EUROPEAN INNOVATION MONITORING SYSTEM (EIMS)

EIMS PUBLICATION N° 38

INNOVATION IN THE EUROPEAN CHEMICAL INDUSTRY

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WZB - WISSENSCHAFTSZENTRUM BERLIN FÜR SOZIALFORSCHUNG

EUROPEAN COMMISSION

DIRECTORATE GENERAL XIII

The Innovation Programme

EIMS Project N° 94/110

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Research Area Market Processes and Corporate Development

THIS STUDY WAS COMMISSIONED BY THE

EUROPEAN COMMISSION,

DIRECTORATE-GENERAL "TELECOMMUNICATIONS,

INFORMATION MARKET AND EXPLOITATION OF RESEARCH",

UNDER THE INNOVATION PROGRAMME

STUDY COMMISSIONED ON: JAN. 95
STUDY FINISHED ON: MAY 96

WISSENSCHAFTSZENTRUM BERLIN FÜR SOZIALFORSCHUNG

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May 1996

Prepared for the International Conference on "Innovation Measurement and Policies"
by EUROSTAT and the European Commission
20-21 May 1996, Luxembourg

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1 Introduction

There are striking differences in innovation performance between Japanese, American, and European firms. For example, even though the cost per time unit of the innovation process seems to be lower in Germany than in Japan, total cost of an innovation is significantly higher in German than in Japanese firms due to longer innovation periods.[1] Thus, it is not surprising to still observe concerns about the innovative performance of European companies. But structural changes are already under way within Europe's chemical industry, whereby corporate concentration on innovative lines of business is of major importance. Thus, the individual companies' innovative capabilities have turned into the most decisive factors for their successful competition.

This study illustrates by means of nine selected European chemical companies those areas of the chemical industry currently holding high innovative potential and at the same time reveals the relevant innovative and corporate strategies dominating today's chemical companies. Furthermore it is using data from the Community Innovation Survey (CIS) to describe and explain the differences of innovative performance across firms within the European chemical industry.

A 'wide interpretation' of the term innovation is used, which includes the whole of the innovation process--from the analysis of a problem, the search for ideas, research and development (hereafter referred to as R&D), production and sales preparations, to the introduction of a new product or procedure into the market. New is used in the sense of the so-called relative novelty definition and includes any company oriented novelties, which means that even a renewned procedure being purchased by a company, e.g. by way of taking out a licence, constitutes an innovation for this particular company.[2]

Most innovations in the chemical industry originate from so-called internal sources, i.e. mainly from company-owned R&D departments. Decisions on the orientation of the corporate R&D activities, as well as on the allocation of R&D resources and capaciues, are made within the framework of the respective technological and innovative strategies.

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[1]For a discussion of these problems see e.g. Albach, H., Culture and Technical Innovation - A Cross-Cultural Analysis and Policy Recommendations, in: Akadmie der Wissenschaften zu Berlin, The Academy of Sciences and Technology in Berlin, Research Report 9, Working Group Culture and Technical Innovation, *Culture and Technical Innovation -- A Cross-Cultural Analysis and Policy Recommendations*, Berlin: Walter de Gruyter, 1994, pp.1-597. See e.g. Acs and Audretsch (1990) for an analysis of the US industry.

[2] See e.g. Albach (1994), p. 50-54 and in particular for the chemical industry Schmidt (1991), p. 7

2 The Chemical Industry

2.1 Products and Industry Structure

The chemical industry[3] is the third largest manufacturing industry in the EU and certainly one facing a paramount challenge regarding its innovative activities. The industry comprises all companies producing their products exclusively or mainly by way of the conversion of substances. The goal of chemistry as such is the substitution of natural substances and/or the creation of new substances. This is done either by the conversion of natural substances (such as modified starches) or by the syntheses of organic or inorganic base material (i.e. the synthesis of chlorinated dissolvents). Companies whose treatment of substances is done exclusively by (or connected with) physical processes, such as mixing, emulsifying or extracting are also often considered to be part of the chemical industry.[4]

The chemical industry differs from other lines of industry mainly through the heterogeneity of its products. As a result, the individual line segments are subject to completely different technical/scientific conditions as well as different R&D situations. Thus, Schulze[5] describes chemistry as a sum of individual lines of industry.

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[3] For a description, data, and analyses of the chemical industry see e.g. the following publications: EC Commission (ed.), Panorama of EC Industry, Brussels/Luxembourg, 1994, and Freeman, C., Chemical Process Plant: Innovation and the World Market, in: National Institute Economic Review, No.45 (August), 1968, pp.29-51; Backman, J., Economics of Chemical Industry, Washington, D.C., 1970; Kölbel, H., Schulze, J., Der Absatz in der chemischen Industrie, Berlin, 1970; Albach, H., Kloten, N., Gutachterliche Stellungnahme zu der Preispolitik auf dem Farbstoffmarkt in der EWG in der Zeit von 1964 bis 1967, Tübingen, 1973; Reader, W.J., Imperical Chemical Industries, a History, 2 volumes, Oxford University Press, 1970, 1975; Dirrheimer, M., Vertikale Integration in der Mineralöl- und Chemischen Industrie, Meisenheim am Glan, 1981; Legler, H., Internationale Wettbewerbsfähigkeit der westdeutschen Chemischen Industrie, Berlin, 1982; Taylor, G.D., Sudnik, P.E., Du Pont and the International Chemical Industry, G.K. Hall, Boston, MA, 1984; Streck, W.R., Chemische Industrie. Strukturwandlungen und Entwicklungsperspektiven, Berlin, 1984; Servatius, H.-G., Methodik des strategischen Technologie-Managements. Grundlage für erfolgreiche Innovationen, 2nd ed., Berlin, 1986; Lieberman, M., Patents, Learning by Doing, and Market Structure in the Chemical Processing Industries, in: International Journal of Industrial Organization, Vol.5, 1987, pp.257-276; Hounshell, D.A., Smith, J.K., Science and Strategy: Du Pont R&D, 1902-1980, Cambridge University Press, 1988; Spitz, P.H., Petrochemicals: The Rise of an Industry, New York, 1988; Stokes, R., Divide and Prosper: The Heirs of IG Farben under Allied Authority 1945-51, University of California Press, Berkeley and London, 1988; Lieberman, M., The Learning Curve, Technological Barriers to Entry, and Competitive Survival in the Chemical Processing Industries, in: Strategic Journal, Vol.10, 1989; Maynard, J.T., Peters, H.M., Understanding Chemical Patents: A Guide for the Inventor, American Chemical Society, Washington, D.C., 1991; Landau, R., Rosenberg, N., Successful Commercialization in the Chemical Process Industries, in: Rosenberg et al. (eds.), Technology and the Wealth of Nations, Stanford University Press, 1992; Liebenau, J., The Management of High Technology: The Use of Information in the German Chemical Industry, 1890-1930, in: Kudo, A., Hara, T., International Cartels in Business History, University of Tokyo Press, 1992;

[4] Cf. Amecke, p. 13

[5] Cf. Schulze, p. 6

industrial clients. Furthermore, as a result of the high degree of vertical integration within the chemical industry, 36 percent of the demand for chemical products originates from the chemical industry itself.[6] Other major consumers of the chemical industry are automobile manufacturers, the construction industry and agricultural industries.

Nowadays, a so-called product-group matrix (see Figure 2.1) prevails for the crude classification of chemical products. Four product groups are distinguished in accordance with the two dimensions of production quantity and differentiation level. Each of these groups shows specific characteristics that need to be observed in strategic planning. The models introduced in the previous section and the ensuing hypotheses can be ascertained by way of said product-group matrix. It is generally assumed that the following applies to the model of the product life cycle:

- For base chemicals, sometimes even for fine chemicals, the curve simply flattens in the stage of maturity and then stagnates, thus preventing a drop.
- For industrial and special products, however, the typical ideal curve applies, i.e. towards the end of the product life cycle the run of the curve begins to slope.

Output

high	**Basic Chemicals:** process development and improvement and only some product developments	**Industrial Chemicals:** process developments and improvements and only some product developments
low	**Fine Chemicals:** product and process developments and improvements	**Specialty Chemicals:** product developments and improvements and only some process developments
	low	**high**

Degree of differentiation

Source: Schmidt, p. 150

Figure 2.1 Product-Group Matrix

[6] Cf. Particulars from European Commission, p. 6-5

The product-group matrix permits conclusions concerning the business concentrations within the individual product groups. Due to their high degree of capitalisation, the base chemicals are produced by the major companies. Fine chemicals, on the other hand, and specialized products, above all, are produced by medium and small firms. Table 2.1 shows that the chemical industry is a fairly concentrated line of industry--although a certain balance between major companies and smaller firms prevails. For instance, the 10 leading EU-companies hold 48.6 percent of the entire industrial turnover; the five leading ones represent 32.6 percent of the turnover.[7]

Table 2.1 Concentration of the Chemical Industry within the European Union

Total Employees	Total Companies	% of all Companies	% of all Employees	% of EU-Turnover
less than 20	25,366	77.6	7.2	11.4
20 - 99	4,748	14.5	10.6	9.6
100 and above	2,595	7.9	82.2	79

Source: European Commission, p. 6-6

2.2 Typical Life Cycles: Two Examples

Products, technologies, and industries can be described in their respective life cycles. It is assumed that the chemical industry has already left its growth phase because of the following developments in the history of chemistry.

Since the beginning of the century, the chemical industry has been growing at a disproportionately high rate. Even between 1970 and 1990, the European chemical industry grew by 10 percent, while general productive industry reached a mere 2 percent.[8] This is mainly due to the substitution of traditional materials, such as wood, steel and glass, by chemical products--a development that was only made possible through continuous

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[7] Cf. European Commission, p. 6-5

[8] Ibid

introduction of new products and procedures. Since this has always called for high research expenses, the chemical industry is considered an extremely R&D-intensive one.

Some authors[9] see the explanation for the development of the chemical industry in so-called waves, triggered by certain basic innovations. According to Franck, the following innovations constituted revolutionary basic innovations: the production of mineral fertiliser in the first half of the 19th century, the introduction of the Haber-Bosch-process, the synthesis of organic colorants, and the development of plastics (the scientific foundation of which had already been laid in the 1920s and 1930s). Amecke, however, and the DRI Europe[10] argue that today the potential for further development of basic innovations made in the past is exhausted. Despite increasing R&D expenses (EU average at 4.8 percent of the turnover), the chemical industry is currently in a phase with little innovative opportunities. Whether or not the development of gene technology currently under way will be able to instigate a new upsurge in the chemical and pharmaceutical industries remains to be seen.

Figure 2.2 shows the life cycles (S-curves) for different processes for the manufacture of cord for tires. Due to differences in their technological potential substitution took place. Decreasing returns to cumulative R&D effort is evident. For example, the investment of the first 60 million US $ before 1962 has led to an improvement of the relative cord performance of 800 percent whereas the next 15 million US $ led only to an increase of 25 percent, and the final 25 million US $ to a performance increase of about 5 percent only. At the same time the nylon technology surpassed the performance of the rayon technology, but it reached its performance limit soon. Then the polyester technology took the lead. Thus it is obvious that the existence of decreasing returns to R&D in the chemical industry intensifies the search of firms for new technologies.

Another example is firm-specific and relates to the BASF portfolio of polymeric materials. Figure 2.3 shows the position of various polymeric material within the a 10 years life cycle. The performance is defined as market performance, that is the annual growth of output over the 10 years period. The circles are indicating the market volume of the particular material. The black circles are speciality polymeric material whereas the white circles are indicating the standadrd materials. The standard materials are in a more mature stage of the life cycle but they exhibit a considerably larger market volume. This simple model would advise the firms to invest R&D first of all into emerging technologies, that is into speciality chemicals but also in basic innovations in their respective areas of competence.

[9] cf. Mensch; Franck; Ayres

[10] Cf. European Commission, p. 6-8

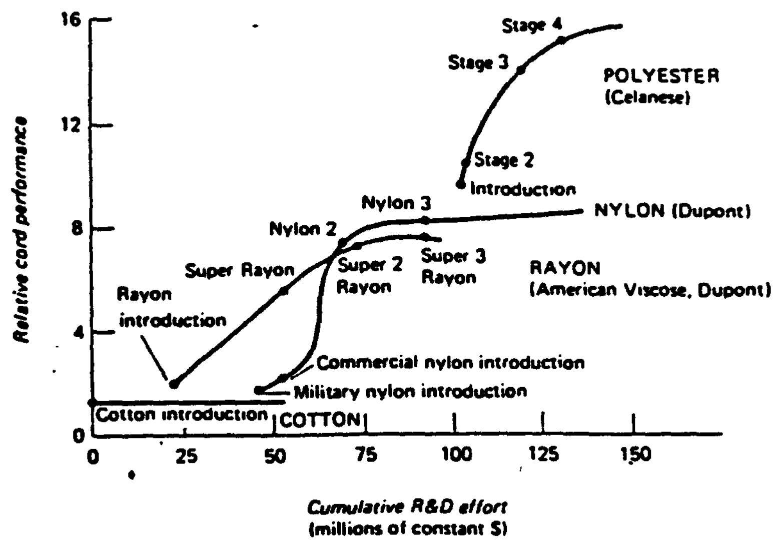

Figure 2.2 Life Cycles for Different Processes for the Manufacture of Cord for Tires
(Source: Ayres, p. 104)

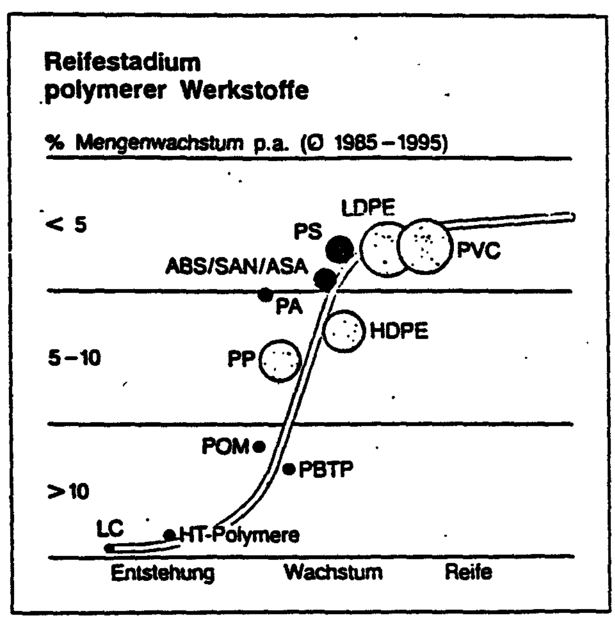

Figure-2.3 Stage of Product Life Cycle for Various Polymeric Materials
(Source: Quadbeck-Seeger, p. 5)

Corporate orientation towards specialized chemistry can also be considered to substantiate the theory of poor innovative opportunities. Specialized chemistry is characterized by higher profit margins and lower competitive pressure. It is highly influenced by clients' needs; very often, however, variations of already existing products are in the fore. The explanation for the distribution of R&D expenses as per Table 2.2 can also be found in this trend towards specialization. Similarly, the partial increase in product development can be explained by the above statement according to which the innovations in the specialized industry concern almost exclusively products. The fact that these product innovations are very often nothing but product variations or further developments of existing products is substantiated by the high and slightly increasing amount of R&D expenses for development shown in Table 2.2.

Table 2.2 Distribution of R&D Expenditures of German Chemical Firms According to Product and Process Innovation and by Innovation Significance
(in percent)

Type of Innovation	1977	1987	1989	1991
Product Innovations	73.8	78.2	77.6	82.5
Process Innovations	26.1	21.8	22.4	18.0
Innovation Significance				
Incremental Innovations	52.2	54.7	50.7	55.5
Major Innovations	47.8	45.3	49.3	44.5

Source: SV-Wissenschaftsstatistik, pp. 38-39

3 Measurement of Innovation Trends

3.1 The Measurement Approach

The subjects of the 10-year investigation at hand are nine selected European chemical companies. Apart from company size being a decisive factor in the selection of the relevant companies, the selection was also carried out with the goal of obtaining a broad range of chemical lines and a certain diversity in strategic orientation.

The annual reports of the respective companies, which are published annually, supply the relevant basic data. The following report items are investigated:

- Product and process innovations, which are then described in detail by means of a specially designed system;
- Quantitative data regarding R&D activities, such as R&D expenses and the number of employees involved in R&D;
- Quantitative data regarding corporate success and growth;
- Qualitative data regarding the strategies pursued by the individual lines of industry.

3.2 Selection of the Companies to be Investigated

The selection of the companies to be investigated was made according to their sizes and their lines of industry. In order to cover as many innovations as possible, and thus achieve results of the most accurate representativeness possible regarding prevailing trends in innovation, the major European chemical companies were chosen for the investigation. Table 2.3 shows the leading 15 European chemical companies, arranged in order of their total economic turnover (this ranking causes certain distortions, since the shares of chemicals in the individual turnovers may well differ in size; e. g. ICI shows a higher engagement in the chemical line than Sandoz).

From these 15 companies, nine were selected according to corporate profile and the availability of annual reports (see last column). Bayer and ICI represent the big, broadly diversified companies, while Ciba-Geigy and Sandoz stand for the specialized companies. Solvay and BASF, on the other hand, are more involved in basic chemicals. The innovative strategies of these companies are primarily dependent on their corporate know-how. This know-how, very often found mainly in the central areas of a company, is often the result of decades of R&D and, at the same time, a component of the corporate history. Therefore, a brief characterization of the companies under investigation is included in the appendix.

Table 3.1 The 15 Leading European Chemical Companies - 1992

Company	Country	Turnover in m ECU	Staff	Selected for study
Hoechst	D	22 727	177 668	yes
BASF	D	22 060	123 254	yes
Bayer	D	20 411	156 400	yes
ICI	UK	16 388	114 000	yes
Ciba-Geigy	CH	12 221	90 554	yes
Rhone-Poulenc	F	11 938	83 300	-
Sandoz	CH	7 935	53 360	yes
Akzo	NL	7 414	62 500	yes
Norsk Hydro	N	7 236	34 036	-
Roche Holding	CH	7 129	56 335	-
Smithkline Beecham	UK	7 091	53 700	-
Henkel	D	6 987	42 244	yes
Solvay & Cie	B	6 125	45 350	yes
Glaxo Holdings	UK	5 801	37 083	-
L'Oreal	F	5 489	31 908	-

Source: European commission, p. 6-7

3.3 Annual Reports as a Source of Information

Annual reports are bound to represent the economic situation of their respective companies in such a manner that the companies' true conditions are clearly reflected. This also applies to expected corporate developments. Since the prospective developments of research-intensive companies, such as chemical companies, very much depend on R&D, German law requires R&D reports. The German chemical association therefore recommends the declaration of the following data:[11] (1) R&D areas and R&D facilities, (2) R&D personnel and R&D expenses, (3) relevant results of R&D activities, as well as (4) the main R&D objectives. Germany's major chemical companies comply with these recommendations, while, in other countries, most annual reports are less detailed.

Usually, the amount of R&D expenses can be taken from the annual reports, which also supply the relevant data on turnover, balance-sheet total, annual net earnings and the respective operating results.

The most important source of information for the study at hand, however, is the status report, which is the main supplier for qualitative data on corporate and innovative

[11] Cf. Graumann, p. 194

strategies, as well as data on the major results and goals of R&D activities. This makes the status report the main source of information for the innovation counting underlying the study at hand.

3.4 Indicators of Innovative Activity

Indicators for the Rating of Innovative Activities The quantitative display of corporate innovative activities is only possible by means of indicators, which in the form of so-called 'representative variables' represent the unimaginable variable of 'innovative activity' more or less accurately. Because of the diversity of the innovative process as such, the indicators are split up into input indicators and output indicators. Typical input indicators include the number of R&D personnel or the amount of R&D expenses. Established output factors include the rate of product innovation (products newly introduced into the range of products over the past 5 or 10 years), the number of patents granted, the frequency of citation in scientific publications and the counting of innovations.

Input Indicators for the Rating of Research Expenses Various studies use the input indicators of R&D expenses and R&D personnel. The indicator of R&D personnel, however, has a certain disadvantage. In companies with capital-intensive R&D, the relevant R&D expenses are easily underestimated, while in companies with personnel-intensive R&D, an overestimation of these activities takes place. In addition, due to industrial reasons, R&D personnel can only be adjusted to changed R&D strategies after a certain time-lag. An additional advantage to using R&D expenses versus R&D personnel is the fact that by incorporation of outside services (such as R&D services carried out on order by third parties) the innovation input can be rated in a more complex manner.

R&D (Expense) Intensity is calculated by the division of the R&D expenses by the relevant turnover, or balance-sheet total, respectively. The turnover-related R&D expense intensity is the indicator more commonly used, while the expense intensity relating to the balance-sheet totals shows greater resistance to market swings.[12]

R&D Personnel Intensity is the quotient of the number of R&D personnel and the total number of employees.

Output Indicators for the Rating of Research Success The R&D output indicator best known and most easily accessible is the number of patents granted to a certain company. As an indicator, however, it also has two distinct disadvantages. First, the number of patents granted is but a poor reflection of the underlying innovations, since only a small number of patents are actually put to economic use. Second, the inclination towards patentation varies greatly among the different companies and lines of business. In some

[12] Cf. Schwitalla, p. 225

cases, inventions are never put up for patentation because other strategies, such as secrecy or an early market introduction, are given priority.

Our study uses therefore the number of innovations recorded in the annual reports as an output indicator. This indicator is characterized by greater proximity to the market and, thus, attaches greater stress to the economic aspect of innovation.

Financial Ratios for Corporate Success Corporate success is generally quoted in the form of profitability, cash-flow and profit-source analysis. This study uses the net profit ratio, as one of the most commonly used financial ratios, and on an analysis of the operating result. The net profit ratio is defined as follows:

- net profit ratio = $\frac{\text{annual net earnings}}{\text{turnover}} * 100$

An examination of the operating result is significant in so far, as it reflects only the result of the corporate effort, at the same time ignoring financial and participation results and taxes. The operating result is used to evaluate the profitability of the individual lines of business.

Financial Ratios for Corporate Growth We characterizes corporate growth by means of the annual turnover growth rates, balance-sheet totals, R&D expenses, R&D personnel and increases in the total numbers of employees.

3.5 The Classification System for the Recording of Innovations

The classification of individual innovations is done according to the product groups most commonly used in the chemical industry. However, a categorization as per Standard International Trade Classification (SITC, 3rd revision) or NACE system was not possible. On the one hand, the data concerning process and product innovations in the annual reports were not detailed enough to carry out an exact classification into the given product groups. On the other hand, the number of innovations under investigation was too small for a meaningful classification into the very specialized product groups of the SITC or NACE systems. As a result, new classifications of the existing material on the basis of prevalent categories (such as SITC, NACE, relevant literature) were developed during the course of the evaluation.

The new classification system was developed in connection with a pilot study and then further refined during the course of the evaluation of the annual reports. The pilot study investigated two annual sets (1988 and 1993) of the periodical "Europa Chemie," recording 135 innovations. The present study uses the pilot study to investigate the quantitative results of the innovation counting from the various annual reports.

Our classification comprises nine key groups, some of which are divided into sub-groups, thus enabling both a significant investigation of the material at hand and an identification of certain innovative trends. In addition, innovations are divided into product and process innovations and records are kept as to possible ecopolitical innovations.

The Classification System:

0 **Environmental Technologies:** This category includes mainly recycling technologies. These constitute a relatively new sphere of operation within the chemical industry, where repeatedly innovations are recorded, but do not fit into the traditional classification for chemical processes and products, so that this special category had to be introduced. However, this group also includes recycling technologies that are mainly used for the recovery of precious raw materials (such as platinum from catalysers) and are of a less ecopolitical nature.

1 **Basic Organic Materials:** Category No. 1 contains chemical elements, as well as intermediate products, produced in large quantities, manufactured from crude oil, natural gas or coal. This includes methanol, ethene, benzole, butadiene, chloroethylene, and unvulcanized rubber.

2 **Basic Inorganic Materials:** Category No. 2 includes inorganic elements manufactured in large quantities, which are needed as source material for various syntheses, such as ammonia, soda and sulphuric acid.

3 **Plastics:** Because of the complexity and heterogeneity of this subject, a further subdivision was attempted. However, the partiality and insufficiency of detailed information in the annual reports presented a problem to the realization of such classification. Finally a division was made into:

30 **Plastics** that do not fit into either 31 or 32.

31 **Traditional Mass Produced Plastics,** such as polyvinyl chloride, polyethylene, polystyrene, polypropylene, as well as any new developments on the basis of mass produced plastics.

32 **Special Plastics,** which are not based on traditional synthetic substances, such as polyetherketones, polyester resins, polysulfones, polyurethane, polyacetals, polycarbonates, and copolymers.

4 **Synthetic Fibres:** This category contains all synthetic fibres including fibres based on natural substances, such as cellulose (viscose, acetates, etc.). Its major component, however, consists of polyamide and polyester fibres.

5 **Paints, Varnishes:** Category No. 5 comprises both organic and inorganic colorants. Besides paints and varnishes, various coatings which are put to use as architectural

coatings, electrical insulation and in the automobiles industry also belong in this group.

6 **Agrochemicals:** Category No. 6 includes fertilizers, plant protectives and veterinary preparations. Plant protectives include insecticides, herbicides, fungicides, pesticides, and plant growth regulators.

7 **Detergents, Cleaning materials and Preservatives:** This category includes detergents, cleaning materials, preservatives, disinfectants and anti-corrosives for domestic and industrial use.

8 **Speciality Chemicals:** As a result of its heterogeneity and its importance concerning current innovative trends this category was split into the following sub-groups:

81 **Glues and Adhesives**

82 **Petrochemical Additives:** Additives for the production of crude oil, fuel additives, etc.

