

Albach, Horst et al.

**Working Paper**

## Innovation in the European chemical industry

WZB Discussion Paper, No. FS IV 96-26

**Provided in Cooperation with:**

WZB Berlin Social Science Center

*Suggested Citation:* Albach, Horst et al. (1996) : Innovation in the European chemical industry, WZB Discussion Paper, No. FS IV 96-26, Wissenschaftszentrum Berlin für Sozialforschung (WZB), Berlin

This Version is available at:

<https://hdl.handle.net/10419/52604>

**Standard-Nutzungsbedingungen:**

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

**Terms of use:**

*Documents in EconStor may be saved and copied for your personal and scholarly purposes.*

*You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.*

*If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.*



WISSENSCHAFTSZENTRUM BERLIN  
FÜR SOZIALFORSCHUNG

SOCIAL SCIENCE RESEARCH  
CENTER BERLIN

**discussion papers**

FS IV 96 - 26

**Innovation in the European  
Chemical Industry**

Horst Albach, David B. Audretsch  
Manfred Fleischer, Robert Greb, Evelyn Höfs  
Lars-Hendrik Röller, Ines Schulz

October 1996

ISSN Nr. 0722 - 6748

**Forschungsschwerpunkt  
Marktprozeß und Unter-  
nehmensentwicklung**

**Research Unit  
Market Processes and  
Corporate Development**

Final Report prepared for the European Commission,  
Directorate General DG XIII-D-4, "Innovation and Technology Transfer",  
Contract: Project EIMS 95/100.

Presented at the International Conference on "Innovation Measurement and  
Policies", organized by the European Commission (Eurostat and DG XIII),  
Luxembourg, 20-21 May 1996.

Zitierweise/Citation:

Horst Albach, David B. Audretsch, Manfred Fleischer, Robert Greb,  
Evelyn Höfs, Lars-Hendrik Röller, Ines Schulz, **Innovation in the  
European Chemical Industry**, Discussion Paper FS IV 96 - 26,  
Wissenschaftszentrum Berlin, 1996.

Wissenschaftszentrum Berlin für Sozialforschung gGmbH,  
Reichpietschufer 50, 10785 Berlin, Tel. (030) 2 54 91 - 0

## ABSTRACT

### **Innovation in the European Chemical Industry**

Firms in the European chemical industry have been among the most successful firms world wide. However, they have had to undertake severe restructuring in order to maintain their market position. These efforts focused in particular on strengthening their innovative capability as product and process innovation have become the most decisive factors in global competition. In order to improve the innovative conditions, the European Commission has supported the Community Innovation Survey (CIS). 1992/1993 was the first time that large-scale harmonised innovation surveys were carried out in all Member States of the European Union. This study uses the CIS micro data from nearly 2000 European chemical firms. This study focuses on the identification of innovative trends within the chemical industry between 1984 and 1993. Using data from annual reports of nine selected European stock companies, the study identifies those areas of the chemical industry currently having the highest innovative potential. Three speciality categories are identified as having the highest number of innovations during this ten year period: chemicals, paints/varnishes, and plastics.

The CIS database provided evidence for the following trends: 1. increasing effort to apply strategies of cost leadership, in particular for mass products such as basic chemicals; 2. an increasing tendency to specialize in certain product areas; 3. a trend to concentrate on key areas and/or competencies, with the 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; 5. a continuing tendency towards globalization, in order to achieve a strong position in global competition. Many firms focus on specialities since they are less vulnerable to the business cycle and allow higher profit margins to be achieved. The primary goal of firms in all countries is to expand within local markets and to stabilize their market shares or to increase them. In most firms, innovations are triggered by people inside the firm. The analysis has shown that the major factors impeding innovative activity are financial factors, in particular financial risk and lack of capital. In general, cost is seen as one of the most obvious barriers to innovation in the chemical industry. For more basic innovations, these costs are mainly due to R&D expenditure.

