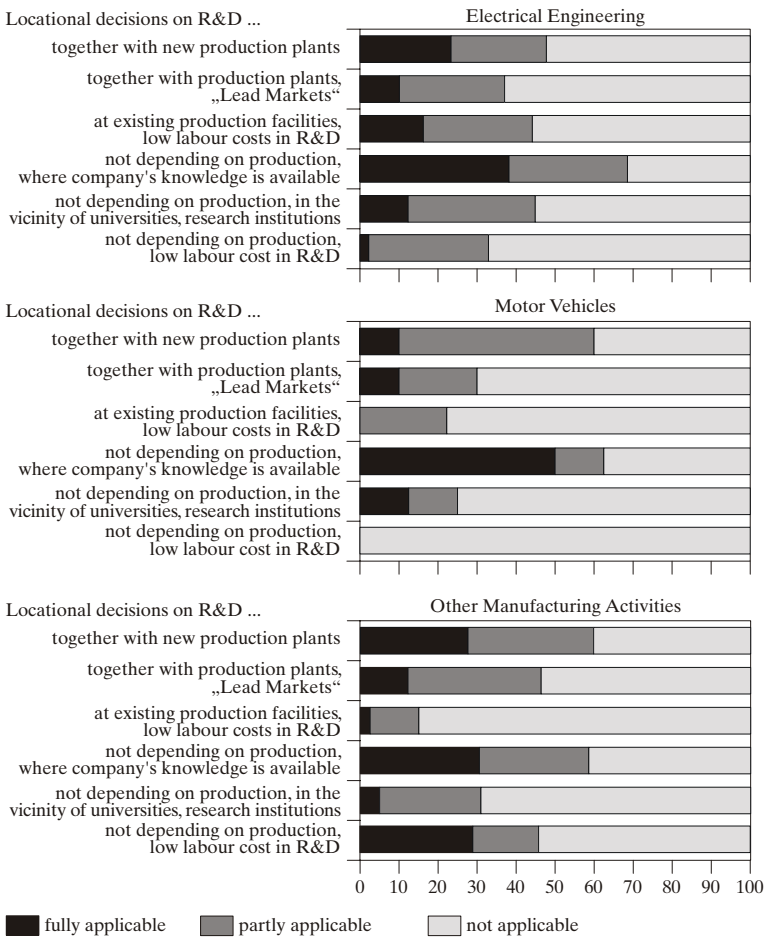
In the *motor vehicles industry,* it is quite obvious that the planning of R&D locations is carried out mainly according to production-independent criteria, which are oriented to the internal company's knowledge. Some 62.5% of the companies gave the answer that R&D locations are set up where the internal company's knowledge about products and processes is available. Even 50% of the companies judged this issue as "fully applicable". At the same time, in some cases it seems to be, however, a connection between locations for research and production. Some 60% of the companies stated that R&D units are set up in connection with new

[10] Partly, a system of *mother factories* is chosen: As also practice-oriented business administration concepts propose such factories should be located close to R&D (thus in high-cost locations) for gaining experience in producing newly developed products before their production is relocated into low-wage locations. Several firms we interviewed (also automobile electronics suppliers) mentioned that their company would aim at such a system.

[11] Three of the firms in our sample competed in that kind of markets.

production facilities, too. Low R&D labour costs or the vicinity of universities and other research institutions as well are only for a smaller section of the companies of importance for location decisions.

Locational Decisions on R&D and Production:
Electrical Engineering, Motor Vehicles, Other Manufacturing Activities.
Share of responses in %



Source: Survey of business enterprises of Stifterverband Wissenschaftsstatistik and RWI Essen 2006. – Electrical Engineering: 90 analysable questionnaires, Motor Vehicles: 10, Other Manufacturing Activities: 86.

Figure 8: Location Decisions on R&D and Production: Electrical Engineering, Motor Vehicles, Other Manufacturing Activities

In the assessment of the responses it is to be taken into account that the system character of the industry can only be represented incompletely by our survey. The automotive industry, which is the dominant section within the motor vehicles industry, is organised as a value-added

network surrounded worldwide by only a few OEMs. The component suppliers differ significantly in both regarding the size and the position in the value-added chain.

The manufacturers of motor vehicles chose their location of development units in close proximity to central production facilities. The central locations have become centres of attraction for investments in the past. However, these locations are the result of past decisions. In case of new locations of research and production activities, different locational patterns can be observed. For instance, the Japanese manufacturers have decided in favour of cost-effective sites for their production in Europe, whereas the locations for research and development are settled in high-wage regions in spatial vicinity of the competitors and markets (Simon 2006: 358). Thus, there are obviously different possible firm strategies in respect to the location of research and production.

The big suppliers acting worldwide (the ones of the United States and Europe in particular) have both production and research activities established close to the large markets. The spatial vicinity to the customers plays a role particularly in motor vehicle parts entailing high freight charges. They do obviously optimise and plan their R&D network regardless of the production network. The ability to manage and to optimise research and production activities, which are spread all over the world, has become a core competence of major-suppliers that is decisive for of the medium-term competitiveness. The smaller suppliers have their R&D activities in many cases still focused (for instance, on the location of the headquarters), whereas the production has followed the locations of the customers.