83 **Finishing Agents for Textiles and Leather**

84 **Paper Chemicals, Specialities for the Printing Industry**

85 **Specialities for Photographic Purposes**

86 **Specialities for Information and Entertainment Technology**

87 **Products for the Construction Industry**

88 **Plastic Additives:** Softening agents, antioxidant agents, etc.

89 **Miscellaneous:** Examples are: lubricants, explosive substances, industrial gases.

9 **New Materials:** The definition of this category is particularly problematic, since numerous so-called special plastics would also have to be included. In order not to mix up different product groups, we include here only those products that do not fit into any of the categories already described above. Accordingly, this category contains high-tech ceramics and special purpose glasses, but no modern polymers.

4 Innovation Trends I: An Analysis of Innovation Counting Data

4.1 An Analysis of Innovative Trends

The following section evaluates the results from the innovation counting, as well as the companies' success and financial ratios. The results from the innovation counting are examined separately for the individual lines of business. The most innovative lines are identified along with the relevant exemplary technological trends dominating the innovative activities in those lines. The extent of ecopolitically motivated innovations is also investigated, as is any progress where technological developments in the area of environment protection were triggered.

Apart from investigating the individual lines of business on the basis of the respective mean values of the past ten years, the study at hand attempts to describe any tendencies that may have appeared during the investigation period (1984 - 1993), i. e. those lines are identified whose innovative frequency was subject to change during the course of the ten years in question. This is done by means of a comparison of the innovative frequency of the respective fields at the beginning of the investigation period (1984/85) and at the end of the investigation period (1992/93).

4.1.1 An Analysis of Innovative Trends by Lines of Business

The evaluation of 1,299 recorded innovations shows that the areas of speciality chemicals, paints and varnishes, and plastics comprise the most innovative fields within the chemical industry. Detailed results are to be found in Table 4.1. A comparison with the results of the pilot study (see Table 4.1, Column 3) shows extensive congruence between the results of the pilot study and those of the annual reports. The following section constitutes an investigation of innovative tendencies by lines of business, presented in the order of the innovative share of that particular line of business in the total number of innovations.

Speciality Chemicals The subdivided evaluation of this line of business shows the areas of glues/adhesives, preparing agents for textiles and leathers, and chemicals used in the paper and printing industry to have been particularly innovative.

New developments in the field of glues and adhesives are very often based on further developments of polymers. The past few years' progress in glues/adhesives technology allowed a substitution of traditional mediums such as screws and bolts. Technologies concerning glues and adhesives are of major economic significance, since they belong to the so-called cross section technologies, i. e. they very often form the basis for innovations in other lines of industry, such as the aviation industry.

Table 4.1 Shares of Product and Process Innovations (in percent)

Category	Description of Category	Pilot Study	Main Investigation - Innovation Counting					
				Share of Product/Process Innovations		Share in Ecopolitically Motivated Innovations		
		Innovative Share	Innovative Share	Share of Product Innovations in Innovation Total	Share of Process Innovations in Innovation Total	Share in ecopolitically motivated Inno. in Innovation Total	Share in ecopolitically motivated Inno. in Product Innovation	Share in ecopolitically motivated Inno. in Process Innovation
0	Environmental Technologies	7.4	2.3	20.0	80.0	93.3	66.7	100.0
1	Basic Organic Chemicals	5.9	3.5	45.7	54.3	39.1	38.1	40.0
2	Basis Inorganic Chemicals	1.5	0.5	28.6	71.4	28.6	0.0	40.0
3	Plastics. that do not fit in 31 or 32		0.5	57.1	42.9	14.3	0.0	33.3
31	Traditional Mass Produced Plastics	4.4	4.0	84.6	15.4	5.8	4.5	12.5
32	Special Plastics	13.3	11.2	95.9	4.1	8.3	7.9	16.7
	Sum Plastics	*17.7*	*15.7*	*91.7*	*8.3*	*7.8*	*7.0*	*17.6*
4	Man-made fibres	3.7	3.2	73.8	26.2	7.1	0.0	27.3
5	Paint. Varnishes	27.4	24.9	94.7	5.3	24.5	22.9	52.9
6	Agrochemicals	6.7	11.8	97.4	2.6	7.2	6.0	50.0
7	Maintenance Products	5.9	9.5	96.8	3.2	12.9	11.7	50.0
81	Glues and Adhesives	11.1	5.1	100.0	0.0	27.3	27.3	0.0
82	Petrochemical Additives		1.0	100.0	0.0	30.8	30.8	0.0
83	Finishing Agents for Textiles and Leather		4.2	92.6	7.4	16.7	16.0	25.0
84	Chemicals for Paper and Printing Ind.		3.4	93.2	6.8	6.8	7.3	0.0
85	Chemicals for Photographic Purposes		2.9	97.4	2.6	2.6	2.7	0.0
86	Chemicals for IT		1.1	100.0	0.0	0.0	0.0	0.0
87	Chemicals for Construction Ind.		1.7	95.5	4.5	0.0	0.0	0.0
88	Plastic Additives		1.9	92.0	8.0	8.0	8.7	0.0
89	Miscellaneous	8.2	6.7	92.0	8.0	5.7	5.0	14.3
	Sum Specialities	*19.3*	*27.9*	*95.0*	*5.0*	*11.6*	*11.6*	*11.1*
9	New Materials	4.4	0.5	85.7	14.3	0.0	0.0	0.0
	Sum of all Innovations	**100**	**100**	**90.3**	**9.7**	**16.6**	**13.5**	**45.2**

The relatively high share (27 percent) of ecopolitically motivated innovations in the field of glues and adhesives is mainly due to the introduction of solvent-free glues and adhesives, such as dispersion binders and adhesives.

The relatively high share of ecopolitically motivated innovations concerning additives for the petrochemistry results for instance from the substitution of drilling aids based on mineral oil by those based on fatty chemicals (biologically decomposable esters) or the introduction of environment friendly fuel additives.

The majority of innovations connected with speciality chemicals are product innovations (95 percent). This is due to the low production quantities and, at the same time, extremely high level of differentiation in the area of speciality chemicals (see product group matrix, Figure 2.1).

Paints and Varnishes Coming second in our quantitative analysis, this line of business shows an innovative frequency of 25 percent--with the companies ICI, BASF, Herberts GmbH (Hoechst subsidiary) and Akzo representing the market leaders. Analogue to glues and adhesives, paints and varnishes have a high share of product innovations (95 percent) and ecopolitically motivated innovations (approx. 25 percent). This high share in product innovations is, among other reasons, the result of a constant change in fashion concerning consumer goods, which leads to new colours having to be introduced into the market with great frequency.

A tendency towards solvent-free varnishes is also noticeable. Especially in the automobile industry--the primary customer for liquid industrial varnishes--which has increasingly been using solvent-free aqueous varnishes in their production (e. g. electrophoretic enamelling). Again, polymers played a very important part in the development of these varnishes. A still greater potential for development than even these varnishes, however, lies in coating powders and multicomponent systems respectively, such as with epoxy-amino systems.[13]

Plastics The investigation shows an innovative share of approximately 16 percent for the field of plastics, which places them in the third position. Upon registration of the innovations, it was attempted to split the plastics up into two groups. Such a classification, however, turned out to present certain problems, since the area of plastics is extremely diverse and the information in the annual reports very often does not suffice for a precise classification. Yet, there is a distinct difference concerning the innovative share between the traditional mass produced plastics and the newly developed speciality plastics. The fact that the innovative share is more than 10 percent higher for process innovations conforms with the statements of the technological life cycle model, according to which the more 'mature' lines of business produce a higher rate of process innovations.

[13] Cf. Annual Report Hoechst 1991, p. 9

Very important for the mass production of plastics was the development of polymerization catalyzers. A new class of metal-based catalysers of great chemical variability was established with the introduction of metallocenes, i.e. zirconium or hafnium compounds. These, among other characteristics, enable the melting point of the developing plastics to be fixed between 100°C and 165°C, and allow their hardness and transparency to be varied.

In the line of plastics it is not the development of new polymers that is in the fore, but the modification of already existing ones.[14] Above all, so-called polymer blends, i. e. polymer alloys are being developed and introduced into the market. Composite materials with a polymer matrix are also considered to be innovative areas. They consist of fibre material immersed in a polymer matrix and, thus, show properties unknown in homogenous material. New developments of the fibre industry, such as carbon fibres and aramid fibres (aromatic polyamide), are also put to use here.

Agrochemicals and Fertilizers Their innovative share of 11.8 percent originates almost exclusively from agrochemicals, not from fertilizers.

Agrochemicals rank amongst the most R&D-intensive lines of business and show similarities to the R&D of pharmaceutics. During the course of the investigation, the extremely low share of biotechnologically manufactured plant protectives became noticeable. Solely, Ciba-Geigy introduced two such products. In research, however, biotechnology (gene technology) plays a vital role. This observation coincides with the S-curve theory. Gene technology is at an early developing stage. This leads to the conclusion that a rapid growth in biotechnologically manufactured products is to expected within the next few years. Accordingly, Ciba-Geigy aim at having introduced ten products on a biotechnological basis by the year 2000. ICI also describe their biotechnological engagement in plant protection as very intensive and complex, as well as "very long-term."[15] Today's innovations in the field of agrochemicals are still being created by means of traditional syntheses, with the focus mainly on a decrease in concentration requirements, an increase in selectivity, a higher environmental acceptability, and a better way of distribution on the fields that presents less problems to the farmers (for instance use of non-powdering granules instead of powder).

Detergents, Cleaning Materials and Preservatives The high innovative share (9.5 percent) in this line of business is mainly due to innovations introduced by Henkel. Accordingly, more than 50 percent of all innovations produced by Henkel are to be found in this category. As far as the relation between product innovations and process innovations is concerned, the conditions are similar to those of the speciality chemicals.

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[14] Cf. Chemische Industrie 10/92, p. 29

[15] Cf. Annual Report ICI, 1988, p. 10

For detergents, priority was given to the development of environment friendly, i. e. biologically decomposable, compact detergents. Henkel, for instance, produced phosphate-free detergents, where the phosphate compounds, which bind the hardening agents of water in soluble complexes, are substituted by synthetic sodium-aluminium silicates that belong to the zeolites (brand name: Sasil). Furthermore, there is a tendency towards materials on the basis of regenerating resources, such as starch and/or fat. The tensides developed by Henkel on the basis of alkyl polyglucosides serve as a relevant example.[16]

Synthetic Fibres This line of fibres accounts for a mere 3.2 percent of all innovations and, with the exception of high-tech fibres, ranks amongst the more mature industries. In accordance with the technological life cycle model this is also confirmed by the generally lower innovative rate and a relatively high share in process innovations (26.6 percent).

The fibres made from polyaramides represent an interesting new development and are characterized by extreme stability. Besides these fibres, extremely temperature resistant fibres such as fibres from polybenzimidazole or fibres on the basis of polyacrylnitrile were specially developed for industrial use in the aviation and construction industries in order to substitute for asbestos.[17] In addition, heavy duty fibres are increasingly used in composite materials, where their main purpose is an increase of elasticity.

Basic Organic and Inorganic Chemicals Similar to the production of fibres, basic chemicals have a poor innovative frequency (4 percent), but generate a high share in process innovations (54 percent for basic organic chemicals and 71 percent for basic inorganic chemicals). Since both these lines of business belong to the more mature industries, the results coincide with the relevant statements made in the technological life cycle model.

There is also a noticeably high share in ecopolitically motivated innovations, due to the introduction of CFC-substitutes. The 40 percent share in ecopolitically motivated process innovations is also very high. Very often these process innovations are, in fact, process optimizations which aim at a reduction of arising by-products and waste. Some of them, however, are new processes, such as the process Hoechst introduced in order to reduce aromatic amines.[18]

Environmental Technologies Environmental technologies constitute a relatively young area within the chemical industry itself. Their innovative share amounts to 2.3 percent. Examples for environmental technologies include the bio-highreactor (Hoechst) or recycling plants for plastic waste.

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[16] Cf. Annual Report Henkel, 1990, p. 13

[17] Cf. Hoechst - Neue Wege, p. 83

[18] Cf. Hoechst - Neue Wege, p.104

New Materials The very low share (0.5 percent) of new materials in the investigation at hand is due to most of the modern polymer compounds and composite materials belonging to the category of special plastics. Ceramic materials, on the other hand, as with special glasses, belong to this category. Ceramic materials, above all others, offer a multitude of applications, thanks to their hardness as well as their resistance to wear and deformation. The innovations in this field aim mainly at a reduction of the typical disadvantages of ceramics, such as brittleness as a possible source of fissuring.

4.1.2 The Innovative Trends of the 1980s and 1990s

In order to highlight the innovative trends of the investigation period (1984 - 1993), the innovations of the first two years (1984/85) and those of the last two years (1992/93) were compared according to lines of business. This was done to draw the attention to possible changes in innovative intensity.

The results are documented in Table 4.2. The strong increase in innovative shares for the areas of environmental technologies and products for information technology (specialities) is due to the increased economic significance of these industries. The extent of the changes that occurred in the fields of plastics, agrochemicals and preservatives/cleaning materials, however, is difficult to explain, since the conditions concerning R&D and production were not subject to significant changes during these ten years in question.

Very noticeable is a strong decrease in the number of innovations reported. While 290 innovations were reported in the years of 1984/85, only 202 were reported for 1992/93. On the one hand, this can be attributed to the major crisis in which the chemical industry was caught up in the beginning of the 1990s. On the other hand, however, this decline can be seen as an indicator for the increasing difficulty of the chemical industry to produce innovations. The latter would then confirm the thesis of the chemical industry being in the so-called phase of maturity.

4.2 An Analysis of Innovation and Performance Measures

The following sections use the extracted data to elucidate the different corporate profiles by comparing R&D input data with the relevant R&D output data for the respective companies. For each of the companies, we will show which of their lines of business are particularly innovative and also identify the lines of business which were able to record an especially large turnover growth. The results are then used to explain the differences in turnover returns of the individual companies.

Table 4.2 Description of Trends: Comparison of Innovations in 1984/85 and 1992/93

Category	Description of Category	Number of Innovations 1984/85	Shares (pct)	Number of Innovations 1992/93	Shares (pct)
0	Environmental Technologies	3	1.0	12	5.9
1	Basic Organic Chemicals	10	3.4	11	5.4
2	Basis Inorganic Chemicals	3	1.0	2	1.0
3	Plastics. that do not fit in 31 or 32	3	1.0	0	0.0
31	Traditional Mass Produced Plastics	15	5.2	3	1.5
32	Special Plastics	37	12.8	13	6.4
	Sum Plastics	*55*	*19.0*	*16*	*7.9*
4	Man-made fibres	11	3.8	10	5.0
5	Paint. Varnishes	74	25.5	35	17.3
6	Agrochemicals	31	10.7	36	17.8
7	Maintenance Products	21	7.2	29	14.4
81	Glues and Adhesives	15	5.2	8	4.0
82	Petrochemical Additives	5	1.7	3	1.5
83	Finishing Agents for Textiles and Leather	11	3.8	8	4.0
84	Chemicals for Paper and Printing Ind.	10	3.4	6	3.0
85	Chemicals for Photographic Purposes	5	1.7	0	0.0
86	Chemicals for IT	2	0.7	6	3.0
87	Chemicals for Construction Ind.	5	1.7	4	2.0
88	Plastic Additives	7	2.4	3	1.5
89	Miscelianeous	22	7.6	13	6.4
	Sum Specialities	*82*	*28.3*	*51*	*25.2*
9	New Materials	0	0.0	0	0.0
	Sum of all Innovations	**290**	**100**	**202**	**100**

4.2.1 A Comparison of R&D Input Indicators

Comparison of R&D Expense-Intensity Figure 4.1 shows the temporary development of R&D expense intensity for the individual companies. It is obvious that almost all companies show increasing R&D expense intensity. This may be due to an increased orientation towards the R&D intensive areas of pharmaceutics and speciality chemicals, but could also be the result of decreasing R&D productivity.

The reasons for these differences in R&D expense intensity are mainly to be found in the individual corporate profiles. Therefore, differences with respect to innovative strategies can only be portrayed with great difficulty by means of this data. Bayer, however, shows a vast increase, which is partially due to Bayer planning to increase their pharmaceutical share in total turnover by 30 percent by the year 2000. Figure 4.1 identifies four groups of companies whose curves show similarities.

The highest R&D intensities were reached by the two Swiss companies, Sandoz and Ciba-Geigy. This is mainly due to their strong engagement in the extremely R&D intensive fields of pharmaceutics and agrochemicals. Accordingly, in 1993, Sandoz spent 18 percent of their pharmaceutical turnover on R&D in the pharmaceutical line. The respective European mean value, however, lies at 4.8 percent.

Another group includes Bayer and Hoechst, whose R&D expense intensities were similar until the late 1980s. This is due to their similarly structured product ranges as well as comparable corporate sizes; both companies show strong engagement in the fields of pharmaceutics, polymers and agriculture.

Remarkable in this context is the fact that not only their R&D expense intensities drifted apart in the beginning of the 1990s, but also their return on sales (see Figure 4.1). The lower R&D expense intensity shown by Hoechst is mainly due to a large increase in turnover as a result of acquisitions, such as Celanese.

The largest economic group includes BASF, ICI, Akzo, and Solvay. The R&D expense intensities of these companies amount to 3-5 percent. These companies are considered to be fairly diverse, i. e. their product ranges include raw materials and basic chemicals, as well as pharmaceutics. Akzo, for instance, is still very active in the production of fibres, while Solvay produces mainly basic chemicals and mass produced plastics--however, they are both very much engaged in the production of pharmaceutics. The vast decrease in R&D expense intensity incurred by ICI in 1992 is a result of their having split off their lines of pharmaceutics and agriculture.

The lowest R&D intensity, approximately 3 percent, was shown by Henkel. Most likely, their multitude of consumer products, such as Persil, requires little R&D, yet contributes greatly to their turnover.

Figure 4.1 R&D Intensities for Large Chemical Firms, 1984-1993

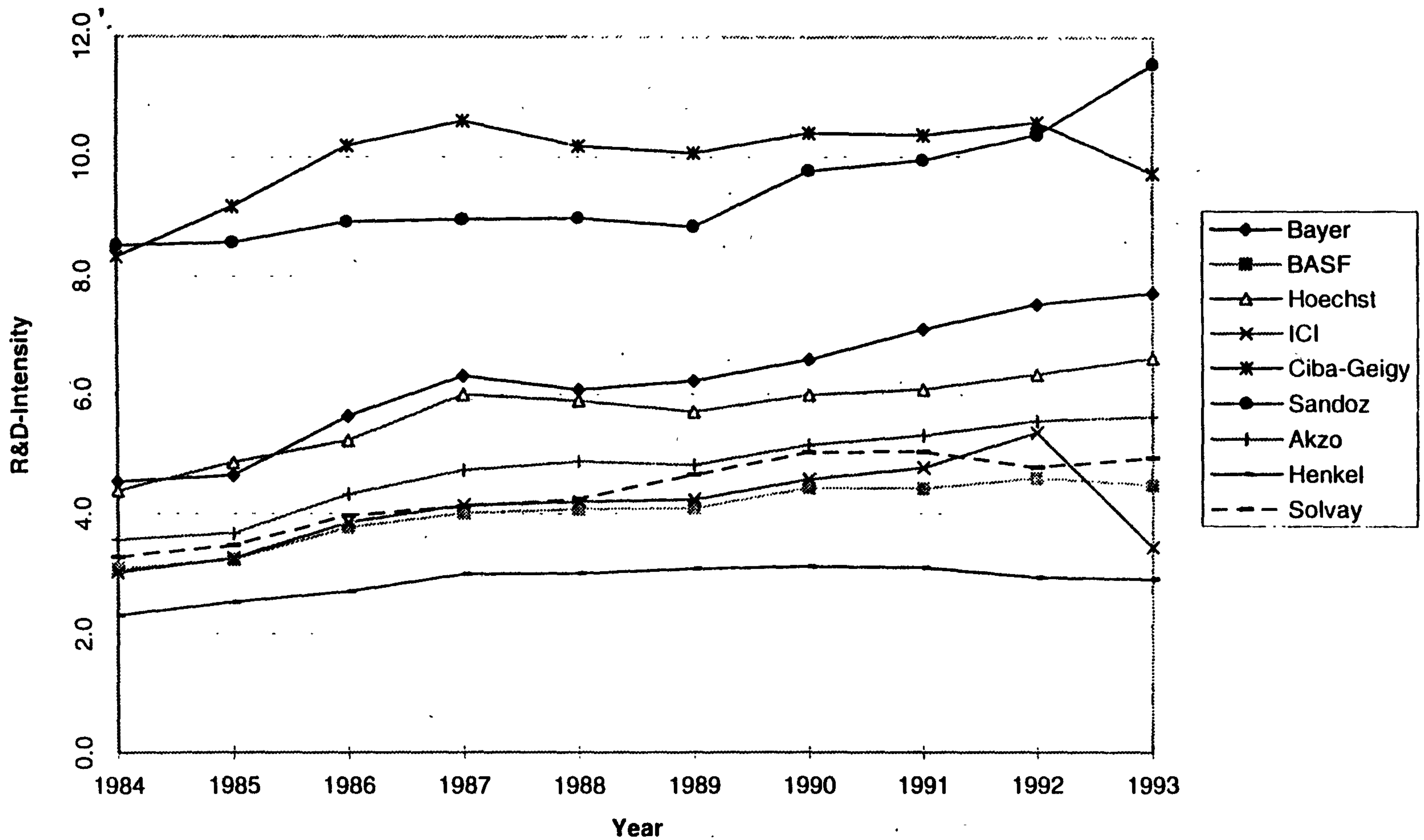

Table 4.3 R&D Shares of Individual Lines of Business

Company	R&D Share Bigger than Sales Share	R&D Share and Sales Share more or less Equal	R&D Share Smaller than Sales Share
Bayer	Pharmaceutics Agriculture	Polymers Agfa-Gevaert	Industrial Chemicals
BASF (as of 1991)	Agriculture Consumer Goods	Chemicals Colorants/ Refining Products	Gas and Oil Plastics/Fibres
Hoechst (as of 1986)	Pharmaceutics Agriculture		Polymers Technics Chemicals/Paints Fibres/Foils
ICI	no data supplied		
Ciba-Geigy (as of 1991)	Pharmaceutics	Agriculture	Industry
Sandoz	Pharmaceutics	Seeds Agrochemistry	
Akzo	no data available		
Henkel	no data available		
Solvay	no data available		

Table 4.3 shows the different R&D expense intensities mentioned above. According to the data extracted from the annual reports the R&D shares were estimated against the turnover shares for the respective lines of business and then split into three categories. The R&D share refers to the share of the respective line of business in the R&D budget of the individual company. Please note that the definitions of these lines were adapted from the individual companies and are therefore not uniform. The share in turnover refers to the share of the respective line of business in the turnover of the individual company.

An R&D share of a certain line of business exceeding the respective turnover share indicates that the line of business in question is an R&D intensive one. R&D-intensive fields include pharmaceutics and agrochemicals, while lines such as mass produced plastics and fibres belong to the lines with a lesser R&D intensity.

Applied to the S-curve model, the results from Table 4.3 show a bigger innovative potential for pharmaceutics and agrochemicals, since companies with knowledge of the S-curve tend to invest more into lines of business with a high innovative potential.

Comparison of R&D Personnel Intensity The evaluation of R&D personnel intensity is subject to certain limitations. Thus, the high personnel intensity of BASF is largely due to their production being less personnel intensive than the production of Bayer or Hoechst. This means that the three companies differ not so much in the number of R&D personnel, but in their total number of employees, as is also confirmed by the low share of salaries and wages in the turnover (see also Table 4.4).

The data pertaining to Henkel and Solvay, however, can only be evaluated in a contradictory manner. Solvay shows an extremely low R&D personnel intensity, although their not very personnel intensive production should indicate a high R&D personnel intensity, further, their R&D expense intensity conforms to the mean value for that particular line of business. The reasons could possibly be found in their extremely capital-intensive, yet barely personnel-intensive R&D.

It is also noticeable that Henkel shows a relatively high R&D personnel intensity, as opposed to their very low R&D expense intensity. The low R&D expense intensity (2.9 percent) of this company seems to indicate that Henkel's R&D is not very capital-intensive.

Perhaps, the above mentioned discrepancies may be attributed, however, to the diverging classification criteria appertaining to R&D personnel used by the individual companies .

Table 4.4 R&D Personnel-Intensity (10-year averages)

Company	R&D Personnel-Intensity (%)	Company Share of Salaries and Wages in Turnover (%)
Bayer	7.6	24.4
BASF	9.1	18.0
Hoechst	8.4	23.5
ICI	6.8	16.2
Ciba-Geigy	no data available	
Sandoz	no data available	
Akzo	9.1	22.8
Henkel	7.3	17.6
Solvay	5.5	18.5

4.2.2 A Comparison of R&D Outputs

Table 4.5 shows the three most innovative lines of business for the individual companies, with the numbers in parentheses indicating their innovative core activities within the area of plastics and speciality chemicals. The allocation is based on the classification system established in the study at hand, not on the categorization of the individual companies. See Table 4.6 for a detailed evaluation.

The order of precedence elucidates once more the different corporate profiles. All in all, the high portion of plastics, speciality chemicals and paints/varnishes is noticeable. The fact that agrochemicals, in spite of their ranking amongst the most R&D intensive fields, only come in third, is partially due to their lower share in turnover. As a result of inconsistent line definitions (turnover shares in accordance with the companies' classifications, and innovative shares in accordance with the classification system established in the present study), an actual weighing of innovative shares against their turnover shares was not feasible.