## ZUSAMMENFASSUNG

### **Innovation in der chemischen Industrie Europas**

Obwohl viele europäische Unternehmen der chemischen Industrie in den vergangenen Jahrzehnten zu den erfolgreichsten in der Welt zählten, mußten sie sich Anfang der neunziger Jahre einem gravierenden Strukturwandel unterziehen, um ihre Position behaupten zu können. Die Fähigkeit der Unternehmen, Innovationen hervorzubringen, stand und steht dabei im Mittelpunkt. Mit dem Ziel, die Rahmenbedingungen für Innovationen zu verbessern, führte die EU-Kommission 1993 eine europaweite Innovationserhebung, den Community Innovation Survey (CIS) durch. In dieser Studie wurden die anonymisierten Antworten von nahezu 2000 Unternehmen der chemischen Industrie analysiert. Um Innovationstrends aufzuzeigen zu können, wurden darüber hinaus Geschäftsberichte von neun großen europäischen Chemieunternehmen ausgewertet. So wurden die Sparten Spezialitäten, Farben/Lacke und Kunststoffe als diejenigen Sparten identifiziert, die im Untersuchungszeitraum (1984-1993) die meisten Innovationen aufwiesen.

Anhand der CIS-Daten konnten folgende Trends festgestellt werden: 1. Trend zur Verfolgung einer Strategie der Kostenführerschaft (angestrebt wird eine günstige Kostenstruktur), damit zusammenhängend 2. Trend zur Spezialisierung auf bestimmte Produkte bzw. Produktgruppen, 3. Trend zur Konzentration auf Kernbereiche, 4. Trend zur strategischen Zusammenarbeit von Unternehmen und 5. dauerhafte Internationalisierung der Aktivitäten, um eine günstige Position im globalen Wettbewerb erlangen bzw. erhalten zu können. Viele Unternehmen konzentrieren sich zunehmend auf die Produktion von hoch veredelten Spezialitäten, da diese weniger konjunkturabhängig sind und aufgrund des geringeren Konkurrenzdrucks höhere Gewinnmargen erzielen. Das vorrangige Ziel der Chemie-Unternehmen aller Länder (und in allen Segmenten) bestand darin, mit Hilfe von Innovationen innerhalb ihrer lokalen Märkte zu expandieren und dort ihre Marktanteile zu konsolidieren oder sogar auszubauen. In den meisten Unternehmen kommen die entscheidenden Anstöße zu Innovationen aus dem Unternehmen selbst. Als Faktoren, die die Einführung von Innovationen hemmen, standen an der Spitze der Nennungen (allerdings mit nur bedingt starker Gewichtung) finanzielle Faktoren, insbesondere "finanzielles Risiko und Mangel eigener Ressourcen". Insgesamt wirkten alle mit Innovationen verbundenen Kosten als "Hemmschuh", bei grundlegenden Innovationen waren es aber in erster Linie die FuE-Kosten.

## Contents

List of Figures	vii
List of Tables	viii
Executive Summary	x
Zusammenfassender Überblick	xiv
<b>1. Introduction</b>	<b>1</b>
<b>2. The Chemical Industry</b>	<b>2</b>
2.1 Products and Industry Structure	2
2.2 Typical Life Cycles: Two Examples	4
<b>3. Measurement of Innovation Trends</b>	<b>8</b>
3.1 The Measurement Approach	8
3.2 Selection of the Companies to be Investigated	8
3.3 Annual Reports as a Source of Information	9
3.4 Indicators of Innovative Activity	10
3.5 The Classification System for the Recording of Innovations	11
<b>4. Innovation Trends I: An Analysis of Innovation Counting Data</b>	<b>14</b>
4.1 An Analysis of Innovative Trends	14
4.1.1 An Analysis of Innovative Trends by Lines of Business	14
4.1.2 The Innovative Trends of the 1980s and 1990s	19
4.2 An Analysis of Innovation and Performance Measures	19
4.2.1 A Comparison of R&D Input Indicators	19
4.2.2 A Comparison of R&D Output Indicators	25
4.2.3 Growth in the Individual Lines of Business	27
4.2.4 Corporate Performance in the Individual Lines of Business	30
4.3 Limitations and Conclusion	32
<b>5. Innovation Trends II: An Analysis of Corporate Strategies</b>	<b>35</b>
5.1 Corporate Strategies and Innovation: Analysis of Annual Reports and First Insights from the CIS Database	35
5.1.1 Changed Conditions in Europe	35
5.1.2 The Main Strategies Driving Innovation: Cost Leadership and Specialization	39
5.1.3 Concentration on Key Areas	44
5.1.4 The Trend Towards Strategic Co-operation	48
5.1.5 The Trend Towards Globalization	52
5.2. Conclusion	53