In the *other manufacturing sectors,*[12] location decisions are partly made in the context of new production sites, partly independently of them. The sectors in the *other manufacturing industry* are very heterogeneous. Many of them were exposed to a fierce cost competition in the last years. Therefore, it is not surprising that for a relatively large share of the companies cost factors are important in the decisions on R&D locations.

4.3 Firm Development and Value Added in the Industrialised Countries

The previous section has focused on the relationship between R&D and production activities. In order to assess the development of value added and its relationship to international competitiveness, we have to take into consideration all kinds of value creating activities in manufacturing, not merely focussing on production itself.

A look into the long-term development of technology oriented business firms shows, how their development contributes to the evolution of industry-wide value added. As Chandler (2005a,b) illustrates for the chemical and parts of the electronics industry, technology-oriented firms in most cases grow by creating an internal learning base. This learning base, which is mostly located close to the original headquarters, also is associated with most of the value added at the beginning. The learning base does not merely consist of technical and production knowledge, but also of the administrative, advertising, and distribution capabilities.

The later development of value added creation has strong sector- as well as firm strategy-related characteristics. This concerns the decision how much production activity is kept inside the firm and where to locate production or service creation. Of cause, also firm success has a decisive influence on the development of value added. In most firms that we visited, a relatively high share of firm activities still persisted in close vicinity to the firm headquarters (although there was sometimes no more production activity left).

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[12] The other manufacturing sectors comprise the food industry, the tobacco, textile, apparel and the leather industry, the wood-bases industry, paper industry, publishing and printing industry, coking plants and oil processing, the processing of fission and breeding products, the manufacture of rubber and plastics, the industry of glass, ceramics and non-metallic minerals, the furniture industry, the manufacture of jewellery and musical instruments, sports goods, games and toys, and recycling.

The analysis has indicated that the general possibility to run decentralised production – and also R&D – activities has increased. Most firms resorted to this possibility because of market pressures: They respond to the necessity to produce in important (new) regional markets as well as to their competitors producing at low-cost locations. However, the sector-specific analysis reveals that there is no general trend according to which in each industrial sector value added has "migrated" to a large extent away from the industrial countries into the fast-developing national economies of Eastern Europe or Asia (China or India). In many high-tech fields, particularly in the electronics sector (computer and telecommunications industry) and in the chemical and pharmaceutical industry, the largest proportion of value added still takes place within the industrial countries.

We also observe that firm activities that take place in the industrialised countries are to an ever smaller extent directly associated with production. One good example are parts of the electronics industry where there is a partial trend that production itself dissociated from other activities related to value creation (research, design, creation of a brand by advertising). Thus, there seems to be a general trend of deindustrialisation of the manufacturing sector in the industrialised countries.

Furthermore, research and production are in many cases not closely spatially connected. Therefore, R&D locations are often planned entirely independently from the production sites. R&D locations – at least the less standardisable, more creative parts of the R&D activities – are still concentrated, on a global scale, within industrial countries. Particularly large-scale companies make their decision of production sites on a world-wide level in which being close to important markets generally plays a dominant role. However, there are many cases where companies as part of their overall location strategy seek to keep R&D in a close vicinity to the technically more sophisticated parts of production.

Beyond sectoral differences in the development of world-wide value added shares, industrialised countries have sustained their attractiveness in the process of world-wide arbitrage in value added by business firms. This is the case for many central functions that are related to the firm-level knowledge base and do still very often remain at high cost locations. Likewise, R&D and sophisticated production processes do still remain at locations in high-cost countries. And locations in industrialised countries still appear to be the "breeding ground" for new high-tech industries.

5. Conclusion: Can we Hope to Influence Competitiveness and Employment by Supporting R&D Activities?

The past years have witnessed an increasing share of total value added going to newly industrialising countries especially in Asia. However, a remarkable share of global value added is still being produced in the industrialised countries. The kinds of activities being performed in industrialised countries have changed with an – at least until today – ever increasing share of not directly production-related value creating activities being performed in industrialised countries.

Several authors have argued that knowledge clusters (like Silicon Valley or Route 128 in the US) seem to be the regions in industrialised countries that gain profit from that international development. This is one possible answer to the question, what possible positive effect R&D in the industrialised world might have. Especially, the development of new industries in the industrialised countries seems to take place in such knowledge clusters. Globally successful technology oriented firms of the recent decades in most cases did acquire their learning base in such clusters.

However, in light of our results, the answer seems to be more complex. Also, many business firms in the manufacturing sector which are not located in any knowledge cluster have been very successful on a global scale. Also the successful European firms in the

telecommunications sector did not develop from such clusters (Nokia, Ericsson). However, different factors contributed to the success of these business firms (Edquist 2004).

To conclude, there is no doubt that innovation systems and differences in innovation systems are going to determine how the competitiveness of firms in different sectors are going to evolve. Our analysis has indicated that high-tech sectors and firms played a central role for growth in value added. Our experience indicates that successful R&D is not sufficient to be successful in increasing value added. Therefore, we need to think about complementary factors that increase the probability that new industries develop in industrialised countries.

For Germany, the specialisation of the innovation system in road vehicle engineering, partly in mechanical engineering as well, has partly contributed to the negative development of value added. Especially in the computer and telecommunications industry and in the pharmaceutical sector, value added in the industrial countries has undergone a highly positive development in the last decades. However, the (successful) sectoral innovation systems in these branches are primarily located outside Germany (partly in the United States, but also in Northern Europe).

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