Table 4.5 Ranking of Innovative Core Activities by Individual Companies

Company	Position 1	Position 2	Position 3
Bayer	Speciality Chemicals (81)	Paints/Varnishes	Plastics (32)
BASF	Paints/Varnishes	Plastics (31)	Speciality Chemicals
Hoechst	Plastics (32)	Paints/Varnishes Speciality Chemicals	Agrochemicals
ICI	Speciality Chemicals	Paints/Varnishes	Agrochemicals
Ciba-Geigy	Paints/Varnishes	Speciality Chemicals	Agrochemicals
Sandoz	Speciality Chemicals (83)	Paints/Varnishes	Agrochemicals
Akzo	Paints/Varnishes	Speciality Chemicals	Agrochemicals
Henkel	Maintenance	Speciality Chemicals (81)	insignificant
Solvay	Plastics (32)	Speciality Chemicals	Basic Organic Chemicals

The innovative core activities of the individual companies also explain the different R&D expense intensities as shown in Figure 4.1. BASF, for instance, has their innovative core activities in paints/varnishes, as well as in mass produced plastics. The R&D expense

Table 4.6 Innovative Shares According to Categories and Corporate Evaluation (in percent)

Category	Description of Category	Bayer	BASF	Hoechst	ICI	Ciba-Geigy	Sandoz	Akzo	Henkel	Solvay	Total
0	Environmental Technologies	1.9	2.0	7.4	5.5	0.0	1.3	0.0	3.1	5.8	**2.3**
1	Basic Organic Chemicals	3.7	2.8	3.7	6.6	0.0	0.0	8.5	1.3	9.6	**3.5**
2	Basis Inorganic Chemicals	0.0	0.0	3.7	2.2	0.0	0.0	0.7	0.0	1.9	**0.5**
3	Plastics, that do not fit in 31 or 32	1.1	0.4	0.0	1.1	0.6	0.0	0.7	0.0	0.0	**0.5**
31	Traditional Mass Produced Plastics	0.7	14.2	4.9	0.0	0.0	0.0	0.0	0.0	19.2	**4.0**
32	Special Plastics	16.7	11.9	19.8	11.0	14.0	1.3	0.7	0.6	34.6	**11.2**
	Sum Plastics	*18.6*	*26.5*	*24.7*	*12.1*	*14.6*	*1.3*	*1.3*	*0.6*	*53.8*	***15.7***
4	Man-made fibres	3.3	2.4	9.9	2.2	0.0	1.3	10.5	0.0	0.0	**3.2**
5	Paint, Varnishes	23.8	34.4	16.0	24.2	29.9	27.6	41.2	2.5	0.0	**24.9**
6	Agrochemicals	10.4	4.7	14.8	16.5	24.4	21.1	15.7	0.0	11.5	**11.8**
7	Maintenance Products	3.3	4.7	2.5	3.3	2.4	3.9	3.3	53.1	1.9	**9.5**
81	Glues and Adhesives	3.7	2.0	0.0	3.3	5.5	1.3	0.7	23.1	0.0	**5.1**
82	Petrochemical Additives	0.0	2.8	1.2	1.1	0.0	0.0	0.0	2.5	0.0	**1.0**
83	Finishing Agents for Textiles and Leather	4.8	5.5	0.0	1.1	4.9	18.4	0.0	2.5	0.0	**4.2**
84	Chemicals for Paper and Printing Ind.	3.7	4.7	7.4	2.2	0.0	9.2	2.6	1.9	0.0	**3.4**
85	Chemicals for Photographic Purposes	13.0	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0	**2.9**
86	Chemicals for IT	2.2	2.4	1.2	1.1	0.0	0.0	0.0	0.0	0.0	**1.1**
87	Chemicals for Construction Ind.	1.1	0.0	0.0	2.2	0.0	9.2	0.7	3.8	5.8	**1.7**
88	Plastic Additives	0.0	2.0	0.0	3.3	6.1	3.9	2.0	0.6	0.0	**1.9**
89	Miscellaneous	5.6	3.2	6.2	12.1	10.4	1.3	11.1	5.0	9.6	**6.7**
	Sum Specialities	*34.2*	*22.5*	*16.0*	*26.4*	*28.7*	*43.4*	*17.0*	*39.4*	*15.4*	***27.9***
9	New Materials	0.7	0.0	1.2	1.1	0.0	0.0	2.0	0.0	0.0	**0.5**
	Sum of all Innovations	**269**	**253**	**81**	**91**	**164**	**76**	**153**	**160**	**52**	**1299**

intensity for paints/varnishes at BASF amounted to merely 2.68 percent[19] in 1988, a figure much lower than the company's total R&D expense intensity of 4.1 percent.

Another very interesting figure is Henkel's share of preservatives and cleaning agents of more than 50 percent. This line of business seems to require only very low R&D expense intensity, a theory which would at least explain Henkel's low R&D expense intensity. As for Sandoz, their high share of preparing agents for textiles and leathers, which exceeds even the innovative shares of paints/varnishes and agrochemicals, calls for attention.

The intended evaluation of companies with a view to innovative strength by way of their number of reported innovations could not be carried out, since during the course of the investigation the companies' inclination to actually report their innovations turned out to vary considerably. Bayer, for instance, reported 269 innovations during the investigation period of 1984-1993, while Hoechst with their similar range of products reported a mere 81 innovations over the same period of time. Another argument against an evaluation of the companies' ability to innovate is the fact that their product ranges differ considerably, while this study was not in a position to consider anything but their chemical fields. Accordingly, the innovative shares shown in Table 4.6 refer only to their chemical activities in accordance with the classification definition underlying the study at hand.

4.2.3 Growth in the Individual Lines of Business

Table 4.7 splits up the individual lines of business into the groups of growth, relative consistency and decline, according to the development of their turnover during the period of 1984 - 1993. In this case, the companies' definitions of the individual lines of business were adapted by the study at hand.

Growth in pharmaceutics and/or consumer-related business lines such as cosmetics (Henkel) or consumer goods (BASF) is of major strategic importance for almost all the companies. The area of paints and varnishes is also expanding, at least as far as Akzo and ICI are concerned. The lines of plastics, fibres and agriculture, on the other hand, are on the decline. The companies under investigation also suffered a turnover decrease in the areas of raw materials/energy (BASF) and petrochemicals (ICI), respectively. Also worth mentioning is the consistency shown by Sandoz with respect to their turnover shares.

The conformance between R&D expense intensity and turnover growth for the individual lines of business is remarkable. Therefore, a positive relation between R&D expense intensity and turnover growth can safely be said to have been established, except where agriculture is concerned. Although agriculture ranks amongst the R&D intensive lines of business, it does not belong to the lines whose turnover is expanding. This is partially due to the declining turnover rates in fertilizers. Innovations, on the other hand, are to be found

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[19] Cf. Rohe, p. 20

in the area of agrochemicals, i. e. in insecticides, herbicides, etc., while the high degree of R&D intensity can partially be attributed to the strict environmental and application regulations.

Table 4.7 Growth Trends by Individual Lines of Business

Company	Growing	Fairly Constant	Declining
Bayer	Pharmaceutics	Polymers Organics Industrial Chemicals Agriculture Agfa-Gevaert	
BASF	Consumer Goods Plastics	Colorants Refining Products	Chemicals Agriculture Raw Materials/Energy
Hoechst	Pharmaceutics Technics	Agriculture	Fibres Polymers
ICI	Pharmaceutics Paints/Varnishes	Chemicals	Petrochemistry and Plastics
Ciba-Geigy	Pharmaceutics	Colorants Chemicals Pigments Mettler	Agriculture Polymers
Sandoz		Chemicals Agriculture Pharmaceutics Nutrition Seeds	
Akzo	Pharmaceutics Paints/Varnishes Chemicals		Fibres
Henkel	Cosmetics	Detergents/ Cleaning Agents Glues/Adhesives Technical Brands Hygiene and Metallo-Chemistry	Chemicals
Solvay	Pharmaceutics	Alkalines Peroxides Plastics and Plastic Processing	

According to Table 4.8 growth rates of the various companies differed greatly. These differences are largely due to acquisitions. Since there is no way to identify exactly the individual shares of said growth, i. e. the share based on innovations and the share based on acquisitions, company growth is not included in the present study.

Table 4.8' Mean Accounting Ratios

Company	R&D Intensity (RD/Sales)	R&D to Balance Sheet Total	R&D-Personnel Intensity	rel. R&D Personnel Intensity	Salary Share of Turnover	Return on Sales	Return on Equity	Return on Total Assets	Return on Operating Profit	Increase Turnover	Increase R&D-Expenses	Increase Balance Sheet Total	Increase Employ-ment	Increase R&D-Employees
Bayer	6.2	7.3	7.6	1.2	24.4	3.9	11.3	7.1	10.4	0.87	5.13	2.58	-1.46	-0.64
BASF	4.0	5.3	9.1	2.3	18.0	2.5	8.6	4.8	8.5	0.78	3.17	4.70	-2.39	-0.62
Hoechst	5.7	7.6	8.4	1.5	23.5	3.5	13.0	7.3	9.6	2.54	5.81	4.88	-0.77	0.46
ICI	4.1	4.5	6.8	1.9	16.2	5.2	9.0	8.4	9.8	2.23	9.08	3.49	0.12	
Ciba-G.	10.0	7.4			30.3	7.0	8.6	6.8	4.5	2.52	4.27	3.69	0.76	
Sandoz	9.4	8.6			20.8	7.8	13.0	8.9	5.5	7.38	10.55	10.11	3.48	
Akzo	4.8	6.1	9.1	1.9	22.8	4.5	16.4	7.9	10.3	-0.31	4.86	3.10	-1.02	2.14
Henkel	2.9	4.0	7.3	2.4	17.6	2.9	9.9	7.0	7.9	4.13	6.55	6.55	2.30	2.02
Solvay	4.4	4.6	5.5	1.3	18.5	4.2	13.4	6.7	10.0	0.86	5.21	3.79	-0.15	

Note: For Ciba-Geigy salary shares of turnover include social expenditures

The data found in Table 4.7 is directly related to the product life cycle model, since it is in said product life-cycle model that the stages of maturity are identified by way of turnover growth. Accordingly, those lines of business that show a growing turnover--pharmaceutics, paints and varnishes, etc.--are placed in an earlier stage of maturity than the areas of fibres or chemicals.

4.2.4 Corporate Success and Profitability in the Individual Lines of Business

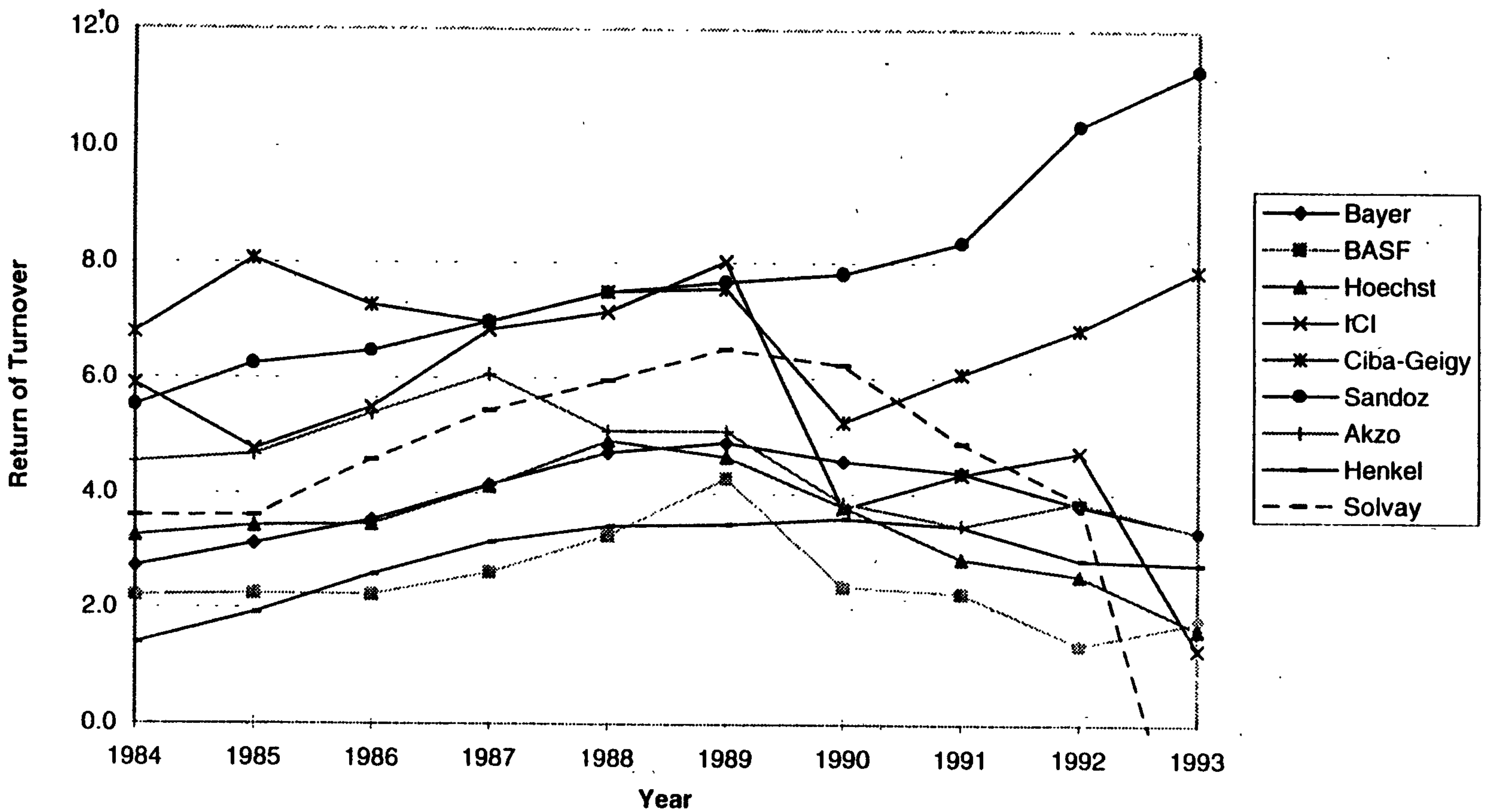
The development of the return on sales as shown in Figure 4.2 reflects the cyclical trends which have occurred. The different rates of return on turnover for the individual companies largely depend on the respective corporate profiles. See Table 4.9, Column 2 for the most profitable fields. Accordingly, those companies are the most successful whose turnover originates mainly from those lines. The companies with profitable pharmaceutics lines were the most successful ones. Furthermore, it is noticeable that:

- the two Swiss companies, Ciba-Geigy and Sandoz, were able to actually achieve a turnover growth at a time when most companies were suffering a decline in turnover returns. This is probably due to their strong orientation towards pharmaceutics and speciality chemicals. Besides, Sandoz is strongly represented in markets for consumer goods, such as nutrition.
- some companies, such as Bayer and Henkel, seem to be less dependent on market swings than others such as Solvay, ICI or BASF. Basic chemicals and plastics are considered especially cyclical, while other fields (such as pharmaceutics, part of the speciality chemicals, cosmetics, and varnishes) are rather resistant to cyclical swings.

Table 4.9 classifies the business lines of the various companies according to their profitability. A share in operating result exceeding the share in turnover of a particular field reflects a contribution towards the corporate success for this particular line of business which is above average. More or less balanced shares reflect an approximate equivalence of turnover return (where return on turnover is defined as the quotient from operating result and turnover) of this particular line of business and the total return on turnover of the company.

Pharmaceutics are by far the most profitable lines of business. Over and above all other fields, it is noticeable that those lines are particularly successful where the individual companies hold a strong market position--such as ICI for explosives, Solvay for alkalines and peroxides, and BASF for part of their finishing products (varnishes). However, most of these results refer to the period of 1988 - 1993, a period which coincided with the grave recession that affected the chemical industry, so that distortions may have to be accepted.

Figure 4.2 Return on Sales for Large Chemical Firms, 1984-1993



Plastics, especially, are much more profitable in more favorable cyclical periods than is reflected in Table 4.9. Due to these inaccuracies and due to the assumed dependency on the respective market position, no conclusions can be drawn with respect to the product life cycle model.

Table 4.9 Profitability and Sales Share of the Individual Lines of Business

Company	Share in Operating Result Bigger than Sales Share	Share in Operating Result and Sales Share more or less Equal	Share in Operating Result Smaller than Sales Share
Bayer (as of 1988)	Pharmaceutics	Organics Industrial Chemicals Agriculture	Polymers Agfa-Gevaert
BASF (as of 1990)	Chemicals Colorants Finishing Products	Raw Materials/Energy	Plastics Agriculture Consumer Goods
Hoechst (as of 1988)	Pharmaceutics	Agriculture Chemicals and Paints Fibres/Foils	Polymers Technics
ICI (Various Periods of Time)	Pharmaceutics Explosives	Petrochemistry/Plastics Varnishes and Paints Chemicals	Agriculture fibres
Ciba-Geigy (as of 1988)	Pharmaceutics	Agriculture	Industry
Sandoz	no data available		
Akzo	Pharmaceutics	Chemicals	Fibres Paints/Varnishes
Henkel	no data available		
Solvay	Pharmaceutics Alkalines Peroxides	Plastic Processing	Plastics

4.3 Limitations and Conclusion

The main problem is the complete lack of obligatory definitions concerning the classification of expenses as R&D-related. The so-called "Frascati-manual," published by the OECD merely documents relevant recommendations.[20] Since research oriented chemical companies are considered dynamic and expansive, the companies are interested in reporting maximum R&D expense rates. According to Amecke[21], many chemical companies declare R&D expenses which are of an exclusively defensive nature, such as

[20] Cf. Schwitalla, p. 101, and Kuhn, p. 107

[21] Cf. Amecke, p. 31

toxicological examinations of already existing products, or advice on applicational problem solving, which should, in fact, be considered part of the sales activities.

Since, as a rule, R&D is extremely personnel-intensive, a large part of R&D expenses is attributed to personnel costs. However, the classification of R&D related personnel can be carried out according to varying criteria and country-specific variations in pay-scales can further contort the figures concerning R&D expense-intensities.

Despite the uncertainties described above, our analysis showed mainly plausible figures and tendencies. Schwitalla[22] and Graumann,[23] who both investigated the annual reports of German companies, came to the conclusion that annual reports comprise R&D data, in particular on R&D expenses, of a surprisingly high quality.

Most of our problems were encountered in connection with the innovation counting and are due to the differing degrees of available information in the various annual reports. It was not possible to evaluate the companies' innovative readiness due to the varying tendencies of the companies to actually report their respective innovations. Another problem is the often rather imprecise information on innovations, which very often shows near advertisement character. In accordance with this data it was impossible to evaluate the quality of the reported innovations, i. e. there was no way of differentiating between incremental product changes and totally new products. Imprecise data also made the classification of categories extremely difficult. Especially in the area of plastics, where the classification according to chemical criteria is also not very clear-cut--it was not possible to differentiate between mass produced plastics or further developments based on them and/or special plastics.

The innovation counting was further hampered by whole new product lines being introduced instead of an exact numbers of innovations. Whenever details were given as to the number of products within a certain line of products, the respective number of innovations was considered. Therefore, repetitions of brand names may be found in the evaluation, since often innovations were, in fact, improvements with no change of name, or else individual products out of a line of products with only one brand name.

Due to the unclear information concerning the economic use of catalyzers (whether as an individual product or as part of a process improvement), catalyzers were always counted as process innovations unless they were explicitly marked as products.

Despite the necessary assumptions in the innovation counting and the uncertainties concerning the annual reports the results achieved are plausible and enable a reasonable

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[22] Cf. Schwitalla, p. 272

[23] Cf. Graumann, pp. 185

description of the innovative trends prevailing in the chemical industry. This is also confirmed by the relatively great conformity with the previously created pilot study (innovation counting on the basis of information taken from the magazine "Europa Chemie").

Most noticeable is the interdependence of R&D expense intensity and return on turnover. This means that companies with a high investment in R&D are, in fact, the most successful ones. The evaluation by lines of business, however, shows the level of R&D expense intensity as extremely dependent on the respective corporate profile, i.e., it demonstrates which lines of business the company in question engages in. Thus, the interdependence mostly concerns corporate profile, R&D expense intensity and return on turnover. The evaluation by lines of business also shows the R&D intensive lines to be those lines which produce the best turnover growth.

These connections serve to confirm the statements of the S-curves and the product life cycle model. Thus, it was shown that the companies tend to spend particularly large sums in business lines with a high potential for growth and profit (such as pharmaceutics). As far as biotechnology is concerned, the time lag between the stages of maturity of the S-curve model and those of the product life cycle model was proved as well.

The lines identified as more mature lines due to lower R&D expense intensity were also classified as more mature lines when applied to the technological life cycle model. This means that, when compared with other lines of business, they show a lower innovative frequency and at the same time a higher share of process innovations (e.g. fibres or basic chemicals).

The evaluation of the innovation counting elucidates the companies' tendency towards speciality chemicals and/or paints and varnishes, which actually resemble the specialities in many aspects.

5 Innovation Trends II: An Analysis of Corporate Strategies

5.1 Corporate Strategies and Innovation: Analysis of Annual Reports and First Insights from the CIS Data Base

The following section introduces several basic innovation and corporate strategies, which are of major importance to the future development of the European chemical industry. It describes the underlying conditions currently determining corporate strategies. In addition, it shows the companies' reactions on the developments identified in the previous section. In order to relate our analysis of the nine large European chemical firms to the CIS data base we will test some of the propositions developed are already in this section. That is, unless other sources are explicitly stated, the relevant data originates from the respective annual reports and from the CIS data base.

5.1.1 Changed Conditions in Europe

The major crisis which gripped the European chemical industry in the early 1990s was a structural one. The companies' reactions to this crisis consisted in structural adjustments and rationalisation measures, which brought forth considerable manpower reductions. The vast extent of these manpower reductions is elucidated in Figure 5.1. In early 1995, the total number of personnel employed in the European chemical industry is approximately 255,000 less than in 1991--a decrease of 14 percent.[24]

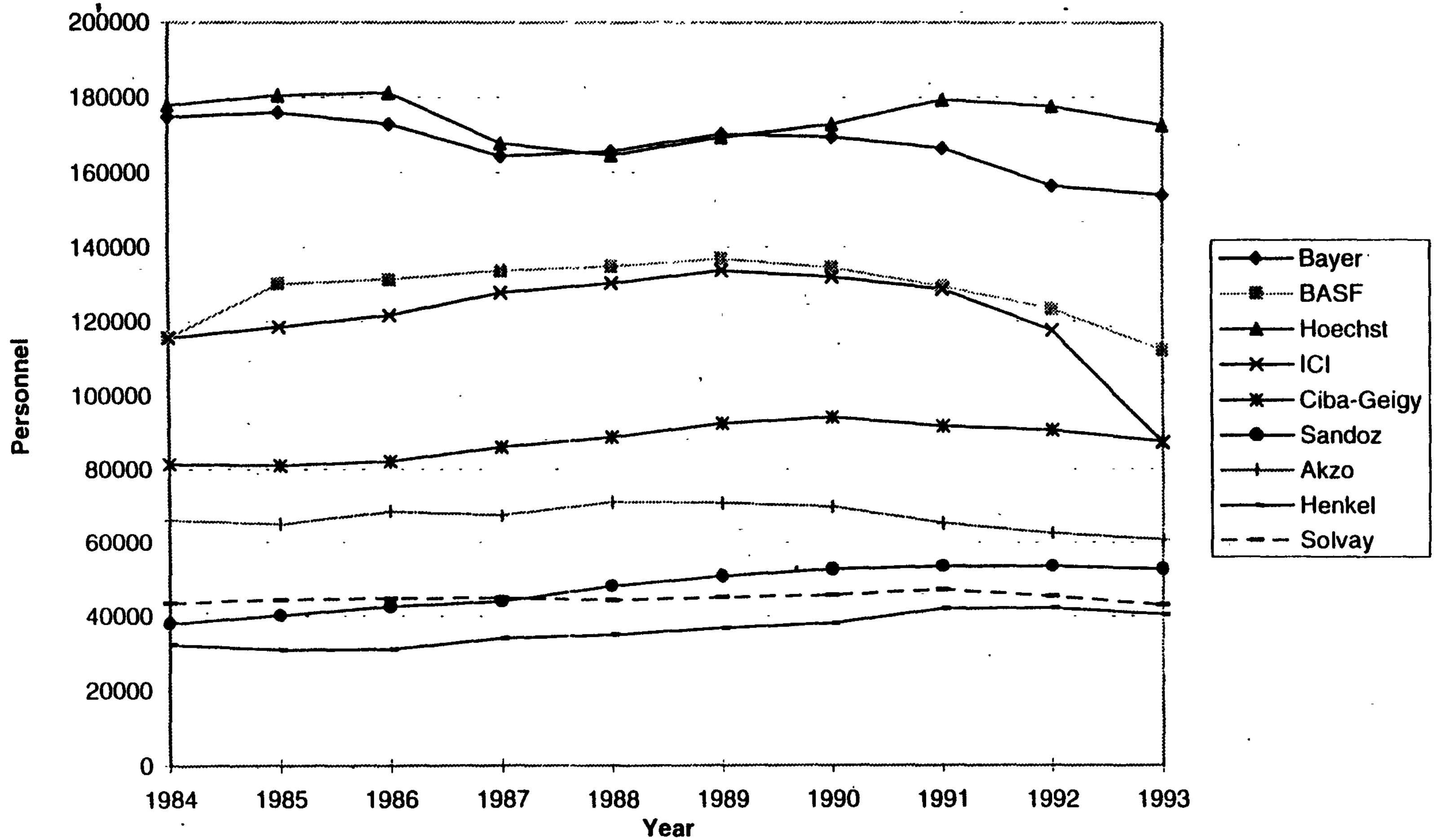
The reason for these structural problems, some of which still exist today, are, above all, to be found in the considerable cost disadvantages in connection with mass products, such as base materials, plastics, fertilizers and fibres compared with producers outside Europe. These cost disadvantages result mainly from higher costs for raw materials, labor and environmental protection. High labor costs as a reason for competitive disadvantage prevalent in Western Europe are shown in Table 5.1, with a broad variation of costs even within Europe itself. In addition, there has been a shift in the production of chemicals towards the locations of major customers. The exodus of the textile industry[25] into the Far East is the result of an increased production of synthetic fibres in that area. A similar danger prevails in R&D-intensive fields, such as the production of highest-grade chemicals for microelectronics.