<b>6. An Analysis of the CIS Data</b>	55
6.1 The Chemical Industry in the CIS Sample	55
6.2 Organizational Characteristics Effecting Innovation	55
6.2.1 Objectives of Innovation	55
6.2.2 Information Sources	63
6.2.3 Barriers to Innovation	67
6.3. Innovative Performance	71
6.3.1 Measuring Innovative Activity	71
6.3.2 The Distribution of Firm Innovative Activity within the Industry	71
6.3.2.1 Innovating Firms	71
6.3.2.2 Innovation Expenditures	75
6.3.3 Comparison of Innovative Performance	76
6.3.3.1 Estimation of Elasticities of Innovative Output	79
6.3.3.2 Estimation of Returns to R&D	86
6.3.3.3 A Logit Model of Innovation	89
<b>7. Conclusion and Recommendations</b>	94
<b>8. References</b>	97
<b>9. Appendix</b>	
9.1 Characteristics of the Selected Nine Companies	104
9.2 Some Considerations Concerning the Chemical Industry	106

## List of Figures

Figure 2.1	Product-Group Matrix	3
Figure 2.2	Life Cycles for Different Processes for the Manufacture of Cord for Tires	6
Figure 2.3	Stage of Product Life Cycle for Various Polymeric Materials	6
Figure 4.1	R&D Intensities for Large Chemical Firms, 1984-1993	21
Figure 4.2	Return on Sales for Large Chemical Firms, 1984-1993	31
Figure 5.1	Employment for Large Chemical Firms, 1984-1993	36
Figure 5.2	Share of Pharmaceutical Products for Large Chemical Firms, 1984-1993	43
Figure 6.1	Firms Involved in R&D and Innovation (as a Percentage of all Chemical Firms in 13 European Countries, 1992)	74
Figure 6.2	Innovation Intensity, R&D and Investment Intensity by Firm Size for Chemical Firms in 13 European Countries	77
Figure 6.3	Innovation Intensity, R&D Intensity and Investment Intensity by Segments of the European Chemical Industry for 8 Countries	77
Figure 6.4	Components of Innovation Expenditures by Firm Size for Chemical Firms in 13 European Countries	78
Figure 6.5	Components of Innovation Expenditures by Sub-Sectors of the Chemical Industry in 8 European Countries	78



## List of Tables

Table 2.1	Concentration of the Chemical Industry within the European Union	4
Table 2.2	Distribution of R&D Expenditures of German Chemical Firms According to Product and Process Innovation and by Innovation Significance (in percent)	7
Table 3.1	The 15 Leading European Chemical Companies - 1992	9
Table 4.1	Shares of Product and Process Innovations (in percent)	15
Table 4.2	Description of Trends: Comparison of Innovations in 1984/85 and 1992/93	20
Table 4.3	R&D Shares of Individual Lines of Business	23
Table 4.4	R&D Personnel-Intensity (10-year averages)	24
Table 4.5	Ranking of Innovative Core Activities by Individual Companies	25
Table 4.6	Innovative Shares According to Categories and Corporate Evaluation (in percent)	26
Table 4.7	Growth Trends by Individual Lines of Business	28
Table 4.8	Mean Accounting Ratios	29
Table 4.9	Profitability and Sales Share of the Individual Lines of Business	32
Table 5.1	Chemical Labor Costs per Man-Hour	37
Table 5.2	Distribution of Firms by 1992 Turnover Size Groups and Segments of Industry (in percent, 8-country sample)	40
Table 5.3	Distribution of Firms According to their R&D Expenditures Allocated to Product and Process Innovation (in percent, 8-country sample)	45
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)	46
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)	47
Table 5.6	Percentage of Firms Utilizing R&D Co-operative Arrangements by Segment of Industry (percentages of the 8-country sample)	50
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)	51
Table 5.8	Importance of the Globalization of Markets According to Firm Size (Based on the Objective "Creation of New Markets"; as a percentage of the 8-country sample, pharmaceutical industry excluded)	54
Table 6.1	Distribution of Chemical Firms in the CIS Sample by Country and Size (in absolute numbers and percentages)	56
Table 6.2	Distribution of Chemical Firms in the CIS Sample by Country and Industrial Sector (in absolute numbers and percentages)	57
Table 6.3	Descriptive Statistics for Turnover, Employment, and R&D of the Firms in the CIS Sample by Country, 1992	58