The Middle East countries in particular, but also Mexico, have at their disposal a supply of raw materials for a large number of base chemicals and mass produced plastics at keen prices that have no competition whatsoever. These countries aim to produce methane and

[24] Cf. Economist, p. 69

[25] Cf. Amecke, p. 37

Figure 5.1 Employment for Large Chemical Firms, 1984-1993



ethane based petrochemicals, normally by-products in the production of crude oil that need to be burnt off, in large plants at low operating costs and thus achieve significant competitive advantages.[26] Accordingly, the world market share of these Middle East countries for ethylene glycols is expected to rise from 12 percent in 1991 to 20 percent in 2000. Western Europe will turn more and more into a net importer for petrochemicals and standard plastics, a development which, in the long run, will become evident for high-grade plastics as well.[27]

Table 5.1 Chemical Labour Costs per Man-Hour

Country	1994 (in DM)	% of 1993
West Germany	62.71	+3.2
Belgium	58.15	+2.8
Japan	55.87	-3.0
Netherlands	55.17	+0.5
France	48.47	+1.5
Denmark	45.85	+4.2
Italy	36.51	+0.3
Luxembourg	35.40	+2.9
USA	34.91	+0.9
Great Britain	34.15	0
Ireland	34.04	+4.2
Spain	29.87	-2.0
Greece	18.57	+5.7
Portugal	17.82	+17.5 (uncertain)

Source: Frankfurter Allgemeine Zeitung dtd. 06 October 1995, p. 24

The 1980s were also characterized by high expenses for the compliance with environmental standards. Accordingly, the environmental costs for the German chemical companies amounted to 6.4 billion DM or 4 percent of their 1990 turnover, which represents a 25 percent increase in comparison with the previous year.[28] These costs, however, have successfully been cut in half in the meantime, so that in 1994 Bayer invested

[26] Cf. Riemann, p. 18

[27] Cf. Fond der Chemischen Industrie, p. 14

[28] Cf. Riggert, p. 9

a mere 330 million DM--approximately half of their environment protection investment of 1990.[29]

As a result of above developments, companies are increasingly backing out of unprofitable production. This, in turn, presents a serious danger to historically interrelated production, which guarantees maximum benefit from utilized raw material and energy. As a result, interrelated structures will collapse as more and more members of these complex production links become unprofitable and thus lose what little cost advantages they have left.[30]

Under these circumstances, a concentration on more refined, more R&D-intensive products becomes even more important. A current study carried out by the British Chemical Association[31] identifies those areas of R&D which will be of major importance in the future. In consideration of all chemical fields, the following list of priorities concerning promising technologies was established:

1. Biotechnology and Catalysis;
2. Materials;
3. Process Technology;
4. Separation Processes, Analytics and Moulding.

Japanese and American companies engaged in the R&D of these promising fields receive government promotion for innovation (such as tax rebates and allowances for R&D in addition to a purposeful governmental purchasing policy). On the other hand, some West European countries, particularly Germany, rather obstruct the progress of research through the introduction of rigid laws and regulations, for instance in the field of gene technology.

The Institute for Applied Innovative Research of Bochum, Germany, investigated the restraining effect on the innovative process caused by the 1982 chemical law. The study came to the conclusion that the present chemical law with its prevailing testing methods and application procedures entails vast competitive disadvantages for German companies. At the same time, it impedes the access to the market for medium-sized and small companies.[32] The poor social acceptance of chemical research reflected in such laws has

[29] Cf. Frankfurter Allgemeine Zeitung dtd. 12 July 1995, p. 22

[30] Cf. Fond der Chemischen Industrie, p. 13

[31] Cf. Chemical Industries Association, p. 72ff

[32] Cf. Chemische Industrie 4/94, p. 16

lead to research in the more promising fields increasingly being shifted abroad, for instance to the USA and Japan.

As a result of two plebiscites, the Swiss chemical companies were at one point in danger of having to give up altogether a vital part of their pharmaceutical research, namely animal experiments. Had these plebiscites been successful, a strong shifting of research activities abroad would surely have occurred.

5.1.2 The Main Strategies Driving Innovation: Cost Leadership and Specialization

We considered strategy so far from the point of view of nine large European chemical firms. For a statistical analysis, we will use the CIS data base to explore the European perspective more systematically. However, due the lack of data for some countries and segments of the industry the analysis focuses on the so-called 6-country sample which includes Belgium, Germany, Ireland, Italy, Luxembourg, the Netherland, Norway, and the United Kingdom.

Two broad lines of strategy research are of interest with respect to the chemical industry. The first group following up the pioneering work of Alfred Chandler (1962), who undertook a series of studies into the evolution of the strategy and structure of large-scale industrial companies in the U.S., the U.K., France, Germany, and Italy. These studies found a trend toward increased diversification, primarily into areas of related activity, and that the firms had adopted a form of divisional organization structure. This structure dominates today, at least with the large firms of the chemical industry.

The second seemingly important distinction of strategies was developed by Michael Porter (1985). In a simplified version of that work one can distingiush three types of strategies, that is, a strategy of cost leadership, a strategy of product differentiation, and a strategy of being stuck in the middle. The analysis of the annual reports has shown that the distinction of cost leadership versus product differention (or specialization, as we will call this strategy) is a relevant one for the firms of the chemical industry. Therefore, and because of the patterns of the firm size distribution in various segments of the industry we will use the concept of cost leadership and specialization strategy for the following analysis.

The Table 5.2 shows that the large firms[33] are located in the industry segments basic chemicals (24.1), soap and detergents (24.5), and man-made fibres (24.7).[34] The share of firms in these segments is in the highest turnover groups (no. 4 and 5) 15 percent and more.

[33] Size is measured as annual turnover in thousand ECU. The size distribution then is based on five groups of turnover.

[34] The pharmaceutical industry is included for the purpose of comparison, but will not be further discussed in the context of the tables.

Table 5.2 Distribution of Firms by 1992 Turnover Size Groups and Segments of Industry (in percent, 8-country sample)

Industry Segment (NACE)	Size Group by Turnover (thousand ECU) 1 (0-499)	2 (500-9,999)	3 (10,000-99,999)	4 (100,000-499,999)	5 (500,000+)	Total Number of Firms
Basic Chemicals (24.1)	1.0	34.0	45.8	13.3	6.0	400
Agrochemicals (24.2)	2.8	41.7	44.4	8.3	2.8	36
Paints, Varnishes (24.3)	1.0	53.8	39.4	5.3	0.5	208
Pharmaceuticals (24.4.)	0.8	30.6	47.5	18.0	3.2	373
Soap and Detergents (24.5)	1.5	46.1	36.8	13.2	2.5	204
Other Chemical Products (24.6)	1.7	51.0	41.9	3.3	2.2	363
Man-Made Fibres (24.7)	0	39.6	45.3	15.1	0	53
Column	19	677	709	181	51	1637
Total	1.2	41.4	43.3	11.1	3.1	100.0

Note: The 8-country sample includes Belgium, Germany, Ireland, Italy, Luxembourg, the Netherlands, Norway, and the United Kingdom.

Paints and varnishes (24.3) and other chemical products (24.6) have 50 percent and more firms in the lower size groups 1 and 2. Agrochemicals is between these two groups with a value of 44.5 percent.

The results are reasonable because the production of basic chemicals requires considerable amounts of capital which usually can be afforded only by lage firms. The manufacture of paints and varnishes is, on the other hand, often feasible as speciality production, that is, a lower volume can be marketed profitable by providing a variety of products. This is an environment where cost leadership strategies based on capital intensity are not a neccessary condition for the survival of small and medium sized firms since the domain for cost leadership strategies looks different.

Cost Leadership The strategy of cost leadership is mainly pursued in areas where the price is the decisive competitive feature. According to the Technological Life Cycle Model this is often the case with products where product innovations accordingly play a less important role. This applies to mass produced plastics and base chemicals, but is also partially true for certain parts of the specialized chemistry.[35]

For the achievement of cost advantages, the availability of low-priced raw material supplies as well as the attainment of a high market share for better use of the sometimes immense scale economies, are of vital importance. In this context, stronger concentration efforts were made by the European chemical industry during the past few years, which were also connected with a strategic tendency for concentration on the individual companies' core areas and/or a tendency to form strategic alliances.

Thus, BASF acquired ICI's European polypropylene branch and, in turn, sold their plexiglass line to ICI. As far as synthetic fibres are concerned, BASF is concentrating on the production of nylon-6, a purpose for which they formed a joint venture with Allied Signal. With polyester fibres, on the other hand, BASF is following a policy of divestment and are putting their focus on the production of polyurethane. In order to secure a relatively favorable raw material supply, the company spent 1.3 billion DM to build a new steam cracker in Antwerp.

The CIS measures the pursuit of the cost leadership strategy in question 5 as a goal of innovative activities. This is plausible because goals are part of the corporate strategy and the goal lowering production cost is at the core of a cost leadership strategy. More than 50 percent of the firms in the sample persue the goals reducing the share of wage costs and reducing materials consumption.[36]

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[35] Cf. Chemische Industrie 8/89, p. 28

[36] These are the points 4 and 5, respectively „very significant" and „crucial" in the Likert scale measurement of question 5. More than 50 percent of the firms have made this evaluation - with the exception of France and Ireland for wages and the exception of France for materials.

Reducing energy consumption is paticularily important for the production of basic chemicals since a significant share of their cost is due to energy consumption. For 16 percent of these firms reducing energy consumption is crucial. The situation is different for the producers of agrochemicals or paints and varnishes. For the former only 4 percent regard reducing the consumption of energy as crucial and for the latter 8 percent of the firms. Thus, a strategy of cost leadership by reducing energy consumption is first of all pursued in the field of basic chemicals.

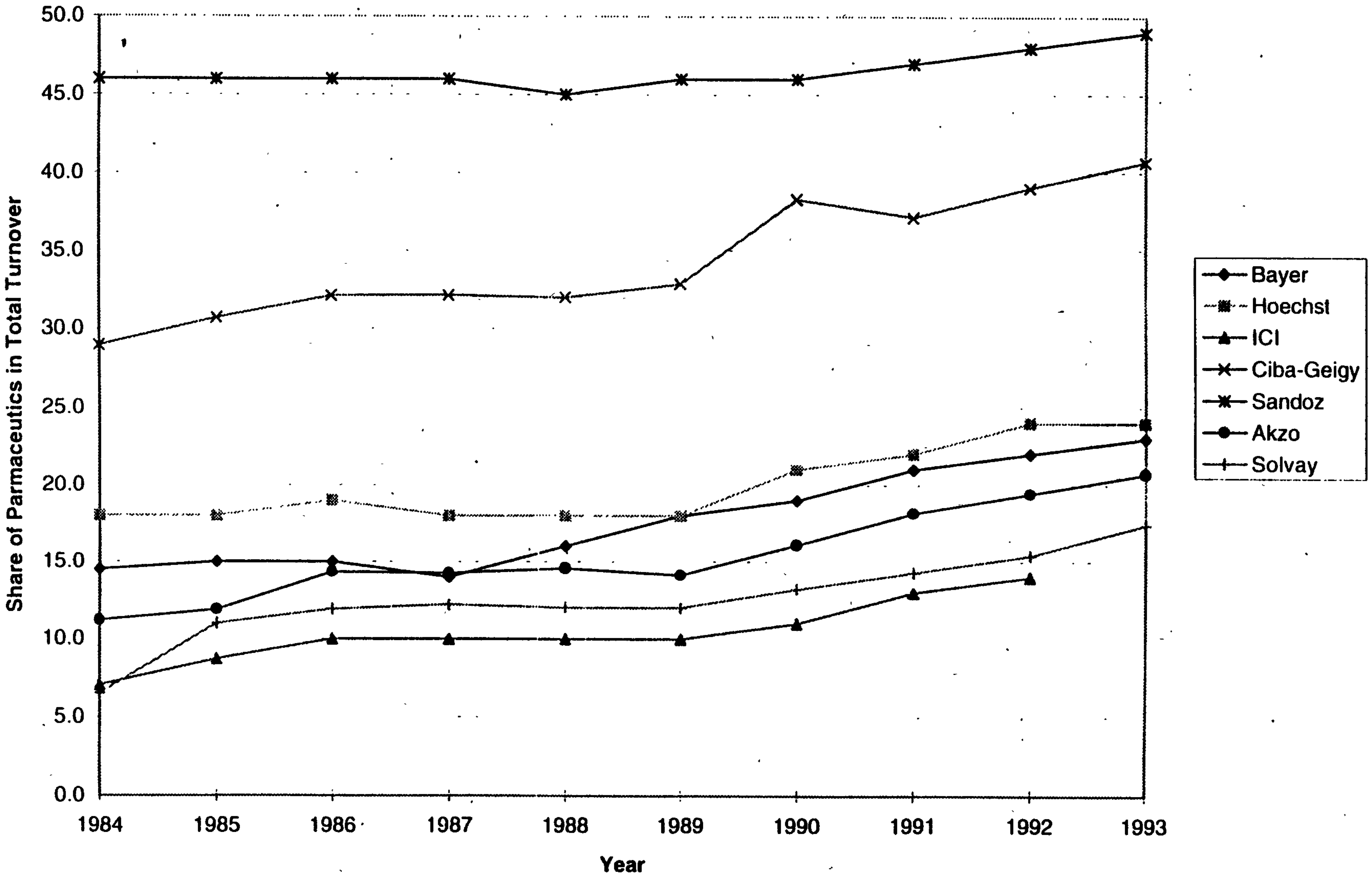
Specialization The strategy of specialization constitutes an attempt on the part of the chemical companies to escape from the price competition dominating the market for mass products. For the chemical industry, specialization means mainly an orientation towards specialities --barring above mentioned exceptions--, i. e., a concentration on the companies' part on certain mass products with the aim of securing cost advantages. The specialities are characterized by a great product diversity, such as certain "tailor-made" polymers (Akzo) or master batches made to customers specifications for the use of pigments and additives with plastics and synthetic fibres (Sandoz). As a rule, these products are highly refined ones and usually guarantee a higher profit margin. Many of these products are also considered resistant to market swings.

During the qualitative evaluation of the annual reports it was noted that companies located in countries other than the German-speaking ones, (ICI, AKZO and SOLVAY), reported the strategies pursued in greater detail. These strategies were mainly focused on the concentration on high-value added, market-intensive products (Akzo). Any specialization trends followed were always pursued at the expense of mass production. As a result, Akzo decreased their fibre production from 52 percent of the 1963 turnover to 30 percent in 1984 and to less than 20 percent in 1993. At the same time, Akzo's share in coatings increased from 5 percent of the 1969 turnover to almost 25 percent in 1993. In order to continue this development, Akzo acquired the Swedish Nobel Industries AB in 1993.

This trend towards specialization can be easily explained by means of the pharmaceutical lines of the companies. As shown in Figure 5.2, almost all companies were able to increase the pharmaceutical shares in their turnovers. Even BASF and Solvay, whose pharmaceutical branches were never part of their historical key areas, are now increasingly diversifying their pharmaceutical lines. This is one of the few examples where companies deviate from the strategy of concentrating on key areas. Thus, in 1995 BASF purchased Boots Pharmaceuticals for 2 billion DM.

The pursuit of the strategy of specialization, however, is no guarantee for success, as BASF proved with their commitment in advanced composites. Having purchased said branch from Celanese Corp in 1985, BASF was forced to discontinue these activities in 1992 due to an unsatisfactory development of demand. In their efforts for better appeal to the ultimate consumers the companies are now increasingly offering customer services in addition to their chemical products. Akzo, for instance, has established special consultancy service centers for the purchasers of their varnishes. In addition, special service equipment,

Figure 5.2 Share of Pharmaceutical Products for Large Chemical Firms, 1984-1993



e.g. for the exact mixing of varnishes and paints, is offered. ICI, on the other hand, offers a computer-aided optimization system for explosions.

Based on information of the innovating firms in the CIS sample we can use responses to questions 10.c)i-ii of the CIS to get an understanding to which extent the firms are investing in product innovation and in process innovation - measured as the share of their total R&D expenditures. As Table 5.3 shows nearly 78 percent of the firms spend more than 50 percent of their R&D budget on product innovation whereas only 26.6 percent of the firms spend half and more of the budget for process innovation. One interpretation is that firms concentrate overall on specialized products. This is underlined by the fact that manufacturers of basic chemicals and of man-made fibres concentrate very much on the investment in process innovation which supports directly their products.

Tables 5.4 and 5.5 are based on the R&D expenditures for product innovation and for process innovation. They are underlining the differences in the specialization of the segments of the chemical industry. On the one hand there are more than 60 percent of the manufacturers of agrochemicals and of paints and varnishes which allocate 75 percent and more of their R&D budget to product innovations. But only 30.8 percent of the basic chemical producers do this and still more different is the profile in man-made fibres. Here only 16 percent of the producers spend three quarters and more of their R&D budget on product innovations. As a result more than 15 percent of the manufactures of basic chemicals and man-made fibres spend 75 percent and more on process innovations.

The data on the allocation of R&D expenditures for product and process innovation highlight the close interrelation between these two corporate strategies--cost leadership and specialization. This interrelation can be elucidated by means of the strategy pursued by Solvay: profits from the stagnating core activities (alkaline, peroxide, plastics), where cost reduction is a key issue, are used to finance new activities. Solvay accordingly increased their share of turnover in the health sector from 6.5 percent in 1984 to more than 17 percent in 1993, while other lines of business remained at an approximate constant.

5.1.3 Concentration on Key Areas

Almost all annual reports assign the concentration on key areas and/or key competencies a central role, with a focus on the achievement of a strong market position and the concentration on areas with a high synergistic effect. These are, in fact, strategies that the companies keep realizing with great consistency. Thus, ICI split off all bio-areas (mainly pharmaceuticals and agriculture) and integrated them into the newly founded company called Zeneca, their own subsidiary. Higher flexibility and effectiveness for both companies were the stated reasons for this step. However, this also means the end of risk

Table 5.3 Distribution of Firms According to their R&D Expenditures Allocated to Product and Process Innovation (in percent, 8-country sample)

Type of Innovation	Share of R&D Expenditures Allocated to Innovation Type				Total Number of Firms
	Group 1 0-0.25	Group 2 0.25-0.5	Group 3 0.5-0.75	Group 4 0.75-1	
Product Innovation	11.5	10.8	34.8	42.9	555
Process Innovation	46.1	27.2	17.1	9.5	555

Note: The 8-country sample includes Belgium, Germany, Ireland, Italy, Luxembourg, the Netherlands, Norway, and the United Kingdom.

Table 5.4 Distribution of Firms According to their Shares of R&D Expenditures for Product Innovations by Segment of Industry (in percent, 8-country sample)

Industry Segment (NACE)	Share of R&D Expenditures Allocated to Product Innovations				Total Number of Firms
	Group 1 0-0.25	Group 2 0.25-0.5	Group 3 0.5-0.75	Group 4 0.75-1	
Basic Chemicals (24.1)	18.4	9.7	41.1	30.8	185
Agrochemicals (24.2)	6.3	0	31.3	62.5	16
Paints, Varnishes (24.3)	2.5	7.6	24.1	65.8	79
Pharmaceuticals (24.4.)	18.7	7.7	26.9	46.7	182
Soap and Detergents (24.5)	11.0	5.5	31.5	52.1	73
Other Chemical Products (24.6)	7.9	14.7	33.9	43.5	177
Man-Made Fibres (24.7)	20.0	24.0	40.0	16.0	25
Column Total	98 13.3	74 10.0	242 32.8	323 43.8	737 100.0

Note: The 8-country sample includes Belgium, Germany, Ireland, Italy, Luxembourg, the Netherlands, Norway, and the United Kingdom.

Table 5.5 Distribution of Firms According to their R&D Expenditures Allocated to Process Innovations by Segment of Industry (in percent, 8-country sample)

Industry Segment (NACE)	Share of R&D Expenditures Allocated to Process Innovations				Total Number of Firms
	Group 1 0-0.25	Group 2 0.25-0.5	Group 3 0.5-0.75	Group 4 0.75-1	
Basic Chemicals (24.1)	34.6	32.4	17.3	15.7	185
Agrochemicals (24.2)	62.5	18.8	12.5	6.3	16
Paints, Varnishes (24.3)	67.1	19.0	12.7	1.3	79
Pharmaceuticals (24.4.)	52.7	18.1	13.2	15.9	182
Soap and Detergents (24.5)	53.4	30.1	9.6	6.8	73
Other Chemical Products (24.6)	48.0	24.9	19.8	7.3	177
Man-Made Fibres (24.7)	20.0	28.0	36.0	16.0	25
Column	352	184	119	82	737
Total	47.8	25.0	16.1	11.1	100.0

Note: The 8-country sample includes Belgium, Germany, Ireland, Italy, Luxembourg, the Netherlands, Norway, and the United Kingdom.

sharing for the individual bio and chemical lines, in the past a feature of special importance for the chemical lines.

Sandoz, on the other hand, decided in 1995, to abandon all lines of business not connected with pharmaceutics and/or nutrition. They are now aiming for an exclusive concentration on pharmaceuticals and nutrition, since health is the common denominator of both businesses. The relevant sales profits are to be used for increased future investments in gene technology and to finance new acquisitions in the areas of pharmaceutics and nutrition.[37] This restructuring effort might already be regarded as a sign towards the merger between Sandoz and Ciba-Geigy announced in early 1996. The new firm Novartis is seen among others as an effort focus on core competences in agrochemicals, pharmaceuticals, and nutrition. Likewise, Hoechst decided to take equally drastic measures and split off their profitable cosmetics line (e. g. Jade and Schwarzkopf), which was not part of their key area.

5.1.4 The Trend Towards Strategic Co-operation

Companies are increasingly entering into strategic alliances in the areas of production and R&D. This indicates, however, a quite new development in the chemical industry. Apart from co-operation between companies, the co-operation between companies and academic institutions is of major importance, especially where basic research is concerned. As a rule, strategic alliances are formed to pursue one of the strategies described.

Co-operation in the area of production usually aims at the grouping together of production capacities in order to increase cost efficiency, mostly in connection with the strategy of cost leadership. The annual reports supply numerous examples for this:

- In 1987, ICI and Mitsubishi Chemicals formed a joint venture for composite materials and for the joint performance of field tests.
- Since 1993, ICI and Kronos have been jointly producing titanium dioxide by means of chloride.
- In 1992, Hoechst and Wacker contributed their respective PVC activities into a joint venture.

A particularly wide co-operation was entered into by Hoechst and Schering in 1994, when they formed a joint venture called "Hoechst Schering AgrEvo GmbH." This enterprise, with a turnover of 3 billion DM and approximately 8,000 employees, is the second biggest producer of plant protectives world-wide after Ciba-Geigy.[38] The objective of this co-

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[37] Cf. Frankfurter Allgemeine Zeitung dtd. 28 March 1995, p. 21

[38] Cf. Chemische Industrie 3/94, pp. 28-32

operation is the achievement of a so-called "critical size" in the generally shrinking market for plant protectives in order to survive both innovative and price competition.

The importance of co-operation is ever-increasing, especially in the R&D sector. According to another study,[39] this is not so much due to increasing R&D expenses, but rather has to be contributed to the fact that co-operation enables the individual companies to enter into new markets, to shorten innovative periods, and to recognize technological potentials at an earlier stage. The fact that Hoechst AG increased its number of co-operative agreements from 230 to 380 in the past ten years indicates the dimensions of this trend towards co-operation.[40]

The CIS has addressed question number 11 to co-operation arrangements on R&D activities with other enterprises or institution. For the chemical and the pharmaceutical industry of the overall sample 43.4 percent of the firms report to have such arrangements.[41] For the 8-country sample the value is 42.2 percent. How this is distributed by segment of industry shows Table 5.6. The highest intensity of R&D co-operation is found within the agrochemical business and the lowest for soap and detergents.

Information on the location of the co-operation partners is provided as well in the CIS.[42] To check for the intensity by which an arrangement is used in a single location we have computed its occurrence for three major types of arrangement. The results are shown in Table 5.7. The likelihood by which at least one co-operation arrangement is mentioned in one of the three major types for one of seven locations is 85.7 percent[43] for agrochemicals. The three major types of co-operation we are looking at are co-operation with competitors, in the form of research joint ventures, and with universities, government labs, and other research institutes. A comparable pattern -- one like in the previous table -- emerges. Again, the argochemical segment exhibits the highest intensity of co-operation in all three areas. Only at a first glance the intensities for basic chemicals and man-made fibres are some what surprising. These segments of industry do rely heavily on co-operation arrangements with universities, government labs, and other research institutes. Perhaps, an even greater challenge to the chemical industry is the increasing trend towards globalization.

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[39] Cf. Fast-Study, p. 32

[40] Cf. Chemische Industrie 1/92, p. 38

[41] It should be recognized that of the 1938 firms alltogether 34.9 percent provide no information. They are the „missing values". 28.2 percent say that they do apply such arrangement whereas 36.8 percent have no such co-operation arrangements.

[42] Seven locations are distiguished. Inside Europe these are regional, national, E.C., and non-E.C. and outside Europe: U.S.A., Japan, and other.

[43] This overall percentage is not included in Table 5.7.

Table 5.6 Share of Firms Applying R&D Co-operation Arrangements by Segment of Industry (in percent, 8-country sample)

	Firm has Co-operation Arrangements on R&D	
Industry Segment (NACE)	Yes	No
Basic Chemicals (24.1)	47.1	52.9
Agrochemicals (24.2)	54.2	45.8
Paints, Varnishes (24.3)	30.8	69.2
Pharmaceuticals (24.4.)	52.3	47.7
Soap and Detergents (24.5)	29.9	70.1
Other Chemical Products (24.6)	38.3	61.7
Man-Made Fibres (24.7)	33.3	66.7
Column Total	308 42.2	482 57.8

Note: The 8-country sample includes Belgium, Germany, Ireland, Italy, Luxembourg, the Netherlands, Norway, and the United Kingdom.

Table 5.7 Distribution of Firms According to the Type of R&D Co-operation they Practise by Segment of Industry (in percent, 8-country sample)

Industry Segment (NACE)	Type of R&D Co-operations: Arrangements with Competitors	R&D Joint Ventures	Arrangements with Government Labs, Research Institutes, Universities etc.
Basic Chemicals (24.1)	17.6	23.1	71.8
Agrochemicals (24.2)	50.2	40.0	75.0
Paints, Varnishes (24.3)	0	33.3	50.0
Pharmaceuticals (24.4.)	31.4	20.0	66.7
Soap and Detergents (24.5)	12.5	0	50.0
Other Chemical Products (24.6)	12.7	12.5	64.8
Man-Made Fibres (24.7)	16.7	0	83.3
Column	47	20	167
Total	18.7	20.6	66.5

Note: The 8-country sample includes Belgium, Germany, Ireland, Italy, Luxembourg, the Netherlands, Norway, and the United Kingdom.

5.1.5 The Trend Towards Globalization

Conclusions can be drawn as to the extent of globalization of certain chemical companies from the layout of their annual reports, which, as a rule, give a detailed account of regional developments (such as Europe, North America, Latin America and Asia). The trend towards globalization shows itself in:

- corporate efforts to *achieve added increased rates of turnover outside Europe* (e. g. in Asia and the USA), since only small growth rates are to be expected within Europe;
- investments in *new production plants* being placed mainly in *close proximity to the main trading areas* (such as Asia);
- *R&D* increasingly being *moved into the proximity of major customers*, and/or *areas with more favourable R&D conditions* (such USA concerning gene technology).

The companies of Switzerland, as well as ICI, rank among the geographically most diversified companies. Thus, Ciba-Geigy and Sandoz between them hold approximately 40 percent of the total European turnover and about 30 percent of the North American one. Solvay and Akzo, on the other hand, are not as geographically diversified, but Akzo is increasingly trying to improve their "geographic mixture," as was explicitly stressed in their 1993 annual report.

Geographic diversification is usually realized by way of acquisition, as is the case with the latest Hoechst acquisition. Hoechst purchased the American company, Marion Merell, from Dow for more than 10 billion DM. With this purchase, Hoechst became one of the four major suppliers of pharmaceutical products in the USA and, thus, managed to considerably strengthen their formerly weak position in the US market--one of the most important pharmaceutical markets world-wide.

The foreign proportion of R&D in promising fields, however, developed in an even more dynamic manner than the foreign share in turnover. The majority of the companies actively engaged in gene technology carry out their research in the USA, while as far as material research is concerned, numerous companies prefer to make Japan their location. Apart from the legal framework, the contact with leading academic research facilities for the respective fields is an important decisive factor for the choice of a location.

Bayer, for instance, established their new pharmaceutical research centre (Miles Laboratories) in West Haven (USA), while their new plant protection research center was built in Yuki (Japan). Although Europe, with its 70 percent of the R&D budget, is still their strongest R&D location, Bayer plans to expand its US and Japanese locations. In the medium term, their foreign portion of R&D is supposed to increase to approximately 50 percent, a quota that has already been reached by the two Swiss companies.

The reaction of Hoechst to this increased internationalization consists of a supraregional research concept. Thus, Hoechst and IBM carry out joint research with an emphasis on photoresisters in the USA, while Japan is the best possible location for new liquid crystal systems for large screens. For ceramic superconductors, however, the company decided on Germany as their favorite location.[44]

To test for the trend of increasing globalization of markets we used CIS data for question 5 („objectives of innovation"). By grouping together those firms which perceive the presence in global markets as „very significant" or „crucial" according to turnover size groups of firms the following obvious pattern emerges in Table 5.8. A share of 50 to 60 percent of the small and medium sized firms view the creation of national markets as important whereas for the largest group (turnover more than 50 million ECU) only 40.6 percent of the firms perceive the importance of crearing nationally new markets. For the creation of new markets within Europe a U-shaped relationship holds, that is, the smaller (64.9 percent) and the largest firms (59.4 percent) perceive that as an important objective. The range of the groups inbetween is 52.1 to 55.8 percent. The importance of being present in the North American market shows a linear increase with firm size, from 10.9 percent in the smallest size group to 29.1 percent for the largest firms of the chemical industry.

5.2 Conclusion

In spite of the corporate profiles partially differing information, quite a few common features concerning corporate and innovative strategies could be established in particular when CIS data is used to complement the picture and to check for regularities in the whole industry. It became obvious the investigated companies operate under similar competitive conditions. The fact that the companies concentrate on certain mass products rendering a strong market position, was particularly noticeable. All the companies studied are also involved with highly refined products.

This part of the study clearly reflects the trends already established within the framework of the innovation counting approach. The strong shifting of turnover shares from mass products to highly refined products indicates how drastically the companies carry out their restructuring processes. Thus, the annual reports include many examples for capacity decreases concerning mass products. In the area of highly refined products, on the other hand, numerous acquisitions, some of them outside Europe were recorded, which shows an increasing globalization of corporate activities. This globalization is further accelerated by the innovation barriers prevailing in many European countries. How this is reflected in the CIS data bases will be investigated in some detail in the next section.

[44] Cf. Chemische Industrie 1/92, p. 38

Table 5.8 Globalization of Markets: Distribution of Firms According to the Objective "Creation of New Markets" by Turnover Size Groups (in percent, 8-country sample, pharmaceutical industry excluded)

	Size Group by Turnover (thousand ECU)				
	1	2	3	4	5
Creating New Markets:	(0-499)	(500-9,999)	(10,000-99,999)	(100,000-499,999)	(500,000+)
Nationally	88.9	60.3	49.7	50.5	44.8
within the European Community	11.1	61.0	55.4	51.6	63.2
in North America	11.1	11.6	13.6	16.7	29.7

Note: The 8-country sample includes Belgium, Germany, Ireland, Italy, Luxembourg, the Netherlands, Norway, and the United Kingdom. The share of those firms was taken for firms for which the creation of new markets is "very significant" or "crucial". This then was related to the total number of firms responding to the question.

6 An Analysis of the CIS Data

6.1 The Chemical Industry in the CIS Sample

The CIS sample for the chemical industry includes observations from 13 countries (see: Table 6.1 and 6.2) . Since December 1995 a „cleaned" data set has been available.[45] The total number of firms classified according to NACE 24 into the chemical industry is 1938. Accoding to turnover, employment, and R&D, these firms are distributed over the countries as follows (see: Table 6.3). The largest number of observations came from Italy with 791 firms and the fewest from the U.K. with nine firms. This large difference in participation in the CIS should be recognized in the course of interpretation and explanation of the statistical results. According to Eurostat[46] the data for 10 countries is comparable. Data from Greece, Portugal, and the U.K. is not comparable. The Greek and Portugese data includes only information on those firms which undertook innovations and the number of U.K. firms is very small. Furthermore, the some answers to CIS questions in the data for France are completely missing. Among others the figures for R&D.

For the type of intra-industry analysis we are undertaking it is important to analyse the industry according to their main product groups. This is because in their innovative activities firms exhibit significant differences regarding these groups. Thus, our analysis will focus on the comparison of the 13 countries and on seven major product groups, the so-called segments of the chemical industry.[47]

6.2 Organizational Characteristics Affecting Innovation

6.2.1 Objectives of Innovation

The objectives for innovative activity are in two ways important. First, they are part of the corporate strategy and insofar they influence the way firms are organizing their innovation activities. Second, if environmental changes outside the firm seem to require innovation by the firm, preferences of their employees may change and as such the innovation objectives of the firm. Jewkes, Sawers, and Stillerman (1960) and other cases studies of innovations[48]

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[45] The lastest corrections from Eurostat regarding the CIS data set beared the date March 7, 1996.

[46] See Eurostat, Statistik kurzgefasst, 1996, No.2, p.1.

[47] Since the whole CIS venture might be regarded at this point in time as an approach to provide opportunities for the study of the competitiveness of European industry we decided to use the maximum amount of information available for our study. That is, we use the for the intra-industry analysis an 8-country sample including Belgium, Germany, Ireland, Italy, Luxembourg, the Netherlands, Norway, and the United Kingdom. In case data for France is available it becomes the 9-country sample.

[48] See e.g. Albach (1994) for recent cases studies on basic innovations and for the importance of the organization for successful innovation.

Table 6.1 Distribution of Chemical Firms in the CIS Sample by Country and Size
(in absolute numbers and in percent)

Country	Firm Size Groups in Employees 1992						Total
	1-4 employees	5-49 employees	50-249 employees	250-499 employees	500-999 employees	1000 and more employees	
Belgium		15 18.8	19 23.8	22 27.5	8 10.0	16 20.0	80 4.1
Denmark		7 17.9	18 46.2	9 23.1	3 7.7	2 5.1	39 2.0
France		68 28.9	81 34.5	36 15.3	24 10.2	26 11.1	235 12.1
Germany	2 1.1	49 27.4	42 23.5	30 16.8	24 13.4	32 17.9	179 9.2
Greece	5 14.7	7 20.6	13 38.2	7 20.6	2 5.9		34 1.8
Ireland		43 43.4	46 46.5	10 10.1			99 5.1
Italy	1 0.1	347 43.9	318 40.2	58 7.3	36 4.6	31 3.9	791 40.8
Luxembourg		9 81.8	2 18.2				11 0.6
Netherlands	1 0.5	54 24.7	127 58.0	14 6.4	12 5.5	11 5.0	219 11.3
Norway		1 5.0	10 50.0	3 15.0	4 20.0	2 10.0	20 1.0
Portugal		13 27.1	19 39.6	10 20.8	5 10.4	1 2.1	48 2.5
Spain		63 36.4	71 41.0	23 13.3	11 6.4	5 2.9	173 8,9
United Kingdom		3 33.3	2 22.2	3 33.3		1 11.1	9 0.5
All Countries							1937 100.0

Note: The overall sample includes 1938 firms. One firm is excluded since the information on firm size is not available.

Table 6.2 Distribution of Chemical Firms in the CIS Sample by Country and Segment of Industry (in absolute numbers and in percent)

Country	NACE							
	24.1 Basic Chemicals	24.2 Agro-chemicals	24.3 Paints, Varnishes	24.4 Pharma-ceuticals	24.5 Soap, Detergents	24.6 Other Chemical Products	24.7 Man-Made Fibres	24 Chemical Industry
Belgium	36 45.0	1 1.3	7 8.8	15 18.8	5 6.3	12 15.0	4 5.0	80 4.9
France	48 20.4	8 3.4	38 16.2	65 27.7	40 17.0	33 14.0	3 1.3	235 14.4
Germany	61 34.1	1 0.6	21 11.7	26 14.5	30 16.8	33 18.4	7 3.9	179 10.9
Ireland	10 10.1	4 4.0	9 9.1	48 48.5	10 10.1	17 17.2	1 1.0	99 6.0
Italy	186 23.5	16 2.0	118 14.9	199 25.2	106 13.4	135 17.1	31 3.9	791 48.3
Luxembourg	3 27.3		2 18.2	1 9.1	1 9.1	3 27.3	1 9.1	11 0.7
Netherlands	45 20.5	5 2.3	9 4.1	17 7.7	10 4.5	128 58.2	6 2.7	220 13.4
Norway	10 50.0		4 20.0	2 10.0	2 10.0	2 10.0		20 1.2
United Kingdom	1 50.0	1 50.0						2 0.1
All Countrys								1637 100.0

Note: Due to a lack of information the sample for the analysis according to the 3-digt NACE classification is smaller than the overall sample.

Table 6.3 Descriptive Statistics for Turnover, Employment, and R&D of the Firms in the Sample by Country

Country	BEL	DK	ESP	FR	GER	GR	IRL	ITL	LUX	NL	NOR	P	UK
Turnover 1992 in thousands of ECU													
Sum	27,483,799	2,100,298	5,464,803	24,939,312	46,254,241	456,978	2,043,346	36,163,844	141,396	27,137,594	2,112,214	1,306,546	500,931
Mean	343,547	53,853	31,588	106,124	258,403	13,440	20,639	45,719	12,854	123,352	105,610	27,219	55,647
Median	56,017	24,398	10,690	20,804	31,249	8,799	7,756	11,128	3,586	13,692	50,346	15,018	20,538
Minimum	1,081	2,307	377	1,031	147	20	657	13	106	440	2,407	0	2,020
Maximum	5,222,849	666,732	882,936	3,295,223	19,356,633	83,024	123,567	2,238,076	101,734	11,506,493	532,056	170,156	296,307
Turnover per Employee	232	135	161	230	139	71	201	227	314	264	300	122	83
Employees													
Sum	118,113	15,486	33,865	108,022	332,812	6,362	10,152	158,858	450	102,642	7,032	10,664	5,974
Mean	1,476	397	195	459	1,859	187	102	200	40	466	351	222	663
Median	302	150	87	123	220	178	59	58	15	95	207	154	124
Minimum	10	11	9	12	3	1	10	4	5	0	10	7	21
Maximum	31,401	5,850	2,186	12,540	136,394	804	486	9,321	228	23,044	1,279	1,614	4,406
R&D 1992 in thousands of ECU													
Sum	888,921	263,039	80,033	-	2,202,073	2,081	57,855	999,973	107	1,105,778	88,100	10,826	14,548
Mean	15,326	7,736	769	-	15,842	115	771	3,257	107	7,898	5,506	338	1,818
Median	1,516	1,663	302	-	701	82	132	399	-	368	1,219	150	1,247
Minimum	20	128	0	-	0	4	7	6	107	0	22	6	14
Maximum	150,666	66,972	8,977	-	978,066	493	19,718	87,159	107	253,480	52,038	2,894	7,456
R&D per Employee	7	17	2	-	6	0	5	6	0	10	12	1	2

emphasized the importance of the organization of innovations and the firm's environment in the innovation process. These studies indicate that the primary limitation on a firms effectiveness in innovation are neither costs nor the technical knowledge required. Rather, the main limitation seems to be their ability in recognizing needs and demands in their external environment which is in turn determined by the innovation objectices of the firm. Therefore it is important to consider the objectives of innovation in some detail.

The purpose of this section will be to identify the innovative objectives that firms have in the chemical industry and to illustrate how these objectives vary across firms, as well as across countries. The CIS (section III) provides a subjective evaluation by firms of their innovative objectives, ranging from 1, which refers to "Insignificant," to 5, for "Crucial." Possible objectives for innovating include "extending the product range," "creating new markets" and "lowering production costs." We will compare the mean values and standard deviations of all of the more specific responses within each main category. We will then compare these means across geographic regions, to determine which objectives are the most important in which countries. For that purpose we will use a graphical ranking device which was already applied by ZEW Mannheim in their analysis of the German innovation survey.[49]

To check for the appropriateness of the items of the CIS with respect to the objectives of innovation we apply in a non technical way factor analysis.[50] Table 6.4 indicates that the factor loadings based on principal component analysis with a varimax rotation exhibit a structure similar to the items as organized in the CIS questionnaire. Five factors are identified using factor loadings higher than 0.45. Tables 6.5 and 6.6 list the objectives of innovation grouped according to these five factors by country and by segment of industry. The factors then were ranked based on the overall mean for the variables of this factor. The ranking over all countries points to the „extension of local markets" as the most important bundle of innovation objectives. The circle • indicates the three most important objectives and the circle o the three least important ones in the table. Increasing and maintaining market share is the crucial objective for innovative effort in the European chemical industry. Of similar importance is to improve product quality by means of innovation. Creating new markets in Japan is the least important goal. One exception regarding the overall quite homogeneous goal structure is France. The French firms have the highest preference for using innovative effort in order to extend the product range outside the main product field, that is to aim at product diversification. Closely related to the question of

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[49] See Felder, Harhoff, Licht, Nerlinger and Stahl (1994), Innovationsverhalten der deutschen Wirtschaft.

[50] Non technical way means that we will not report the statistical properties of the analysis and that we will extract more factors than according to the Kaiser criterium should be extracted. The Kaiser criterium limits the extraction to factors representing eigenvalues greater than 1 because for values of 1 and less the use of variables themselves is statistically more appropriate.

Table 6.4 The Structure of Objectives of Innovation

Variable	Mean	Std.Dev.	Process Innovation incl. environmental issues	Opening up of Global Markets	Extension of Local Markets	Product Innovation	Product Diversifi-cation
Replace products being phased out	3.135	1.390	0.046	0.207	-0.060	0.825	0.146
Extend product range: within main product field	3.800	1.204	0.044	0.194	0.243	0.752	0.120
Extend product range: outside main product field	2.742	1.439	0.007	0.131	0.063	0.244	0.830
Increasing or maintaining market share	4.191	0.927	0.266	0.436	0.515	0.558	0.221
Creating new markets: nationally	3.437	1.199	0.173	0.017	0.651	0.273	0.323
Creating new markets: within the European Community	3.282	1.225	0.184	0.445	0.498	0.366	0.020
Creating new markets: in North America	1.954	1.209	0.012	0.848	0.148	-0.009	0.117
Creating new markets:in Japan	1.673	1.032	0.072	0.831	0.011	0.023	0.039
Creating new markets: in other countries	2.263	1.228	0.177	0.741	-0.061	0.224	0.086
Improve production flexibility	3.507	1.154	0.567	0.209	0.308	0.143	-0.125
Reducing the share of wage costs	3.431	1.220	0.657	0.049	0.386	-0.070	-0.025
Reducing materials consumption	3.266	1.215	0.643	0.166	0.256	0.230	0.769
Reducing energy consumption	2.890	1.196	0.765	0.086	0.110	-0.013	0.046
Reducing product design costs	2.311	1.129	0.451	0.257	0.247	-0.027	0.469
Reducing production lead times	3.518	1.077	0.662	0.049	0.358	-0.004	0.152
Reducing environmental damage	3.345	1.239	0.789	0.026	-0.307	0.127	0.093
Improving product quality	4.084	1.051	0.611	0.107	0.201	0.348	-0.028
Improving working conditions/Safety	3.520	1.226	0.855	0.048	-0.125	0.061	0.093

Table 6.5 The Importance of Objectives of Innovation by Countries

	All Countries	BEL	DK	ESP	FR	GER	GR	IRL	ITL	LUX	NL	NOR	P	UK
Extension of Local Markets	1	1	1	1	3	2	1	1	1	2	1	1	1	1
Increasing or maintaining market share	●	●	●	●		●	●	●	●	●	●	●	●	●
Creating new markets: nationally				●			●							
Creating new markets: within the European Community														●
Product Innovation	2	3	2	3	2	1	-	2	2	3	2	2	3	2
Replace products being phased out				O										
Extend product range: within main product field	●			●	●	●		●			●	●		
Process Innovation incl. environmental isuses	3	2	3	2	4	3	2	3	3	1	3	3	2	3
Improve production flexibility					O									
Reducing share of wage costs		●			O		O			●				
Reducing materials consumption					O		●							
Reducing energy consumption												O		
Reducing product design costs		O	O	O			O		O		O	O	O	O
Reducing production lead times			●						●					
Reducing environmental damage							O							
Improving product quality	●	●	●		●	●		●	●	●	●	●	●	●
Improve working conditions/Safety													●	
Product Diversification	4	4	4	4	1	4	-	4	4	5	4	5	5	4
Extend product range: outside main product field				O	●	O				O		O	O	
Opening up of Global Markets	5	5	5	-	5	5	-	5	5	4	5	4	4	5
in North America	O	O	O			O		O	O	O	O			O
in Japan	O	O	O			O		O	O	O	O			O
in other countries	O							O					O	

Note: The ranking of the objectives is based on the mean value of the respective cluster of objectives. 1 represents the highest ranking. The circle ● indicates the three most important single objectives and the circle O the three least important ones.

Table 6.6 Importance of Objectives of Innovation by Segments of Chemical Industry

	NACE							
	Chemical Industry without Pharma-ceuticals	24.1 Basic Chemicals	24.2 Agro-chemicals	24.3 Paints, Varnishes	24.4 Pharmaceu-ticals	24.5 Soap, Detergents	24.6 other chemical Products	24.7 Man-Made Fibres
Extension of Local Markets	1	1	1	1	1	1	1	1
Increasing or maintaining market share	●	●	●	●	●	●	●	●
Creating new markets: nationally								
Creating new markets: within the European Community								
Product Innovation	2	3	2	2	2	2	2	3
Replace products being phased out								
Extend product range: within main product field	●	●	●		●	●		●
Process Innovation incl. environmental isuses	3	2	3	3	3	3	3	2
Improve production flexibility								
Reducing share of wage costs								
Reducing materials consumption								
Reducing energy consumption								
Reducing product design costs	○	○			○		○	
Reducing production lead times				●				
Reducing environmental damage								
Improving product quality	●	●	●	●	●	●	●	●
Improve working conditions/Safety								
Product Diversification	4	4	4	4	4	4	4	5
Extend product range: outside main product field							●	○
Opening up of Global Markets	5	5	5	5	5	5	5	4
in North America	○	○	○	○	○	○	○	○
in Japan	○	○	○	○	○	○	○	○
in other countries			○	○		○		

Note: The ranking of the objectives is based on the mean value of the respective cluster of objectives. 1 represents the highest ranking.
The circle ● indicates the three most important single objectives and the circle ○ the three least important ones.

objectives of innovation is the question of how firms scan their environment in order to pursue their innovation objectives.

6.2.2 Information Sources

There is general agreement that important information for innovation in the chemical industry has come from basic research in chemistry. This leads to a related question whether one can isolate technology-push or demand-pull factors as the major source of innovation. Empirical research showed that both are important. For example, Freeman (1968, 1974) provided evidence using 810 innovative chemical processes that the user as the source of information for these innovations made up a share of 70 percent whereas only 30 percent of the ideas came from the innovating firm. Along these lines von Hippel (1978, 1988) developed his theory of the locus of innovation, that is, the likelihood for the success of innovation projects increases when they are a result of interaction with customers. How the importance of external sources of innovation is evaluated by the firms of the European chemical industry today, will be show with the following tables.

Again, we used factor analysis to measure the underlying structure of the importance of the sources of information. We extracted three factors which are shown in Tables 6.7, 6.8, and 6.9. The most important factor covers all external sources of information, which we simply labelled as „other firms"[51]. The day-to-day innovation business may have led to the fact that science-based sources are regarded as less important. This pattern results for the countries as well as for the segments of industry. The highest importance was still attributed to the variable „internal sources from within the firm" (mean score 3.7). Next follow „clients and customers" with 3.4 and the least important source are „technical institutes" (1.8). We can draw the conclusions that the locus of innovation is most commonly within the innovating firm, but a second locus is certainly with the customer. The CIS data for the chemical industry already underlines the importance of a network approach to the souces of innovation. This is at least what one gets when considering again the various arrangements used by the firms in order to achieve R&D co-operation (see Section 5.1.4). Furthermore, the network approach might also help to overcome some of the barriers to innovation.

6.2.3 Barriers to Innovation

This section is devoted towards identifying the major factors impeding innovative activity, both at the firm and country level. Section VI of the CIS provides subjective responses evaluating "Factors Hampering Innovation" on the 1-5 scale. Possible factors range from economic factors, including "excessive perceived risk" and "lack of appropriate sources of

[51] We should have labelled this factor as „external sources non-science based".

Table 6.7 The Structure of Sources of Information for Innovation

Variable	Mean	Std.Dev.	Other Firms	Science	Internal Sources, Patent Disclosures
Internal Sources: within the enterprise	3.648	0.968	0.114	0.012	0.584
Internal Sources: witin the group of enterprises	1.948	1.253	-0.027	0.244	0.511
Suppliers of materials and components	2.891	1.102	0.725	0.245	-0.089
Suppliers of equipment	2.862	1.112	0.707	0.296	-0.245
Clients or custumer	3.364	1.274	0.694	0.065	0.327
Competitors in your line of business	2.876	1.276	0.654	0.113	0.330
Consultancy firms	1.971	1.034	0.298	0.561	0.023
Universities/higher education	2.047	1.117	0.170	0.700	0.438
Government laboratories	1.824	1.027	0.111	0.791	0.224
Technical institutes	1.775	1.052	0.158	0.746	0.139
Patent disclosures	2.287	1.291	0.201	0.367	0.652
Professional conferences, meetings, professional journals	2.942	1.168	0.553	0.205	0.475
Fairs/exhibitions	2.738	1.262	0.706	0.108	0.195

Table 6.8 The Importance of Sources of Information for Innovation by Countries

	All Countries	BEL	DK	ESP	FR	GER	GR	IRL	ITL	LUX	NL	NOR	P	UK
Other firms	1	2	1	1	2	1	2	1	1	1	2	1	1	1
Suppliers of materials and components			●	O			O		●		●			●
Suppliers of equipment										●				
Clients or custumer	●	●	●	●	●	●	●	●	●		●	●		●
Competitors in your line of business				●				●						
Professional conferences, meetings, professional journals	●	●			●	●	●					●	●	
Fairs / exhibitions				●		●	O			●			●	
Internal sources, Patent disclosures	2	1	2	2	1	2	1	2	2	2	1	2	2	2
Within the enterprise	●	●	●		●		●	●	●	●	●	●	●	●
Within the group of enterprises	O		O			O			O	O			O	O
Patent disclosures				O									O	
Science	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Consltancy firms		O	O		O			O		O	O	O		O
Universities / higher education					O		O	O			O	O		
Government laboratories	O	O	O	O		O		O	O	O		O		O
Technical institutes	O	O			O	O			O		O		O	

Note: The ranking of the objectives is based on the mean value of the respective cluster of objectives. 1 represents the highest ranking. The circle ● indicates the three most important single objectives and the circle O the three least important ones.