Table 6.4	The Structure of the Objectives of Innovation	60
Table 6.5	The Importance of the Objectives of Innovation by Countries	61
Table 6.6	The Importance of the Objectives of Innovation by Sub-Sector of Chemical Industry	62
Table 6.7	The Structure of the Sources of Information for Innovation	64
Table 6.8	The Importance of the Sources of Information for Innovation by Countries	65
Table 6.9	The Importance of the Sources of Information for Innovation by Chemical Industry Sub-Sector	66
Table 6.10	The Structure of Factors Hampering Innovation	68
Table 6.11	The Importance of Factors Hampering Innovation by Countries	69
Table 6.12	The Importance of Factors Hampering Innovation by Chemical Industry Sub-Sector	70
Table 6.13	Descriptive Statistics for Innovation, R&D, and Investment by Country, Sub-Sector, and Firm Size (Unweighted mean values of intensities and shares of firms in percent)	72
Table 6.13a	Distribution of Sales Shares According to the Stages of the Product Life Cycle (Unweighted mean shares in percent)	73
Table 6.14	Estimated Elasticities of Innovative Output (New Product Sales) with Respect to R&D Expenditures by Country for the Chemical Industry (Including Pharmaceuticals)	81
Table 6.15	Estimated Elasticities of Innovative Output (New Product Sales) with Respect to R&D Expenditures by Chemical Industry Sub-Sector	82
Table 6.16	Estimated Elasticities of Innovative Output (New Product Sales) with Respect to R&D Expenditures by Size Group for the Chemical Industry (Including Pharmaceuticals)	83
Table 6.17	Estimated Elasticities of Innovative Output (New Product Sales) with Respect for Firm Size by Country and by Chemical Industry Sub-Sector	85
Table 6.18	Country-Specific Regressions for Innovative Product Sales (for Major Innovations) and R&D in 1992 (with Pharmaceuticals)	87
Table 6.19	Industry-Specific Regressions for Innovative Product Sales (for Major Innovations) and R&D in 1992	88
Table 6.20	Logit Regression Estimates for Product and Process Innovators in the European Chemical Industry (Including Pharmaceuticals)	93

## **Executive Summary**

The European chemical industry is the third largest manufacturing sector in Europe and produces a heterogeneous range of products subject to different technical and scientific conditions and R&D goals. Apart from the pharmaceutical branch the industry is divisible into four main sectors: basic chemicals where R&D is largely focused on cost reduction; industrial chemicals and fine chemicals, where the goal is both process and product development; and specialty chemicals where the emphasis is on developing new products. Due to the high capitalisation level and scale economies required, basic chemicals tend to be produced by large firms whereas fine and specialized chemicals are often produced by small- and medium-sized firms.

Average R&D intensity is 5 percent in Europe's chemical industry. Although this is above the industrial average, much of the chemical industry faces fewer innovative opportunities and diminishing returns to R&D. Exceptions are innovative fields like pharmaceuticals and biotechnology where R&D intensity may exceed 20 percent. The study by the Chemical Industry Association (1995) forecasts that the most promising areas of R&D in the future will be in biotechnology and catalysis, materials, process technology, and separation processes. Another challenge is increasing competition from lower-cost countries for basic chemicals and the trend towards locating production close to the consumer, which in some cases has meant shifting production to the Far East. The European industry has responded to these problems by shifting from the more unprofitable products to speciality products where profit margins are higher. It has also shed jobs, with the number of employees falling 14 percent between 1991 and 1995. One danger in closing some production lines is that this damages the interrelated production systems that maximized the benefits from raw material and energy inputs.