Table 6.9 The Importance of Sources of Information for Innovation by Segments of Chemical Industry

	NACE							
	Chemical Industry without Pharmaceuticals	24.1 Basic Chemicals	24.2 Agro-chemicals	24.3 Paints, Varnishes	24.4 Pharmaceuticals	24.5 Soap, Detergents	24.6 other chemical Products	24.7 Man-Made Fibres
Other firms	1	1	2	1	1	1	1	1
Suppliers of materials and components	●		●	●		●	●	
Suppliers of equipment								
Clients or custumer	●	●	●	●	●	●	●	●
Competitors in your line of business								●
Professional conferences, meetings, professional journals		●			●			
Fairs / exhibitions								
Internal sources, Patent disclosures	2	2	1	2	2	2	2	2
Within the enterprise	●	●	●	●	●	●	●	●
Within the group of enterprises					O			
Patent disclosures								
Science	3	3	3	3	3	3	3	3
Consltancy firms	O	O	O				O	
Universities / higher education				O		O		O
Government laboratories	O	O	O	O	O	O	O	O
Technical institutes	O	O	O	O	O	O	O	O

Note: The ranking of the objectives is based on the mean value of the respective cluster of objectives. 1 represents the highest ranking.
The circle ● indicates the three most important single objectives and the circle O the three least important ones.

finance," to firm-specific factors, including "lack of innovative potential in the firm," "lack of skilled personnel," and "lack of information." Other reasons, such as "lack of technological opportunities" and "innovation too easy to copy" are also explored.

To determine which of these factors constitute the most significant deterrents to undertaking innovative activity, we had in mind to estimate a simple ordinary least squares regression model,

$$Y^* = \beta X + \varepsilon$$

where

y* is the ranking of each type of barrier to innovative activity,

X is a vector of exogenous variables including firm size and dummy variables representing the specific country,

ß <is the estimated coefficient, and

ε is the stochastic disturbance with an expected value of 0 and variance of σ^2.

After having checked the CIS data and run the first regressions we had to recognize that the variation in the data was to small to use regression analysis in the first place. This had led us to apply again factor analysis to get an idea of the structure of impediments and factors hampering innovations. The correlations between the variables and the factors -- our factor loadings -- are quite high and provide a clear factor structure (see: Table 6.10). Using this structure of the barriers to innovation the dominance of the factor „financial risk and lack of capital" becomes obvious. The ranking of the factors by countries and by segments of industry is shown in Tables 6.11 and 6.12. There is nearly no difference between the firms located in the different European countries, except Luxembourg. For France no data is available. The picture becomes still clearer if we analyse by segment of industry. There we find a uniform ranking in the evaluation of „financial risk and lack of capital". But we have to admit, that the highest averages of the single variables are located nearby „3" which implies literally translated a „moderately significant" barrier to innovation.

„Innovation cost to high" has an average of 2.8 and the „lack of appropriate sources of finance" of 2.6. Thus, cost is one of the most obvious barrier to innovation in the chemical industry. The cost might be attributed to the whole number of items of innovation costs but in particular to R&D effort when it comes to more radical innovations. If this is complemented by a lack of financial capital then both factors presumably interact in the same direction, and then, regardless of prospective profitablity of the innovation, the barrier might become insuperable. This result clearly demands some policy considerations.

Table 6.10 The Structure of Factors Hampering Innovation

Variable	Mean	Std.Dev.	Internal Implemen-tion Risk	Financial Risk and Lack of Capital	Competi-tive Risk	Lack of opportunities for co-operation and technical service	First-Mover Impediment	Lack of .Technological Opportunities
Economic factors: excessive perceived risk	2.219	1.179	0.539	0.534	0.199	-0.047	0.032	0.053
Economic factors: lack of appropriate sources of finance	2.625	1.327	0.1666	0.740	0.191	0.318	0.106	-0.063
Economic factors: innovation costs too high	2.841	1.336	0.294	0.895	0.170	0.201	0.125	0.055
Economic factors: pay-off period of innovation too long	2.651	1.314	0.352	0.697	0.281	0.022	0.128	0.184
Enterprise´s innovatio potential too small	2.118	1.126	0.723	0.315	-0.006	0.207	0.199	0.068
Lack of skilled personel	2.076	1.081	0.768	0.233	0.024	0.204	0.170	0.065
Lack of information on technologies	1.820	0.948	0.759	0.164	0.157	0.328	0.066	0.037
Lack of information on markets	1.965	1.031	0.706	0.187	0.359	0.155	0.092	-0.021
Innovation costs hard to control	2.073	1.060	0.641	0.287	0.383	0.109	-0.0001	0.148
Resistance to change in the enterprise	1.722	0.885	0.634	0.109	0.356	0.077	0.111	0.159
Deficiencies in rhe avalaibility of external technical services	1.743	0.985	0.352	0.202	0.497	0.718	0.173	0.059
Lack of opportunities for co-operation with other firms and technological institutes	1.813	1.086	0.308	0.225	0.269	0.765	0.130	0.166
Lack of tehnological opportunities	1.600	0.877	0.121	0.061	0.191	0.123	0.188	0.917
No need to innovate due to earlier innovations	1.557	0.836	0.156	0.134	0.205	0.136	0.853	0.192
Innovation too easy to copy	1.888	1.117	0.233	0.227	0.618	0.164	0.490	-0.011
Legislation, norms, regulation, standards, taxation	2.091	1.263	0.152	0.269	0.732	0.305	0.089	0.111
Lack of custumer respon-sivness to new products and processes	1.935	1.182	0.236	0.159	0.595	0.150	0.427	0.206
Uncertainty in timing of innovation	1.967	1.208	0.331	0.309	0.612	0.270	0.094	0.243

Table 6.11 The Importance of Factors Hampering Innovation by Countries

	All Countries	BEL	DK	ESP	FR	GER	GR	IRL	ITL	LUX	NL	NOR	P	UK
Financial Risk and Lack of Capital	1	1	1	1	-	1	1	1	1	2	1	1	1	1
Excessive perceived risk		●				●					●	●		●
Lack of appropriate sources of finance	●		●	●			●		●				●	●
Innovation costs too high	●	●	●	●		●	●	●	●		●	●	●	
Pay-off period of innovation too long	●	●	●	●				●	●		●			
Internal Implemention Risk	3	3	2	3	-	4	3	2	3	3	2	3	2	2
enterpris´s innovation potential too small								●		●		●	O	●
Lack of skilled personnel										●			●	
Lack of information on technologies										O				
Lack of information on markets		O				O								
Innovation to hard to control							O							
Resistance to change in the enterprise	O		O	O		O	O		O			O	O	
Competitive Risk	2	2	3	4	-	2	2	3	2	4	3	6	-	3
Innovation too easy to copy								O		O				O
Legislation, norms, regulations, standards, taxation						●	●					O		
Lack of custumer reponsivness to new products and processes														
Uncertainly in timing of innovation														
Lack of Opportunities for Co-operation and Technical Service	4	5	5	2	-	5	4	5	4	6	3	4	-	5 O
- Deficiencies in the availability of external technical services		O	O				O	O		O		O		
- Lack of opportunities for cooperation with other firms and technological institutes						O								
Lack of Technological Opportunities	5	4	4	6	-	3	-	4	5	3	3	2	3	3
Lack of technological opportunities	O			O					O				O	
First-Mover Impediment	6	6	6	5	-	-	-	5	6	1	-	5	-	6
No need to innovate due to earlier innovations	O	O	O	O				O	O	●				O

Note: The ranking of the objectives is based on the mean value of the respective cluster of objectives. 1 represents the highest ranking.
The circle ● indicates the three most important single objectives and the circle O the three least important ones.
Due to the number of equal mean values for the Netherlands the three least important objectives are not indicated.

Table 6.12 Importance of Factors Hampering Innovation by Segments of Chemical Industry

	NACE							
	Chemical Industry without Pharmaceuticals	24.1 Basic Chemicals	24.2 Agro-chemicals	24.3 Paints, Varnishes	24.4 Pharmaceu-ticals	24.5 Soap, Detergents	24.6 other chemical Products	24.7 Man-Made Fibres
Financial Risk and Lack of Capital	1	1	1	1	1	1	1	1
Excessive perceived risk								
Lack of appropriate sources of finance	●	●	●	●	●	●		●
Innovation costs too high	●	●	●	●	●	●	●	●
Pay-off period of innovation too long	●	●	●	●	●	●	●	●
Internal Implemention Risk	2	3	2	3	3	3	2	4
Enterpris´s innovation potential too small							●	
Lack of skilled personnel								
Lack of information on technologies				O		O		
Lack of information on markets								
Innovation to hard to control								
Resistance to change in the enterprise		O		O		O		O
Competitive Risk	3	2	4	2	2	2	3	2
Innovation too easy to copy			O					
Legislation, norms, regulations, standards, taxation								
Lack of custumer reponsivness to new products and processes			O		O			
Uncertainly in timing of innovation								
Lack of Opportunities for Co-operation and Technical Service	5	5	3	5	4	5	4	5
- Deficiencies in the availability of external technical services	O	O						
- Lack of opportunities for cooperation with other firms and technological institutes							O	O
First-Mover Impediment	6	6	6	6	6	6	6	6
No need to innovate due to earlier innovations	O	O		O	O	O	O	O
Lack of Technological Opportunities	4	4	5	4	5	4	5	3
Lack of technological opportunities	O		O		O		O	

Note: The ranking of the objectives is based on the mean value of the respective cluster of objectives. 1 represents the highest ranking.
The circle ● indicates the three most important single objectives and the circle O the three least important ones.

6.3 Innovative Performance

6.3.1 Measuring Innovative Activity

The CIS covers a few input and output measures of innovative activity of the firm. The following measures[52] are of interest for this study:

- Firm is an innovator or not. Information is provided on whether the firm has developed or introduced any technologically changed products or any technologically changed processes during 1990-1992.
- Expenditures on activities related to product innovation and the financial effort dedicated to process innovation.
- The innovative output, that is, the outputs of incrementally and radically changed products, and sales flowing from these products.

6.3.2 The Distribution of Firm Innovative Activity within the Industry

6.3.2.1 Innovating Firms

Innovative output is due to a number of factors like technological competence, market opportunities, and the opportunity to appropriate returns. By simply comparing the share of innovators to non-innovators in our sample these factors cannot be isolated. As seen from Table 6.13 with the shares of product innovators per country show, there are significant differences. They are probably due to the specificities of the country samples and to a measurement bias resulting fron the short period (1990-1992) were firms ought have to report any changed products or processes. Since the table exhibits also the share of process innovations -- which is highly correlated with the process innovations -- we expect that there is also a country bias.

For the purpose of comparison we should exclude the Greek and Portuguese firms because these firms ought to be all innovators. Due to small sample size observations from Luxembourg and the U.K. should be excluded. Then, the lowest share of innovating firms is observed for Italy with 47.7 percent, which is probably due to the large sample size (791 firms, that is 40.8 percent of the whole sample) and the dominance of 347 small firms with 5 to 49 employees.[53] The next lowest share of 62.6 percent product innovators we find in France. The largest share of innovators we find for Denmark (89.7 percent) and Germany (89.9 percent).

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[52] The other pertinant information regarding R&D strategies and technological co-operation was already analyzed in Chapter 5.

[53] But Italy has -- according to our definition of a product innovator -- the highest share of product innovators in the sample, that is, 50.2 percent (see second last column in Table 6.13).

Table 6.13 Descriptive Statistics for Innovation, R&D, and Investment by Country and Segment of Industry (Unweighted mean values and shares)

	Share of Total Sales			Share of all Firms						
	Innovation Intensity	R&D Intensity	Investment Intensity	Product Innovation 1992	Process Innovation 1992	Innovation Intended 1993-95	R&D 1992	R&D Planned next 3 Years	Product Innovators	Process Innovators
Country										
Belgium	4.19	3.37	2.79	80.0	78.8	76.3	90.6	93.8	31.0	58.6
Denmark	6.79	9.13	2.41	89.7	87.2	87.2	97.1	82.9	29.4	38.2
France	-	-	-	62.6	60.9	71.9	-	-	-	-
Germany	7.63	4.36	8.74	89.9	89.9	89.4	86.3	91.9	44.6	46.8
Greece	6.45	5.10	0.62	(55.9)	(52.9)	52.9	85.7	-	-	-
Irland	4.43	3.12	4.99	79.8	79.8	84.8	93.8	93.8	37.3	53.3
Italy	3.64	3.06	4.45	47.7	47.0	73.3	80.8	83.2	50.2	50.5
Luxembourg	1.17	0.92	0.38	(18.2)	(18.2)	45.5	50.0	50.0	-	-
Netherlands	3.01	3.71	15.76	81.4	80.9	80.9	77.8	66.7	37.9	59.3
Norway	4.42	3.90	8.95	85.0	85.0	95.5	94.1	94.1	43.8	43.8
Portugal	1.85	2.37	0.26	(95.8)	(100.0)	97.9	66.7	4.2	37.5	0
Spain	6.96	3.13	-	68.2	63.6	-	88.1	93.2	-	-
United Kingdom	10.03	4.27	4.32	(88.9)	(88.9)	77.8	100.0	100.0	50.0	37.5
All Firms (Sample means)	4.78	3.64	6.79	64.6	63.6	77.2	83.7	81.0	56.9	50.6
Segment										
24.1 Basic Chemicals	3.74	2.56	4.30	63.5	63.5	77.8	82.6	87.1	30.8	65.4
24.2 Agrochemicals	3.41	3.06	1.88	66.7	61.1	77.8	84.2	89.5	62.5	37.5
24.3 Paints, Varnishes	3.06	3.01	3.85	56.3	55.3	74.5	87.8	88.9	65.8	32.9
24.4 Pharmaceuticals	6.05	5.60	4.19	64.1	63.3	79.4	89.7	87.7	46.7	47.3
24.5 Soap, Detergents	4.56	2.49	3.53	56.9	56.4	71.6	76.8	78.9	52.1	46.6
24.6 other Chemical Products	3.59	3.13	3.62	68.0	67.2	78.0	78.0	73.6	43.5	52.0
24.7 Man-Made Fibres	3.16	2.19	6.59	56.6	56.6	71.7	92.6	92.6	16.0	80.0
Firm Size (Employees)										
5-49	4.65	3.52	5.15	47.9	46.8	69.8	69.8	72.7	45.7	49.1
50-249	3.61	3.12	3.50	66.7	66.1	76.3	84.6	79.8	43.5	49.0
250-499	2.90	2.70	2.30	78.2	76.9	84.7	91.0	88.7	42.5	46.7
500-999	6.68	4.23	3.92	86.8	85.3	89.8	93.8	85.1	40.5	49.4
1000 and more	5.05	6.08	3.40	95.3	94.5	95.9	99.0	95.9	40.7	53.8

Note: The following countries are included in the analysis by segment of industry: Belgium, France, Germany, Ireland, Italy, Luxembourg, Netherlands, Norway, United Kingdom.
The intensities are computed for the innovating firms reporting either innovations and/or R&D activity.
In case of R&D there are 931 innovating firms and 1007 non-innivators ("missing values"). The observations for about one percent of the innovating firms are excluded from the analysis. These outliers are defined as intensities above 50 percent.

Table 6.13a Distribution of Sales Shares According to the Stages of the Product Life Cycle (Unweighted mean shares in percent)

	Share of Total Sales				
	Stages of the Product Life Cycle				
Country	Introduction	Growth	Maturity	Decline	No. of Observations
Belgium	8	11	26	55	64
Denmark	10	17	30	43	35
France	-	-	-	-	-
Germany	13	15	25	47	120
Greece	5	17	27	51	21
Ireland	10	11	29	49	80
Italy	8	10	23	59	380
Luxembourg	3	14	36	48	2
Netherlands	9	16	22	54	180
Norway	11	13	21	55	17
Portugal	-	-	-	-	-
Spain	-	-	-	-	-
United Kingdom	8	14	19	59	8
All Firms (Sample means)					
Segment					
24.1 Basic Chemicals	9	11	23	57	210
24.2 Agrochemicals	12	14	20	55	19
24.3 Paints, Varnishes	9	10	22	58	82
24.4 Pharmaceuticals	11	12	29	48	199
24.5 Soap and Detergents	10	10	24	56	86
24.6 other Chemical Products	9	13	21	57	221
24.7 Man-Made Fibres	8	10	29	53	27
Firm Size (Employees)					
5-49	9	9	23	58	201
50-249	10	12	23	54	400
250-499	10	12	27	51	128
500-999	9	12	26	53	82
1000 and more	9	13	25	53	91

Note: This table is not discussed in the report.

Figure 6.1 show the observed average share for innovators. The left bar exhibits the share of firms which introduced product innovations in the period 1990-1992. Only half of the small firms with 5 to 49 employees report to have developed an innovaton. The share of innovators increases significantly up to 68 percent with firms having 50 to 499 employees. Then the share converges to about 95 percent innovators in the group of firms with 1000 employees and more, and, the largest firms are all innovators.

A different picture emerges when analysing the distribution of innovating firms by segment of industry. The variation among the segments is quite small. The size effect is somehow equalized when applying a distribution according to segments of industry. The highest shares are with agrochemicals and with other chemical products.

Whether innovative activities are planned the next three years is shown as third bar („Innovation Intended 1993-1995) in the figure. This share is for some countries lower than the actual value and for some greater as shown in Table 6.13. Significantly more innovations are to be expected for Italy (plus 25.6 percent), France (plus 11 percent), and Norway (plus 10 percent).

6.3.2.2 Innovation Expenditures

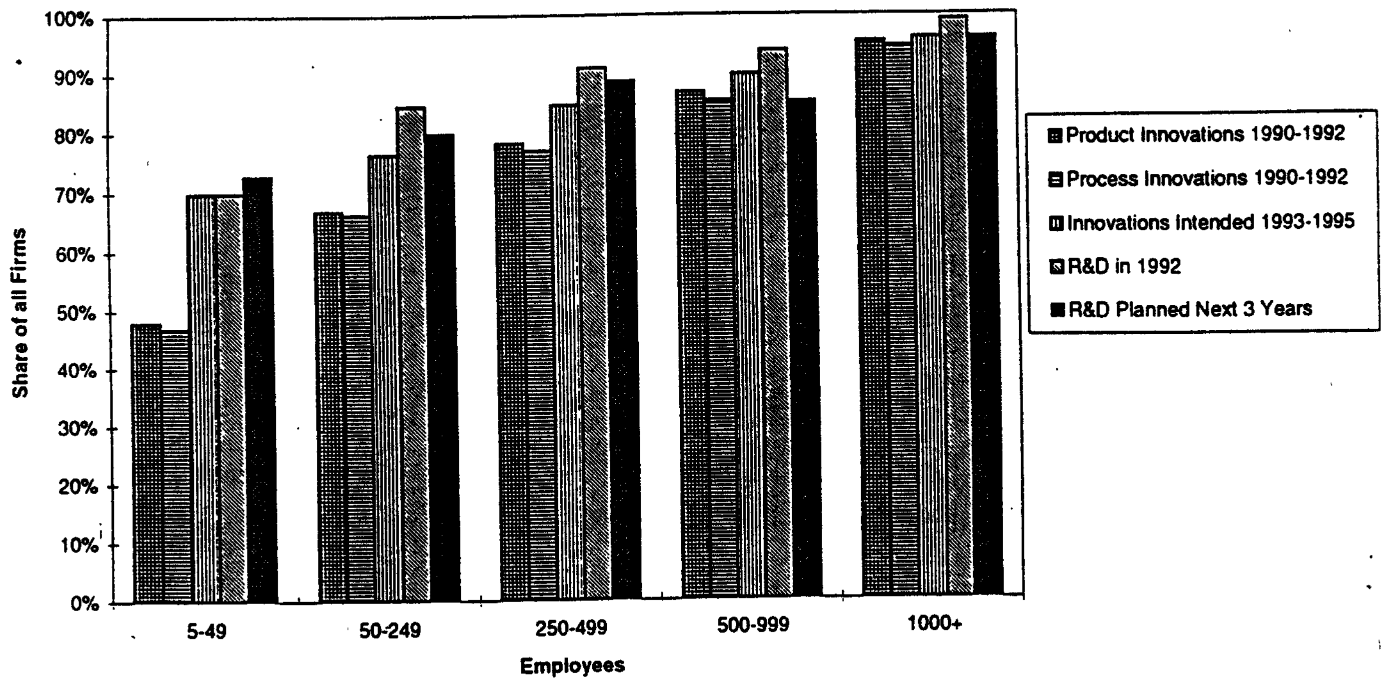
The innovation expenditures measured in the CIS are a result of the various stages of the product innovation process. According to the CIS the total amount of expenditures on innovative activity ought to be attributed to the following activities: R&D; acquisition of patents and licenses; product design; trial production, training and tooling-up; market analysis (excluding launch costs) and other activities. This measurement is based on the new definition in the OSLO-Manual (OECD 1992). Previous work used a more narrow definition focusing on applied reseach and development expenditures. The CIS data allows to single out the importance of the various expenditure items.

The analysis of R&D effort plays a crucial role in economic analysis.[54] The first hypothesis in these studies is that more important innovations require on average a larger share of innovation costs for R&D. A second hypothesis says, that large firms devote a larger percentage of total innovation cost to R&D than smaller firms. And thirdly, it is assumed the more experienced firms are with R&D the higher the likelihood that they learn and become more efficient, and thus would use a smaller share of innovation expenditures for R&D to innovate.

The overall picture is shown in Figure 6.2. This figure allows to compare intensities of innovation, R&D, and investment (that is their expenditures as a share of total sales). The innovation intensity is highest for firms of the size 500 to 999 employees and - - among

[54] See for an overview of empirical research on R&D Cohen and Levin (1989) and for detailed analysis of the distributions of R&D expenditures in various industries Cohen and Klepper (****), in: AER.

Figure 6.1 Innovating and R&D Performing Firms as Share of all Chemical Firms in 1992 in 13 European Countries



Note: Observations with R&D intensities greater than 30 percent are not included in this figure.

others for firms with 1000 employees and more -- the innovation intensity is lower. Regarding R&D intensities this pattern is reversed. That is, the R&D intensity of the largest firms is highest. Structural differences with respect of segments of industry become clear from Figure 6.3. The similarity in the pattern „innovation-R&D-investment intensity" of the segments agrochemicals and pharmaceuticals is obvious but the magnitude is different. The R&D intensity of the pharmaceutical industry is twice as large as the one for agrochemicals. As expected, the investment intensity of the manufacturers of man-made fibres is the highest in the whole industry and 50 percent higher than the one of the pharmaceutical segment.

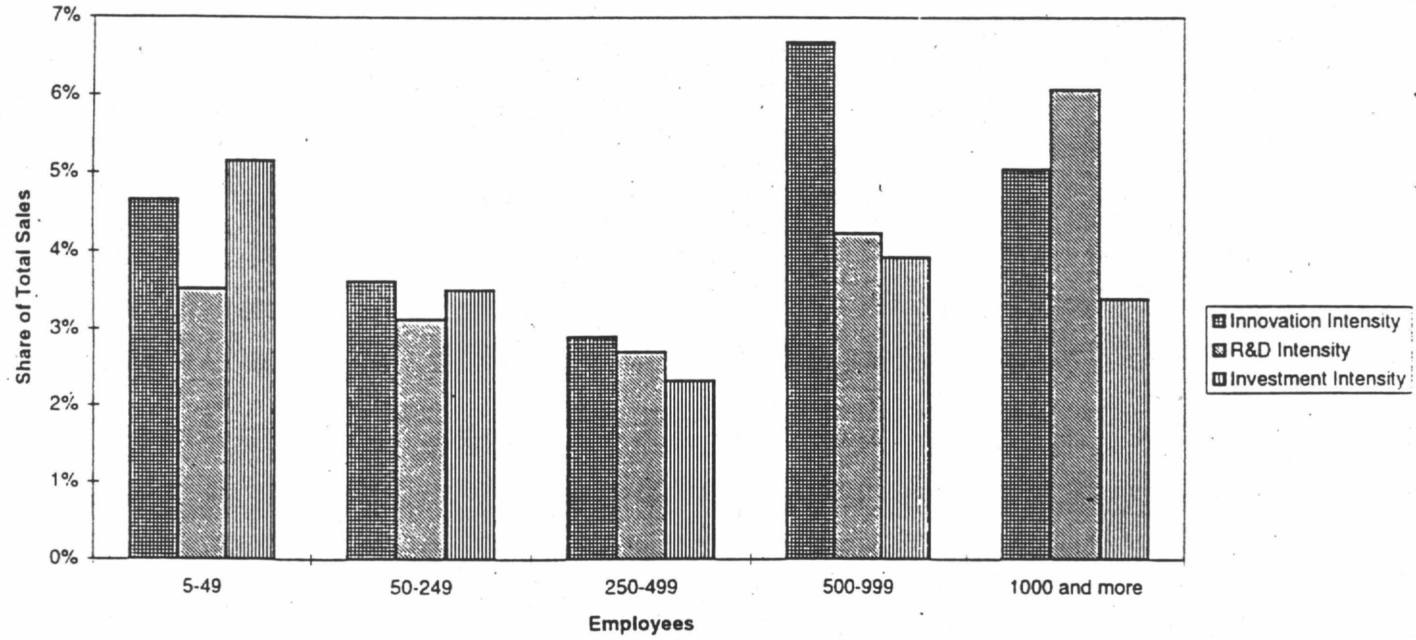
How the particular components of innovation expenditures vary according to firm sizes is shown in Figure 6.4. Again the R&D share of innovation expenditures increases with inceasing firm size. It is nearly twice as large for the largest firms as compared with the smallest firms. But, for the small firms the share „other innovation expenditures" is about 18 percent which in part might also be devoted to R&D activities of these firms.