This study uses two methods to examine innovation trends and firm strategies in the European chemical sector. The first method is based on an analysis of 1,299 innovations described in the annual reports between 1984 to 1993 of nine of Europe's 15 largest chemical firms while the second method is based on an analysis of the Community Innovation Survey (CIS) results for chemical firms.

### **Innovation Counts Drawn from Annual Reports**

The amount of information provided in the annual reports on innovative activities differs among the nine firms and may therefore contain certain biases. A comparison of the distribution of all 1,299 innovations counted over the 10 year period across nine categories shows innovative activity is concentrated in specialty chemicals with 27.9 percent of all reported innovations, paints and varnishes with 24.9 percent, and plastics with 15.7 percent. Environmental technologies account for only 2.3 percent of innovations, although this share did increase from 1 percent to 5.9 percent between 1984/85 and 1992/93. The share of agrochemical innovation also increased (10.7 to 17.8 percent) while the share of

plastics declined from 19.0 to 7.9 percent. Over the same time period, average R&D intensities increased slightly. R&D spending was concentrated in lines of business with the highest sales growth, such as pharmaceuticals and coatings (paints and varnishes). The pharmaceutical sector is also one of the most profitable sectors, as shown by the ratio between its share of operating profits to its share of sales. Only in very few other sub-sectors has profitability been above average; a few exceptions are explosives for ICI at some time periods, colorants and fine chemicals for BASF, and alkalines and peroxides for Solvay.

### **Analysis of the CIS Data**

Results are available for a maximum of 1938 chemical firms from all 13 countries surveyed by the CIS. However, due to problems with the data from a few countries, most of the results presented here are for a maximum of 1637 firms of which 1027 (62.7 percent) introduced at least one innovation between 1990 and 1992. For these firms the sub-sector is known. They are from up to nine countries: Belgium, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Norway, and the United Kingdom. In some cases France is excluded because of missing data, leaving an eight-country sample. Results are available at the three-digit NACE level for seven sub-sectors: basic chemicals, agrochemicals, coatings, pharmaceuticals, soaps and detergents, other chemical products, and man-made fibres. All analyses presented here are unweighted. This means that results need to be cautiously interpreted because of the over-representation of Italian cases. (Italian firms account for 40.8 percent of the whole CIS sample of the chemical industry).

The data show that the percentage of firms that innovate increases with firm size. Slightly less than half of the firms with less than 50 employees innovate, compared to 68 percent of firms with 50 to 499 employees and 95 percent of firms with more than 1000 employees. There is little difference in the innovation frequency by sub-sector. The most important objective of innovation is to increase or maintain market share, followed closely by improving product quality. A cost-leadership strategy of competing on the basis of price was also found to be very important. Over 50 percent of innovators pursue a strategy of reducing wage costs and materials consumption, as shown by a response of 'very' important or 'crucial' to these objectives. This strategy is most important in basic chemicals. The question on the percentage of R&D spent on product versus process innovation is used as an indicator of the importance of developing specialty products. It was found that nearly 78 percent of the firms spend more than 50 percent of their R&D budget on product innovation. The focus on product innovation is highest in agrochemicals and coatings and lowest in basic chemicals.

The effect of the increasing globalization of markets can be estimated using the results to the objective questions on the importance of new markets within Europe compared to North America. Excluding pharmaceutical firms, which are highly globalized, there is a strong relationship with firm size. The importance of national markets decreases with firm size while the importance of North American markets increases. For example, only 11.1

percent of firms with sales of less than 0.5 million ECUs rate creating new markets in North America as very significant or crucial, while the same holds for 29.7 percent of firms with sales over 500 million ECUs.

Information on the use of cooperative R&D agreements and the type of these agreements is provided in the CIS. Cooperation is most prevalent in the more R&D intensive sectors (pharmaceuticals and agrochemicals,) although it is also important in basic chemicals. Interestingly, cooperation with public research is considerably more common than cooperation with competitors, though it is not possible to estimate which is more frequent or more valuable.