Figure 6.5 provides a comparison of the structure of innovation expenditures according to the segments of the chemical industry. The highest R&D share are with agrochemicals and paints and varnishes. There are also considerable differences in the shares of product design costs and costs for trial production, training and tooling-up.

6.3.3 Comparison of Innovative Performance

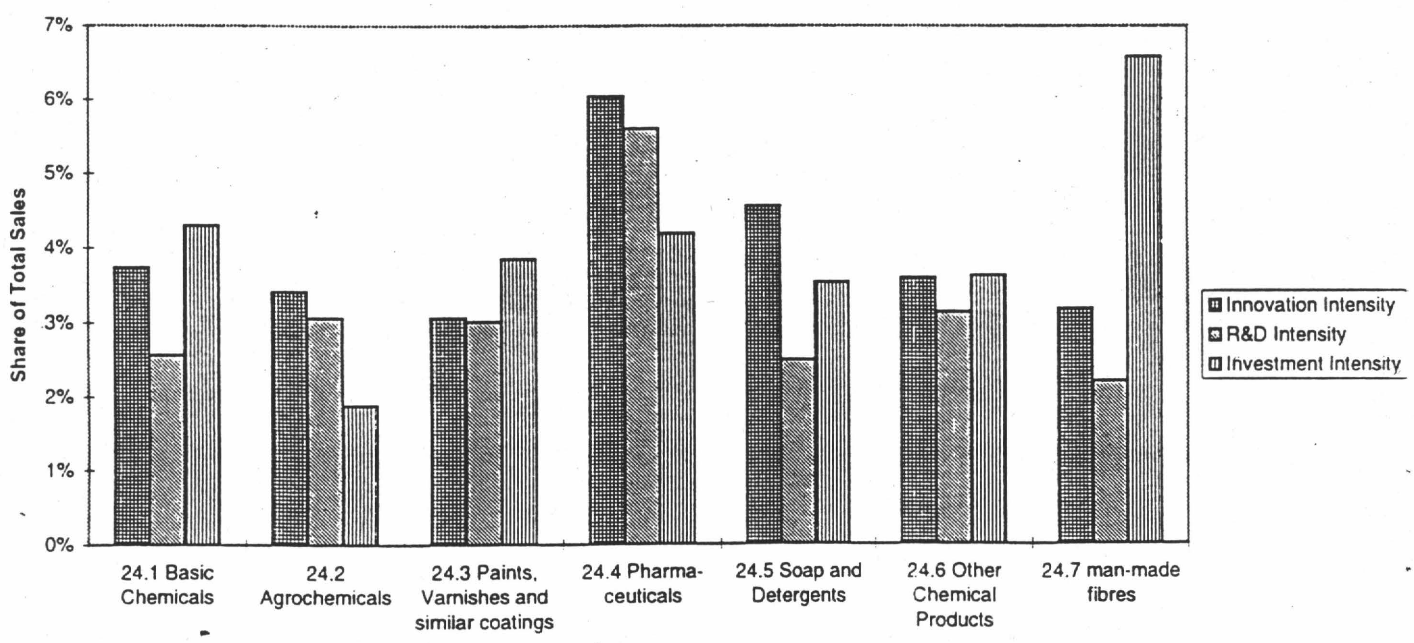
The CIS does not include any particular measure of innovative through-put like the number of patents applied for or the stock of patents. Neither it does include information on the number of new products introduced into the market nor is information on any profitability measure reported. As a result this study has to focus on innovative outputs of incrementally and radically changed products, and sales flowing from these products. In particular, responses to Question 15a (How were the enterprise's total sales distributed across these types of products? *(1) Products which essentially have remained technologically unchanged during 1990-1992; (2) products subject to incremental technological changes in 1990-92; and (3) significantly changed from a technological viewpoint or newly introduced products during 1990-92).* These responses will be used alternatively as a continuous variable, bounded by zero and one, and as a binary variable (zero if the enterprise is not innovative and one if it is innovative) in a logit analysis.

Figure 6.2 Innovation Intensity, R&D Intensity and Investment Intensity by Firm Size for Chemical Firms in 13 European Countries



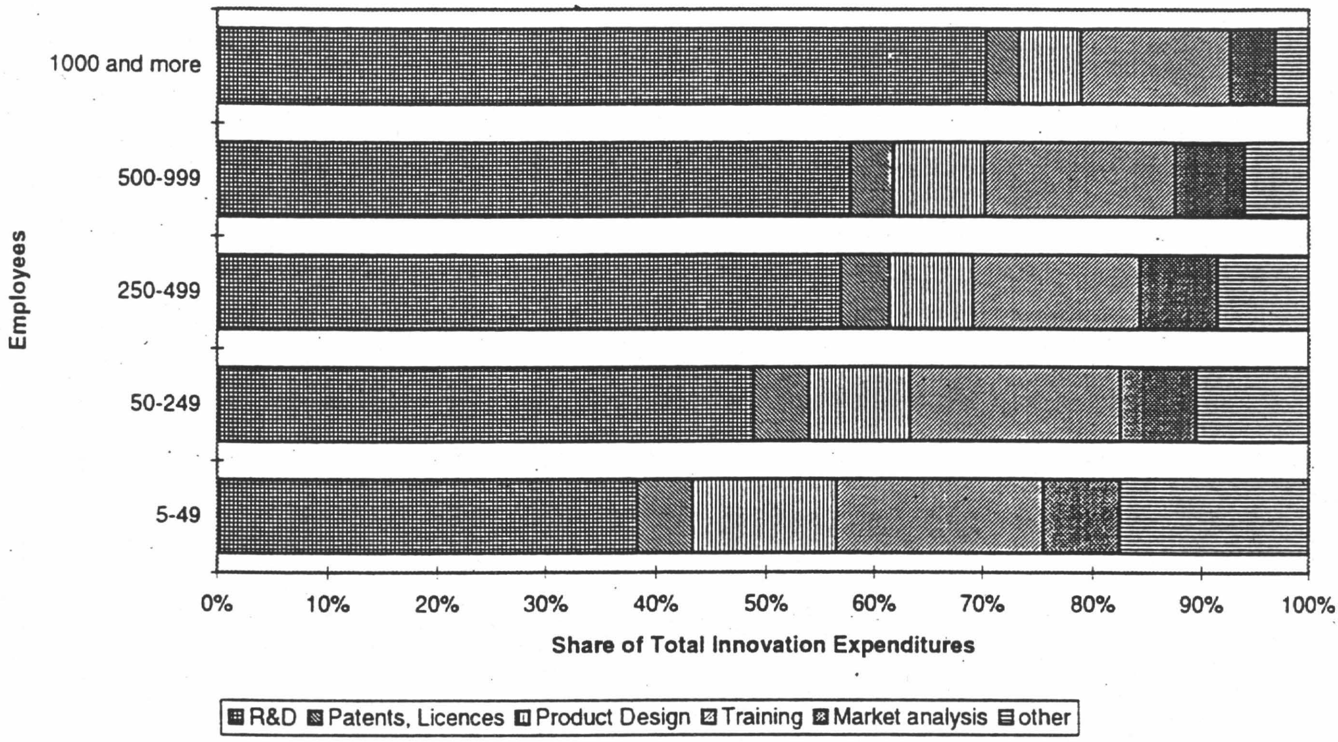
Note: Observations with intensities greater than 50 Percent are excluded from the computation of the averages in the figure.

Figure 6.3 Innovation Intensity, R&D Intensity and Investment Intensity by Segments of the European Chemical Industry for 8 Countries



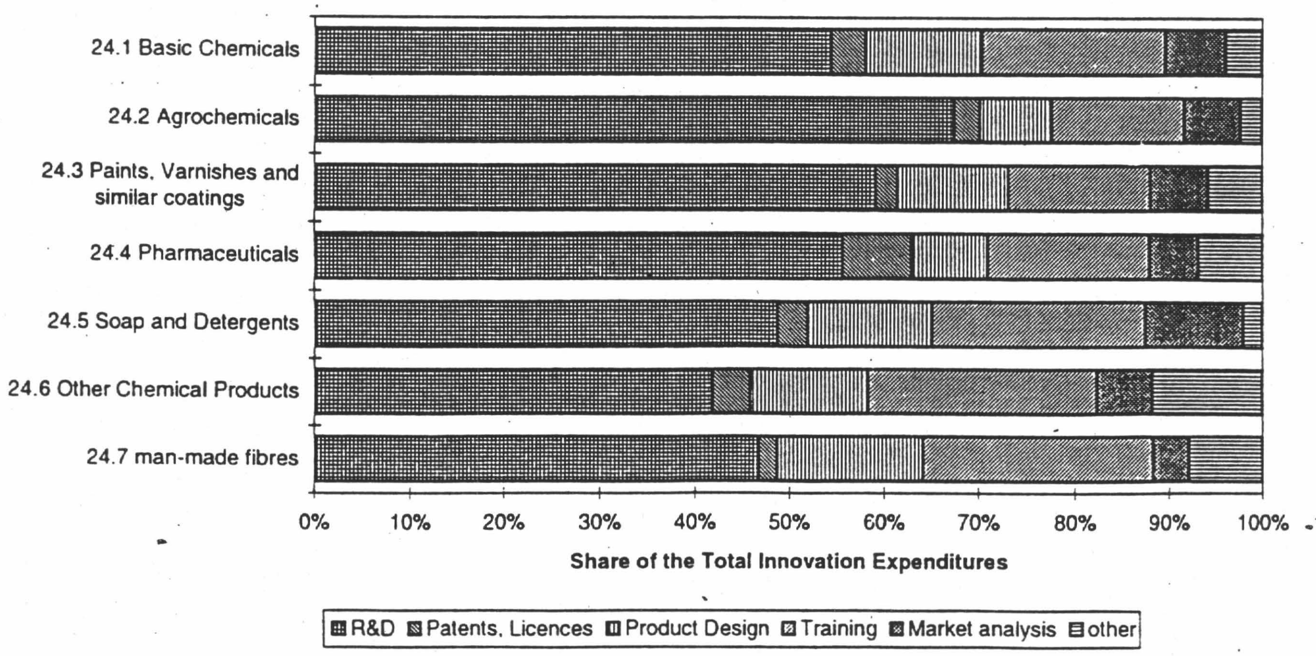
Note: The following countries are include in the analysis: Belgium, Germany, Ireland, Italy, Luxembourg, the Netherlands, Norway, and the United Kingdom.
Observations with intensities grather than 50 Percent are excluded from the computation of the averages in the figure.

Figure 6.4 Components of Innovation Expenditures by Firm Size for Chemical Firms in 13 European Countries



Note: Observations with R&D Intensities greater than 30 Percent are not included in this figure.

Figure 6.5 Components of Innovation Expenditures by Segments of the Chemical Industry in 8 European Countries



Note: The following countries are include in the analysis: Belgium, Germany, Ireland, Italy, Luxembourg, the Netherlands, Norway, and the United Kingdom.
Observations with R&D Intensities greater than 30 Percent are not included in this figure.

6.3.3.1 Estimation of Elasticities of Innovative Output

This part of the analysis leads directly to the „Schumpeterian Hypothesis", a classic issue of public policy which has centered on the size of innovating firms. Because of assumed scale economies for R&D inputs in producing innovative output, it has been hypothesized that large firms have an inherent advantage in innovative activity. As Scherer (1983, pp. 234-5) reports, the empirical evidence suggests that „... size is conducive to vigorous conduct of R&D." However, as Fisher and Temin (1979) and later Kohn and Scott (1982) demonstrated, the determination of an elasticity of R&D inputs with respect to firm size exceeding unity does not necessarily imply that scale economies exist for R&D in producing innovative output. This became clear in the work by Acs and Audretsch (1987; 1988; and 1990) who found that small firms can be at least as innovative as their larger counterparts in certain industries. Although their analyses were undertaken at the aggregate industry level, the results cast some doubts on the virtually untested but central proposition that scale economies exist for R&D in generating innovative activity.

R&D and Innovation The purpose of this part of the study is to apply the CIS measure of innovative sales output at the firm level to determine whether scale economies do exists for R&D inputs in the European chemical industry. It is conceivable that the quality or significance of innovations is not constant across either firm size or with respect to R&D effort. However, using two measures of innovative output[55] and a quite large and homogeneous sample of firms, these measurement issues will be ruled out.

As a first approximation to answering the question whether scale economies exist for R&D in producing innovative output in the chemical industry, a simple production function relationship of the type used by Bound et al. (1984) can be examined:

$$NPS = aRD^{\beta 1}$$

where NPS is the sales due to significantly changed products or introduced in 1990-1992 („new product sales") and RD is the firm's expenditure on R&D. For the linear regression the logarithmic values[56] are used, that is

$\ln NPS = \ln a + \beta_1 \ln RD$ with the estimated coefficients for the whole sample:

$$\ln NPS = 4.01 + 0.64 \ln RD \qquad R^2_{Adj.} = 0.50 \qquad F = 742.73 \qquad N = 760$$

$$(25.78) \quad (27.25)$$

[55] These measures are (1) the sales share of significantly changed products and (2) the sales share of incrementally and significantly change products.

[56] We use the natural logarithm (ln) where as Bound et al. (1984) apply the logarithm at basis 10 (lg). They are equivalent, that is, $\ln N = 2.30259 \lg N$. For the estimation of the regression equation this implies that the constant term of the ln-equation is 2.3 times the constant of the lg-equation.

where the t-values are listed in parenthesis. The estimated elasticities of new product sales with respect to R&D expenditures by country for the chemical and pharmaceutical industry are listed in Table 6.14. These elasticities are the elasticities at the sample mean of NPS and RD. The estimation for Denmark is not significant. For the other countries the elasticity ranges from 0.39 for Portugal to 0.79 for Ireland. These values are some what different from the elasticities between 0.32 and 0.38 for R&D and patents based on 2582 firms estimated by Bound et al. (1984).

The range of elasticities for the various segments of the industry is smaller (see Table 6.15). The values range from 0.49 for man-made fibres to paints and varnishes 0.73, that is, 1 ECU spend for R&D in paints and varnishes results in new product sales of 0.73 ECU.

Two considerations should be mentioned when discussing these elasticities. First, there is an estimation effect due to the homogeneity of the sub-samples. As Table 6.16 shows the values are lower and the range of coefficients is much smaller when the elasticities are estimated according to firm size groups. The values range for the whole chemical and pharmaceutical industry from 0.23 to 0.32. The size effect has an impact on the estimations, that is, the broader the size range the steeper the slope of the estimated relationship and the higher the estimated elasticity because the sums of R&D spend by larger firm are much higher than those of small firms. A second consideration is based on spillover effects. One could argue -- in case spillover effects are observed in the whole industry -- that the most reasonable estimation of elasticities is for the whole industry. This estimation then would capture the spillover effects. On the other hand the estimations for more homogeneous groups are lacking spillover and their elasticities as such are significantly lower. Which, in fact, is observed.

Firm Size and Innovation As Baldwin and Scott (1987) confirm in their review of the literature, there has already been a plethora of studies examining the relationship between firm size and R&D effort.[57] Although the work by Bound et al. (1984) indicates that expenditures on R&D increase proportionately with firm sales, and Soete (1979) found that R&D increases more than proportionately with firm sales, virtually no one has found that this relationship is anything less than proportional. However, just as there have only been a handful of studies examining the relationship between innovative outputs and inputs, the lack of meaningful data has not enabled researchers to estimate the relationship between firm size and innovative output. Thus, it remains to be empirically answered: To what extent does innovative activity increase or decrease along with firm size?

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[57] See Cohen and Klepper (1992) for a recent review and analysis of R&D intensities in the U.S. industry.

Table 6.14 Estimated Elasticities of Innovative Output (New Product Sales) with Respect to R&D Expenditures by Country for the Chemical and Pharmaceutical Industry.

Country	R&D Elasticity	$\bar{R}^2$	Significance (p values)	Number of Firms
Belgium	0.64	0.42	0.0000	48
Denmark	0.24	0.05	n.s.	30
Germany	0.75	0.59	0.0000	115
Ireland	0.79	0.50	0.0000	60
Italy	0.58	0.48	0.0000	251
Netherlands	0.61	0.50	0.0000	121
Norway	0.45	0.58	0.0024	12
Portugal	0.39	0.15	0.0333	24
Spain	0.69	0.39	0.0000	92
United Kingdom	0.69	0.68	0.0145	7

Table 6.15 Estimated Elasticities of Innovative Output (New Product Sales) with Respect to R&D Expenditures by Segment of Industry

Industry Segment (NACE)	R&D Elasticity	$\bar{R}^2$	Significance (p values)	Number of Firms
Basic Chemicals (24.1)	0.62	0.49	0.0000	143
Agrochemicals (24.2)	0.43	0.05	n.s.	11
Paints, Varnishes (24.3)	0.73	0.53	0.0000	63
Pharmaceuticals (24.4.)	0.68	0.61	0.0000	150
Soap and Detergents (24.5)	0.66	0.37	0.0000	61
Other Chemical Products (24.6)	0.74	0.54	0.0000	159
Man-Made Fibres (24.7)	0.49	0.26	0.0102	21

Note: The 8-country sample includes Belgium, Germany, Ireland, Italy, Luxembourg, the Netherlands, Norway, and the United Kingdom.

Table 6.16 Estimated Elasticities of Innovative Output (New Product Sales) with Respect to R&D Expenditures by Size Group for the Chemical and Pharmaceutical Industry

Size Group (Employees)	R&D Elasticity	$\bar{R}^2$	Significance (p values)	Number of Firms
5 - 49	0.30	0.10	0.0000	162
50 - 249	0.32	0.11	0.0000	329
250 - 499	0.11	0.01	n.s.	113
500 - 999	0.23	0.14	0.0007	72
1000+	0.31	0.12	0.0007	83

Note: The 8-country sample includes Belgium, Germany, Ireland, Italy, Luxembourg, the Netherlands, Norway, and the United Kingdom.

We again follow the example of Bound et al. (1984)[58] in providing a first approximation of the relationship between firm size, measured by ECU thousands of sales (SAL), and the innovative output measured as new product sales. The estimated function for the whole sample of firms from the chemical and pharmaceutical industry then is:

$$\ln NPS = -1.51 + 0.94 \ln SAL \qquad \bar{R}^2 = 0.77 \qquad N = 1027$$
$$(-9.10) \quad (57.96) \qquad F = 3359.22$$

The elasticity of innovative output with respect to firm size (measured in ECU) is at the sample mean 0.94, that is less than unity, implying that innovative activity does not increase proportionately along with firm size. A different result emerges when an alternative measure of firm size, employment (EMP) is substituted for sales:

$$\ln NPS = 2.97 + 1.00 \ln EMP \qquad \bar{R}^2 = 0.65 \qquad N = 1027$$
$$(24.85) \quad (43.45) \qquad F = 1887.89$$

That is, the elasticity of innovative output with respect to firm size (measured in employees) is at the sample mean 1.00, that is unity, implying that innovative activity does increase proportionately along with firm size.

Table 6.17 shows the estimated elasticities of innovative output with respect to firm size by country and by segment of industry. Much lower than unity are the values for Portugal with 0.69 for size in employees and 0.63 in sales. The innovative output increases significantly with employment in Ireland with 1.45. For the other countries it reasonable to assume that innovative activity does increase proportionately along with firm size.

With respect to industry segments a less than proportionate increase with size is observed for the manufacture of basic chemicals. This is plausible due to the limited opportunities. On the other hand we find a more than proportionate increase with size measured in employees for the agrochemical segment which is also reasonable on the same grounds but with an opposite sign, that is, agrochemicals are confronted with an increasing number of opportunities to innovate when firm size increases.

6.3.3.2 Estimation of Returns to R&D

Further insights with respect to the returns of R&D might be achieved the estimation of a linear and quadratic relationship. Some authors use an additional cubic term. For statistical reasons, but also due to problems to be expected with the interpretation of the estimated coefficients, we have not used a cubic term. The correlation we found between the quadratic and cubic R&D term was higher than 0.9. Using the cubic term would have led

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[58] See also Schwartzman (1976) for an estimation of elasticities for the pharmaceutical industry. His equation includes also the term $(\ln size)^2$ which allows to derive the elasticity for the whole range of sizes.

Table 6.17 Estimated Elasticities of Innovative Output (New Product Sales) with Respect for Firm Size by Country and by Segment of Industry

Country[1]	Size Elasticity Employees	Size Elasticity Sales	$\bar{R}^2$ emp	$\bar{R}^2$ sal	N
Belgium	0.92	0.92	0.56	0.72	49
Denmark	0.89	0.96	0.60	0.75	31
France	1.03	0.97	0.68	0.79	147
Germany	1.01	0.88	0.75	0.84	129
Ireland	1.45	1.21	0.64	0.77	63
Italy	0.96	0.96	0.61	0.76	302
Netherland	1.03	0.97	0.60	0.70	147
Norway	0.93	0.78	0.88	0.85	12
Portugal	0.63	0.69	0.39	0.65	37
Spain	1.02	0.97	0.55	0.67	103
United Kingdom	1.12	1.06	0.85	0.93	7
Industry Segment (NACE)[2]					
Chemical Industry (24)	1.00	0.94	0.65	0.77	1027
Basic Chemicals (24.1)	0.88	0.86	0.60	0.77	200
Agrochemicals (24.2)	1.27	1.02	0.73	0.78	17
Paints, Varnishes (24.3)	1.13	0.97	0.70	0.73	97
Pharmaceuticals (24.4.)	0.99	0.94	0.64	0.74	206
Soap and Detergents (24.5)	1.02	0.98	0.66	0.83	96
Other Chemical Products (24.6)	1.03	0.99	0.69	0.78	208
Man-Made Fibres (24.7)	1.17	0.98	0.71	0.73	26

Note: [1] All coefficients are significant at $p < 0.0001$, except the one for the U. K. with $p = 0.002$.
[2] All coefficients are significant at $p < 0.0001$.

us into problems of autocorrelation. The interpretation of the cubic term would require to check each individual function for turning point. For these two reason we have estimated the following model:

$$NPS = a + b\,RD + c\,RD^2 .$$

For the dependent variable we used only one measures of innovative output, that is the one for significant product innovations. In case we would have used the sum of sales due to incremental and significant product innovations there is less discrimination between innovators and non-innovators. Table 6.18 shows the estimated coefficients for the countries and their chemical industry as a whole, including pharmaceutical firms. Based on the type of returns to scale of R&D observed we can distinguish three groups of countries: those with decreasing returns to scale in R&D (positive coefficient of the linear term and negative coefficient of the quadratic term), those with increasing returns to scale in R&D (positive coefficient of the linear term and positive coefficient of the quadratic term), and a group for which we have no conclusive evidence.

We find decreasing returns to scale for Italy, the Netherlands, Spain, Ireland, and Norway. For 134 firms in the German sample there is evidence for increasing returns to scale in R&D. No conclusive evidence we find for Belgium, Denmark, and Portugal.

Table 6.19 shows the returns to scale in R&D for the segments of the chemical industry. We find no conclusive evidence for the manufacture of man-made fibres and for agrochemicals. The returns for all other segments are decreasing.

The result of increasing returns to R&D for Germany is surprising. Surprising with respect to results reported in the literature and compared to the other countries. Except this one country there is no evidence that increasing returns to R&D expenditures in producing innovative output exist. Rather, our empirical results for the European chemical industry suggest, with the one exception, diminishing returns to R&D are the rule. Thus, while larger firms are observed to undertake a geater effort towards R&D, each additional ECU of R&D is found to yield less in terms of innovative output. Therefore it is reasonabel tocheck whether we can find differences which distinguish innovators and non-innovators in our sample.