Innovation intensity is measured as the percentage of total sales spent on all innovative activities and on R&D. For the full sample (including non-innovators), R&D intensity shows a U-shaped distribution, falling from 3.5 percent for firms with less than 50 employees to 2.9 percent for firms with 250-499 employees, and then increasing to 6.1 percent for firms with more than 1000 employees. In contrast, innovation intensity is highest for mid-size firms with 500-999 employees. R&D intensities vary only slightly by sub-sector, ranging between 2.2 percent (man-made fibres) and 3.1 percent (other chemical products), with the exception of pharmaceuticals where R&D intensity is 5.6 percent.

A breakdown of innovation expenditures by sub-sector shows, that R&D, as indicated by its percentage of total costs, is highest in agrochemicals, while patent and license costs are greatest in pharmaceuticals.

Innovative output for the 760 innovating firms can be measured using the CIS estimates of the total sales due to significantly changed products. Linear regression (using natural logs) of the relationship between R&D expenditure and the share of sales from significantly changed products shows that this share increases with R&D expenditure. By sub-sector, the elasticities at the sample mean for sales and R&D expenditure range from 0.43 for agrochemicals to 0.74 for other chemical products, indicating that the share of significantly changed products increases less than proportionately with R&D expenditure. A similar regression of new sales share on the number of employees gives an elasticity of 1.00, implying that innovative output increases proportionately with firm size.

Differences by country in the returns to R&D (estimated by significant new product sales) were investigated using a quadratic model. Decreasing returns to scale were found in Italy, the Netherlands, Spain, Ireland and Norway, while returns to scale increase for the sample of 134 German firms. The evidence is inconclusive for Belgium, Denmark and Portugal. By sub-sector, there were decreasing returns to scale in five sectors and inconclusive results in man-made fibres and agrochemicals. These results suggest that diminishing returns to R&D are the rule in Europe, with the exception of the German results.

Finally, a logit model is used to investigate the factors that influence a strategy of being a product innovator or a process innovator. A firm is defined as a product innovator if its

share of sales from incrementally and significantly changed products combined is over 30 percent. A separate model is used for process innovation. Here a firm is defined as a process innovator if the percentage of total R&D expenditures allocated to process innovation is over 25 percent. The significance of the estimated parameters of the logit model provides a clear picture. Two factors influence the probability of being a product innovator: the importance of improving product quality as an innovation objective and the effectiveness of lead time advantages as a method of appropriation. The probability of being a process innovator increases with export share and the importance of creating new markets in Japan, both indicators of the need to compete on price, and the importance of reducing energy use.

### **Conclusions**

The evaluation of the innovation count data obtained from the annual reports shows clearly discernable trends in innovation, with the greatest number in specialty chemicals, coatings, and plastics. This is part of a general strategy to increase the sales share of technically advanced products. The CIS results provide further evidence for several trends. These include the importance of cost leadership, particularly for basic chemicals, the importance of cooperation on R&D, and the effect of an export strategy on the need to reduce costs for process innovators.

## Zusammenfassender Überblick

Die chemische Industrie ist der drittgrößte Industriezweig in Europa. Sein Produktspektrum ist breit und sehr heterogen und hängt von unterschiedlichen technisch-wissenschaftlichen Bedingungen ab. Vier Hauptzweige lassen sich, von der pharmazeutischen Industrie abgesehen, unterscheiden. Grundchemikalien (organische und anorganische Grundstoffe), bei denen Forschung und Entwicklung (FuE) vor allem kostensenkenden Prozeßinnovationen dienen, Industriechemikalien und Feinchemikalien, bei denen es um Prozeß- und Produktinnovationen geht und die Spezialitätenchemie, die Nachdruck auf die Entwicklung neuer Produkte legt. Bedingt durch die hohe Kapitalintensität und Größenvorteile in der Produktion werden chemische Grundstoffe vor allem von Großunternehmen hergestellt, während Feinchemikalien und Spezialitäten oft auch von Klein- und Mittelbetrieben produziert werden.