Table 6.18 Country-Specific Regressions for Innovative Product Sales (for Major Innovations) and R&D in 1992 (with Pharmaceuticals)
(in thousand ECU; t-statistics in parentheses and significance in squares; R&D Intensities greater than 30 percent are excluded)

Country	RD	RD^2	Constant	R^2	F	n
Decreasing Returns						
Italy	2.516 (7.472) [0.0000]	$-2.577*10^{-5}$ (-4.730) [0.0000]	4037.9 (2.713) [0.0071]	0.218	41.093 [0.0000]	288
Netherlands	2.116 (11.294) [0.0000]	$-7.811*10^{-6}$ (-10.299) [0.0000]	2726.4 (2.093) [0.0383]	0.502	69.975 [0.0000]	138
Spain	8.511 (3.469) [0.0008]	$-8.132*10^{-4}$ (-2.283) [0.0245]	1520.9 (0.863) [0.3901]	0.126	8.454 [0.0004]	104
Ireland	6.519 (3.840) [0.0003]	$-2.731*10^{-4}$ (-2.925) [0.0049]	2455.4 (1.405) [0.1654]	0.228	9.744 [00002]	60
Norway	4.680 (4.473) [0.0006]	$-9.084*10^{-5}$ (-4.538) [0.0006]	2330.2 (0.656) [0.5235]	0.554	10.313 [0.0021]	16
Increasing Returns						
Germany	1.036 (3.457) [0.0007]	$1.936*10^{-6}$ (6.007) [0.0000]	17151.9 (2.211) [0.0287]	0.896	577.022 [0.0000]	134
No Conclusive Evidence						
Belgium	-4.831 (-1.285) [0.2048]	$9.861*10^{-5}$ (3.913) [0.0003]	31227.7 (1.051) [0.2982]	0.782	96.388 [0.0000]	54
Denmark	0.325 (0.610) [0.5468]	$8.857*10^{-6}$ (1.111) [0.2762]	5013.2 (3.281) [0.0029]	0.732	40.648 [0.0000]	30
Portugal	-1.558 (-0.364) [0.7186]	0.016 (1.031) [0.3112]	2624.7 (2.437) [0.0214]	0.108	2.824 [0.0763]	31

Table 6.19 Industry-Specific Regressions for Innovative Product Sales (for Major Innovations) and R&D in 1992
(in thousand ECU; statistics in parentheses and significance in squares; R&D Intensities greater than 30 percent are excluded)

Industry	RD	RD^2	Constant	R^2	F	n
Decreasing Returns						
24 Chemical Industry (without Pharmaceuticals)	3.945 (13.666) [0.0000]	$-1.069*10^{-6}$ (-3.266) [0.0012]	4799.603 (0.974) [0.3307]	0.618	444.271 [0.0000]	548
24.1 Basic Chemicals	13.536 (10.524) [0.0000]	$-4.767*10^{-5}$ (-8.310) [0.0000]	-20946.5 (-1.619) [0.1072]	0.443	72.940 [0.0000]	182
24.3 Paints, Varnishes and Similar Coatings	11.319 (6.288) [0.0000]	$-1.515*10^{-4}$ (-5.132) [0.0000]	-2766.9 (-1.099) [0.2752]	0.501	39.634 [0.0000]	78
24.4 Pharmaceuticals	1.602 (9.481) [0.0000]	$-5.78*10^{-6}$ (-6.910) [0.0000]	4648.2 (2.123) [0.0352]	0.363	51.490 [0.0000]	178
24.5 Soap and Detergents	10.192 (1.163) [0.2490]	$-3.856*10^{-4}$ (-0.582) [0.5625]	6346.2 (1.074) [0.2867]	0.125	6.066 [0.0037]	72
24.6 Other Chemical Products	4.659 (20.104) [0.0000]	$-1.731*10^{-6}$ (-7.168) [0.0000]	769.2 (0.235) [0.8142]	0.966	2541.039 [0.0000]	177
No conclusive Evidence						
24.2 Agrochemicals	0.492 (0.180) [n.s.]	$-3.956*10^{-4}$ (-0.401) [n.s.]	1842.2 (-0.613) [n.s.]	-0.111	0.251 [0.7816]	15
24.7 Man-Made Fibres	3.255 (0.773) [0.4718]	$3.191*10^{-5}$ (0.064) [0.9494]	6505.4 (1.495) [0.1498]	0.228	4.411 [0.0251]	24

Note: The following countries are include in the analysis: Belgium, Germany, Ireland, Italy, the Netherlands, and Norway.

6.3.3.3 A Logit Model of Innovation

The pace of innovation in the European chemical industry has been truely remarkable. An important question is whether such a development will continue and what factors have affected such innovative behavior. That is, in particular, how can a firm in a scientifically and technologically based industry build and maintain its capabilities? In view of the fact that the CIS data provides no information on individual innovations in this section we will nevertheless examine the relationship between important characteristics of firms of the chemical industry and their innovative behavior. Obviously this can only be done in recognition of the limitations of survey data available in the CIS.

Although this is not the place for a critical examination of the literature on innovation and R&D in the chemical industry we should mention two frequently cited studies which relate to the innovative behavior of Du Pont, the largest US-manufacturer in the chemical industry.[59] These are the studies by Mueller and by Hollander. Mueller analysed 25 of Du Pont's most important product and process innovations made between 1920 and 1950 and which accounted for about 45 percent of the company's sales. Mueller found that of 18 new products only five could be credited to Du Pont and another as the co-inventor. The Du Pont record for process innovations was five out of seven. Mueller's conclusion is important because it sheds light on the economics of innovation in large chemical firms -- not only to Du Pont -- but also with some qualifications to the nine large European fims we have analysed in the first part of this report. Mueller concluded:

> „Du Pont has been more successful in making product and process improvements than in discovering new products. Except for nylon, [O]rlon, and neoprene, Du Pont's major product innovations have been based upon technology acquired from others. Next to be considered is the significance of these findings in relation to the frequent statement that Du Pont's bigness has created a perfect environment for inventive activity resulting in important new products and processes. The record during the period of this study does not support such a generalization. Although Du Pont has expanded its research expenditures as it has grown - from slightly under $1 million annually shortly before 1920 to $38 million in 1950 - there has not been a proportional acceleration in the number of important inventions (as defined herein) coming from its laboratories. Nylon still remains its greatest success story. Neoprene, discovered in 1931 [sic], probably has been exceeded only by nylon and [O]rlon; and the latter was an outgrowth of its basic discoveries underlying nylon".[60]

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[59] These studies are Mueller, W.F. (1962), The Origins of the Basic Inventions Underlying Du Pont's Major Product and Process Innovations, 1920-1950, and Hollander, S. (1965), The Sources of Increased Efficiency: A Study of Du Ponts Rayon Plants. Our presentation of the Du Pont case study draws on the publication by Hounshell (1995).

[60] Mueller, p. 346, quoted according to Hounshell (1995), p. 176

In line with this conclusion Mueller raised the issue about incentives for basic research. He agreed with Richard Nelson's 1959 thesis that „though private profit motives may stimulate the firms of private industry to spend an amount on applied research reasonable close to the figure that is socially desirable, it is clear [...] that the social benefits of basic research are not adequately reflected in opportunities for private profit, given our present economic structure".[61]

A provoking result was put foreward by Hollander (1965). While looking for the sources of increased efficiency of productivity in Du Pont's manufacturer of rayon he found that minor and almost routine improvements added up to significantly greater gains in productivity than did process improvements deriving from Du Pont's rayon research and development laboratories. Hollander's conclusion was that industrial R&D did not contribute as much to technological change within Du Pont as some people had thought. If there were benefits deriving from basic R&D, they were not being appropriated by Du Pont but were becoming public property through such routes as conference presentations and publications.

According to Hounshell (1995) these studies were strongly colored by the context of that time, that is, they argued for massive funding of basic research. They are, nevertheless, interesting because they shed some light on the uncertainties involved. Furthermore, recent theoretical research has developed a better understanding of the economics involved in process and product innovations and in the economics of research joint ventures. For example, Rosenkranz (1996)[62] studied individual and cooperative R&D decisions as an example of feedback processes of market structure and firm behavior. This is important because today firms are more and more deciding to coordinate their R&D activities with their most potential rivals. Furthermore, in Europe and in the USA, anti-trust authorities tend to treat these cooperative increasingly favorably and it is also being discussed whether to extend this favorable treatment to R&D agreements which also provide for joint exploitation of the results. But, there is still little empirical evidence and theoretical knowledge on these relationships regarding the chemical industry.

Of similar interest for the purpose of our study is theoretical work by Rosenkranz (1995) on the simultaneous choice of process and product innovation.[63] She shows how the optimal division between these two kinds of R&D activities changes with market size. The higher consumers' willingness to pay, the more firms' investment is driven to product innovation. If firms coordinate their R&D activities and share R&D costs but remain rivals in the product market, they will reduce costs and intensify product innovation more than

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[61] Mueller, p. 346, quoting Nelson, R.R., The Simple Economics of Basic Scientific Research - A Theoretical Analysis, in: Journal of Political Economy, 1959, pp. 297-306; quoted according to Hounshell (1995), p. 176

[62] Rosenkranz, S. (1996), Product Innovation and Cooperation, Berlin: Edition Sigma

[63] Rosenkranz; S. (1995), Simultaneous Choice of Process and Product Innovation, Discussion Paper FS IV 95-30, Wissenschaftszentrum Berlin.

under R&D competition. The optimal proportion of R&D investment is driven more to product innovation than under R&D competition. A further result of the game-theoretic analysis by Rosenkanz is, that welfare is increased if firms coordinate their research activities and share R&D costs. When firms cooperate but do not share their R&D costs, welfare is only enhanced if product innovations are not too expensive.

The foregoing discussion suggests that is important also for firms in the European chemical industry to explore the possibilities of coordinating their research effort and if it is possible to share R&D costs. Furthermore a firm's strategy formulation determines how the firm allocates its R&D budget to product and process innovation activities. Here is not the place to provide further details on these issues, but attention should be given to studies which discuss the relative importance of characteristics of firms in promoting technological innovations.[64] We have to answer the question in what kinds of firms and under what conditions are product and process innovations are undertaken? What are the characteristics of the firms that are expected to affect strategy formulation of the firm and thereby determine its innovative behavior? For that purpose we will use a simple logit regression model to estimate the likelikhood that a firm is a product innovator or a process innovator respectively.

The Variables and Analysis The dependent variable distinguishes the firms on the basis of their innovative sales. A firm is defined as a product innovator, that is the variable is 1, when the share of total sales due to incrementally changed and significantly changed products is 30 percent and more and equal to 0 when the share is less than 30 percent.

The firm is defined as being a process innovator, that is the dependent variable is 1, when the percentage of total R&D expenditures allocated to process innovation is 25 percent and more. If the share of these expenditures is less than 25 percent the variable is equal to 0.

Five independent variables are used to determine whether a firm is a product innovator or not. The first variable is the perceived importance of an objective of innovation, that is, the importance which is attributed to improve product quality by means of innovation activity. The second variable measures the commitment towards competition. That is, if a firm regards it as important to have a lead time advantage over competitors in order to maintain or increase product innovation it is regarded as being committed to innovation competition. The third variable measures the perceived risk of a strategy of product innovation. For that purpose a measue of the barriers to innovation is used, namely the role of excessive perceived risk related to a product innovation.

To determine what might characterize best the process innovator we assumed that this would be a very strong orientation towards competition. We expected something which

[64] See e.g. for a detailed analysis of these issues Albach (1994).

would have to do with price-volume competion since this can only be achieved via process innovations. The most appropriate variable to proxy this from the CIS data base is the inclination to create new markets in Japan. We would expect this to be an important characteristic of a process innovator since that is a domain of the Japanese and other Asian rivals in global competion. Furthermore, we expected an economical use of resouces as an important determinant of being a process innovator. For the chemical industry we thought it must be an important objective to reduce energy consumption. This seems to be a rational strategy in case the pay-off period of an innovation is expected to be too long to approach this via the use of a process innovation. That is, a relationship is assumed to exist between the attitude to regard a pay-off period as too long and the use of process innovation to compensate for this. The riskiness towards the imitation of product innovations would reduce the likelihood of the use of process innovations, that is, in case the innovation is easy to copy, it is regarded as crucial for the firm (to a lesser extent) to be a process innovator.

To test for the impact of the resources commited to product and process innovation we include the innovative intensity. This is reasonable because it measures the overall commitment of the firm towards innovation, that is for product and for process innovation. A similar argument can be made for the export intensity of a firm. A firm is more commited to innovation and therefore to competition the higher the export intensity is. Export intensity is measured as exports dived by sales in percent.

The results of the models are in Table 6.20. The product innovator model provides a strong support for the view that a commitment to product innovations and the awareness of the risks related to it increases the likelihood of being a successful product innovator. It is in particular the commitment to improve product quality that increases the probability of being a successful product innovator. The innovation intensity is not significant and neither is the export intensity as measured by the export share.

The process innovator model provides support for the view that emphasis on competition and to compete with rivals in their own arena as well as a commitment to the economical use of resources increases the probability of being a process innovator. In case product innovations are easy to copy the probability for process innovation decreases. While the innovation intensity is not significant, the export intensity is. That is, the more a firm pursues an export strategy the higher the likelihood of being a process innovator.

The two equations are different in character. This has to do with differences in the properties of each particular type of innovation. The patterns found here imply that models of innovation strategy would do have to make a clear distinction between product and process innovation but to stress the importance of uncertainty related to innovation as well as a clear focus on competition. However, the CIS data are too crude to be definitive on this point, and further theoretical and empirical work on innovation processes in the chemical industry is appropriate.

Table 6.20 Logit Regression Estimates for Product and Process Innovators in the European Chemical and Pharmaceutical Industry

	Type of Innovator	
Variable	PRODUCT INNOVATOR	PROCESS INNOVATOR
Improving product quality *(objective of innovation, v5_17)*	0.466 (0.000)	
Effectiveness of having lead time over competitors *(effectiveness of methods, v9a_5)*	0.159 (0.052)	
Excessive perceived risk *(innovation barrier, v12_1)*	0.140 (0.091)	
Creating new markets: in Japan *(objective of innovation, v5_8)*		0.247 (0.005)
Reducing energy consumption *(objective of innovation, v5_13)*		0.309 (0.000)
Pay-off period of innovation too long *(innovation barrier, v12_4)*		0.120 (0.091)
Innovation too easy to copy *(innovation barrier, v12_15)*		-2.890 (0.000)
Innovation intensity	0.007 (0.330)	0.006 (0.312)
Export Share (as pct of sales)	0.151 (0.570)	0.394 (0.097)
Constant	-2.933 (0.000)	0.685 (0.000)
-2 (log likelihood)	721.54 (0.000)	1007.79 (0.000)
Percentage correctly classified	62.6	61.3
N	545	762

Note: The table reports logit regressions. Numbers in parentheses are p values.
The dependent variables are defined as follows: PRODUCT INNOVATOR is equal to 1 when the share of total sales due to incrementally changed and significantly changed products is 30 percent and more and equal to 0 when the share was less than 30 percent (CIS question 15a_2 and 15a_3).
PROCESS INNOVATOR is equal to 1 when the percentage of total R&D expenditure allocated to process innovation is 25 percent and higher (CIS question 10c_2) and equal 0 when the share

7 Conclusion and Recommendations

Conclusion This study has focused on the identification of innovative trends within the chemical industry between 1984 and 1993. Much of the information was gathered from the annual reports of nine major European chemical companies. Furthermore data from the Community Innovation Survey (CIS) was used to describe and explain the differences of innovative performance across firms within the European chemical industry. This novel methodological approach to combining two different data bases for the study of innovative behavior in the chemical industry seems to be very promising.

The quantitative evaluation of said annual reports showed clearly discernible innovative trends, which conform with the findings of the pilot study previously carried out. The categories of speciality chemicals, paints/varnishes and plastics were identified as the categories having shown the highest number of innovations during the course of the investigation period (1984 - 1993).

The analysis of R&D input factors and financial ratios for corporate success established a positive interdependence between R&D expenses and corporate success. An analysis of the individual categories, however, showed the strong dependence of R&D expenses on the respective corporate profiles. Since the companies' inclination to report their innovations varied considerably, an evaluation of the innovative strength of the individual companies on the basis of their numbers of innovations was not possible.

The overall plausibility of the results of the quantitative investigation proves that annual reports are indeed very suitable as a basis for such an investigation. The study was further able to confirm certain statements concerning various life cycle models. Life cycle models rank among the few practice-orientated approaches with which innovative processes can be described.

The qualitative investigation established similarities describing the momentary corporate and innovative strategies of Europe's chemical companies. Especially noticeable in this context was the attempt to increase the turnover share of highly refined products. The strategies described in Chapter 5 are of special importance, since they are decisive for future innovative trends and, thus, for the future of the chemical industry in Europe. The CIS data base provided further evidence for the following trends:

1. Increasing effort to apply strategies of cost leadership; in particular, for mass products such as basic chemicals. This takes place as restructuring within the basic chemical business and has concentrated on cost cuts. Since 1991 employment has been reduced by 255,000, a reduction of 14 percent.

2. An increasing trend to specialize in certain product areas also has to do with Trend 1. For large firms, we could show an attempt to build up large market shares in relatively few products. The CIS data on the allocation of R&D expenditures for product and

process innovation highlight the close interrelationship between the two corporate strategies: cost leadership and specialization.

3. Almost all annual reports assign a central role to the concentration on key areas and/or key competencies, with a focus on the achievement of a strong market position and the concentration on areas with a high synergistic effect.

4. Increasing activities towards strategic co-operation in the areas of production and R&D. This also because co-operation enables the firms to enter into new markets, to shorten innovative periods, and to recognize technological potential at an earlier stage. The results from the analysis of the annual reports are supported by the CIS data. Although, regarding the CIS data, we were not able to evalute the quality of the co-operative arrangement and had to relay simply on the numbers.

5. A continuing trend towards globalization. The analysis of the annual reports suggests a significant level of globalization. The reports give a detailed account of regional developments (such as in Europe, North America, Latin America and Asia). One gets the impression that the large chemical firms are of a really international character. Thus, they are able to compensate for a lack of opportunities within Europe by simply operating on an international level. The CIS provided support for the trend towards globalization, at least at the level of the European market. An interesting result is that for the creation of new markets within Europe a U-shaped relationship holds, that is, it is important for about 60 percent of the smaller and of the largest firms but not as important for the medium-sized firms.

The detailed analysis of the CIS data base has shown a number of similarities and significant differences in the patterns of innovative behavior. We have analysed these patterns for countries, segments of the chemical industry and for different size classes of firms. Finally, we provide two simple models of innovative behavior in the European chemical industry.

The product innovator model provides a strong support for the view that a commitment to product innovations and the awareness of the risks related to it increases the likelihood of being a successful product innovator. It is in particular the commitment to improve product quality that increases the probability of being a successful product innovator. The innovation intensity is not significant and neither is the export intensity as measured by the export share.

The process innovator model provides support for the view that emphasis on competition and to compete with rivals in their own arena as well as a commitment to the economical use of resources increases the probability of being a process innovator. In case product innovations are easy to copy the probability for process innovation decreases. While the innovation intensity is not significant, the export intensity is. That is, the more a firm pursues an export strategy the higher the likelihood of being a process innovator.

Recommendations As far as we can see there seems to be already agreement that the Green Paper on Innovation launched by the European Commission in December 1995 is a useful basis for an effective discussion of policy implications. Therefore we will refer to the major problem regarding the chemical industry and we will cite a few other problems. The major problem needs obviously a solution at the national and European level if the concern of policy-makers is to keep employment and competitiveness of the European chemical industry at a high level. This problems is due to the unfavorable legal and regulatory environment as an obstacle to innovation in the European chemical industry. It seem to be that the Green Paper on Innovation does not recognize this obstacle in an appropropriate fashion because it makes little use of the so-called „Molitor-Report" on the evidence of unfavorable legal and regulatory. Not only the climate for innovation needs to be improved but also the regularitory environment. Therefore we think it is useful to mention a paper by the Association of the German Chemical Industry on the removal of obstacles to innovation.[65] This is in line with the argument Guilio Grata raised in Berlin that the discussion needs to come to earth and that „we must now explore all these path and many more, and identify priorities".[66] In this sense we are providing a brief summary of VCI-paper on the removal of obstacles to innovation.

Some Considerations of the Chemical Industry The chemical industry indicates four reasons for innovative weaknesses in Europe:

- laws and regulations cause excess regulation in all areas concerning R&D
- the existing state (tax) innovation incentives are too weak
- the public policy of procurement aims minimally at innovative stimulation
- there is not enough social acceptance of many R&D policies

The task of the politician should be to overcome the above mentioned innovation obstacles step by step.

Aspects to the excess regulation The EU guideline *67/548/7.Change guideline (Änderungsrichtlinie)* is considered to be one of the greatest obstacles. Therefore the industry demands to release all substances serving only R&D from the compulsory registration and tests because the 100 Kg/year limit is not sufficient.

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[65] See VCI, Beseitigung von Innovationshemmnissen, Dokumentation, dated 20 June 1994.

[66] Grata, G., Grata, Guilio C., Speech on the Green Paper on Innovation, Conference „Innovation", Berlin, 9 -10 May 1996.

Additionally it is criticized that the draft of indication of quantity (Mengenschwellen-konzept) admits no exposition view. That means that new materials from substance classes with known small toxic value have to pass the same test program as those with high toxic substance classes.

The time limit of one year for introducing new material to use for produce-oriented R&D is often inadequete for the completition of producing.

The EU guideline *90/219, article 4 (1), Group 1* causes a highly bureaucratic procedure without any advantage for the safety measures.

The industry proposes to minimize the license-technical and bureaucratical conditions considerably for the gen-technical work where are expected for human health or environment.

It is criticized in the EU guideline *90/219, article 2d*, that the research volume is unsuitable as a distinguishing feature. The basis for regulation must be the risk potential of the cultivated micro-organism and the objects of work. The research and production in the field of fermentation with safety strains (Sicherheitsstämmen) (GLISP) are not subjected to any restriction in opposition to the EU regulation.

Aspects to state stimulations of innovation This point especially applies to Germany. Germany is the only big industrial country which does not favor R&D by government tax funding. Besides this, the decision in the year 1988 to tax the income of the inventors had a negative effect on the innovation activities and resulted in only a modest fiscal profit (tax income of 87 Mio DM/year).

The prevalent opinion in regard to the size of the patent fees is that they are to high for the independent inventors as well as for small and medium-sized businesses and welfare enterprises. In the USA the patent fees were reduced by half for these groups in 1983. The result was an essential increase of patent activities among smaller firms.

Aspects to state policy of procurement The member states of EU should make plans for producing innovative products within the public sector. In Japan and in the USA this method of innovation stimulation more successfully.

The subsidization of R&D activities is too small in the member states of EU. A big share of the funds for subsidy is wasted in industries which have nearly no development potential, for instance, agriculture or mining.

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9 Appendix: Characteristics of the Selected Nine Companies

Nine large companies of the chemical industry were selected for the analysis. To provide a better understanding of the analysis the following a brief characterization of these companies is given:[67]

Bayer AG Bayer was founded in 1863 for the production of aniline colorants, but later achieved trailblazing developments--mainly concerning pharmaceutical products and polyurethane chemicals. Even today, a great part of Bayer's product range are prepared products, such as pharmaceutical products (23 percent of the 1993 turnover with 30 percent as their goal for the year 2000), plant protectives and photo products. By concentrating on polycarbonates, polyurethanes, and polyphosphonates, Bayer managed to avoid the typical problems connected with mass production in the areas of plastics and synthetic fibres.

BASF Aktiengesellschaft The Badische Anilin & Soda Fabrik was also founded for the production of colorants. BASF was especially successful with their development of the Badische process, their chlor-alkali electrolysis and the Haber-Bosch process. Even at a time when they were still with the I.G. Farben, BASF was considered *the* supplier of raw materials within the I.G. Farben, a tradition that has been preserved until the present day. Accordingly, in 1993, raw materials and energy accounted for 10 percent of their total turnover, plastics for 24 percent, chemicals for 13 percent, and colorants and prepared products for 19 percent.

Hoechst AG The Hoechst AG was founded in the same year as Bayer. Having also started with colorants, their further development resembles that of Bayer. Colorants were followed by the successful development of numerous pharmaceutical products. After 1945, rapid growth temporarily made Hoechst the biggest chemical company world-wide. Traditionally, Hoechst is very active in the pharmaceutical business, but does not produce any basic petrochemicals. Hoechst is considered extremely diversified, both product-wise and geographically.

Imperial Chemical Industries PLC ICI resulted from a merger of four British companies in 1926, and was originally intended to present a counterpart to the German I. G. Farben. In the 1930s, ICI produced the synthetic substance polyethylene. Even today, the diverse range of products reflects this descent from the fusion of different companies.

Their particular strong points are paints and varnishes, as well as explosive agents. During the past few years, ICI carried out notably active and radical restructuring policies. In 1992, for instance, ICI split off their extremely profitable "bioscience activities (pharmaceutical industry and agriculture)" and put them into an enterprise newly founded especially for this purpose, called Zeneca.

[67] Based on Amecke, p. 45-55 and various annual reports

Ciba-Geigy AG Ciba-Geigy is the product of a 1970 merger between Ciba AG and J. R. Geigy. Ciba was founded in 1884 for the production of colorants. Later on, analogue to Bayer and Hoechst, pharmaceutical products and plant protectives (such as DDT) were added. As a result of the relatively limited domestic market, Ciba-Geigy is geographically extremely diverse and their balanced product range ensures consistently high profits.

Sandoz AG Sandoz was founded in 1885 and, as with Ciba-Geigy, is fairly specialized in the pharmaceutical industry and agriculture with their pharmaceutical products constituting 49 percent of their 1993 turnover. In addition, Sandoz is very much involved in the production of seeds and special food stuffs. As far as their chemical activities are concerned, their competence lies mainly in the line of colorants/pigments and chemicals for the textile and leather industries, as well as for the building industry. The company plans to concentrate solely on pharmaceutical products and nutrition in the future. The first radical step in that direction is the intended demerger of their chemical line (16 percent of the 1993 turnover, 8200 employees) by the end of 1995. Furthermore, Sandoz plans to separate from its agricultural and building chemistries as well.

Akzo N. V. Akzo resulted from the merger of Aku (synthetic fibres) and KZO (salt) in 1969. In the 1970s, the production of synthetic fibres still dominated Akzo, but its capacity overshoot soon pushed the company into a major crisis. During the past few years, however, Akzo's dependence on fibre production was successfully diminished. While fibres accounted for 52 percent of the turnover in 1969, it was down to less than 20 percent in 1993, so that today Akzo is indeed considered very competitive due to its special strengths in paints/varnishes and its vast pharmaceutical production (20 percent of turnover). In 1993, Akzo merged with the Swedish company Nobel.

Henkel KGaA Founded in 1876, the company is still run as a family business. The development of Henkel has its origin in the production of detergents and bleaching soda and related raw materials. To this day, Henkel's product range is characterized by proprietary articles, such as Persil, which was first introduced in 1907.

Furthermore, Henkel is very strong in the line of fatty chemicals and adhesive substances. Henkel calls themselves specialists for applied chemistry, and environmental-consciousness constitutes an important marketing factor for Henkel. Their geographical diversity is very advanced.

Solvay & Cie. Founded in 1863, the company concentrated on the production of soda. Nowadays, Solvay is also very active in the production of peroxides, the production and processing of plastics (46 percent of the 1993 turnover), as well as in alkaline chemistry. The relatively low degree of diversification is a result of Solvay's policy to handle only products with which a strong position in the market can be obtained. Due to problems with mass production, the past few years saw an expansion in the health sector (mainly veterinary medicine).