Die durchschnittliche FuE-Intensität der chemischen Industrie Europas (Verhältnis von FuE-Aufwendungen zu Umsatz) beträgt 5 Prozent. Obwohl diese FuE-Intensität über dem Durchschnitt der gesamten europäischen Industrie liegt, sind große Teile der chemischen Industrie mit seltener werdenden Innovationschancen und abnehmender FuE-Produktivität konfrontiert. Ausnahmen sind innovative Felder wie die Entwicklung pharmazeutischer und biotechnologischer Produkte. Dort kann die FuE-Intensität 20 Prozent übersteigen. Die Studie der britischen Chemical Industry Association (1995) hat als vielversprechende Bereiche für FuE die Biotechnologie und Katalyse, neue Materialien, Prozeßtechnologie und Trennverfahren identifiziert. Eine weitere Herausforderung bildet die Konkurrenz der Niedrig-Kostenländer im Bereich der chemischen Grundstoffe in Verbindung mit dem Trend, die Produktion in der Nähe der Nachfrage anzusiedeln. Das führt zu einer Verlagerung der Produktion in Länder des Nahen Ostens. Die europäische Industrie hat auf diese Probleme mit einer Veränderung der Produktschwerpunkte von den weniger profitablen Produkten zu Spezialprodukten mit höheren Gewinnspannen reagiert. Sie hat auch die Zahl der Beschäftigten im Zeitraum von 1991 bis 1995 um 14 Prozent verringert. Dabei besteht bei der Stilllegung einzelner Fertigungslinien die Gefahr, Verbundvorteile zu verlieren, die aus einer optimalen Nutzung von Rohstoff- und Energiezufuhren resultieren.

Die Studie verwendet zwei Methoden, um Innovationstrends und Unternehmensstrategien in der chemischen Industrie Europas zu analysieren. Erstens werden 1299 Innovationen ausgewertet, die anhand der Geschäftsberichte von neun der 15 größten europäischen Chemieunternehmen für die Zeit von 1984 bis 1993 erhoben wurden. Zweitens werden die Daten von 138 Unternehmen analysiert, die sich am Community Innovation Survey (CIS) im Jahre 1993 beteiligt haben. Beim CIS handelt es sich um eine gemeinschaftliche Innovationserhebung der Europäischen Kommission und von Eurostat.

## **Innovationszählung anhand der Geschäftsberichte**

Die quantitative Analyse der Geschäftsberichte verdeutlicht, daß die Unternehmen in unterschiedlichem Maße über Innovationen in ihren Geschäftsberichten informieren. Die Interpretationsprobleme, die daraus für die Ergebnisse der Analyse resultieren, lassen sich jedoch durch einen Vergleich des Innovationsoutputs verschiedener Zeitpunkte begrenzen. So konnten diejenigen Sparten der chemischen Industrie identifiziert werden, die ein hohes Innovationspotential besitzen. Desweiteren werden die vorherrschenden Innovations- und Unternehmensstrategien aufgezeigt. Bei der Auswahl der Unternehmen wurde Wert darauf gelegt, ein möglichst breites Spektrum verschiedener Chemiesparten sowie von Unternehmen mit jeweils unterschiedlicher strategischer Ausrichtung zu haben. So sind beispielsweise mit den Unternehmen Bayer und ICI große, breit diversifizierte Unternehmen vertreten, Ciba-Geigy und Sandoz repräsentieren die auf Spezialitäten konzentrierten Unternehmen und Solvay und die BASF sind stark in der Grundstoffchemie engagiert.

Die Auswertung der Geschäftsberichte ergab deutlich erkennbare Innovationstrends. Der Vergleich der Verteilung aller 1299 für die zehn Jahre gezählten Innovationen geht von neun Hauptgruppen aus. Dabei ist mit einem Anteil von 27,9 Prozent aller Innovationen eine Konzentration auf chemische Spezialitäten festzustellen. Auf Farben und Lacke entfallen 24,9 Prozent, auf Kunststoffe 15,7 Prozent und auf Umwelttechnologien 2,3 Prozent, obwohl der Anteil umwelttechnologischer Innovationen von 1,0 auf 5,9 Prozent zwischen 1984/85 und 1992/93 angestiegen ist. Der Anteil der agrochemischen Innovationen nahm ebenfalls zu (von 10,7 auf 17,8 Prozent) während die Innovationen im Bereich Kunststoffe von 19,0 auf 7,9 Prozent abnahmen. In derselben Periode nahm die durchschnittliche FuE-Intensität leicht zu. FuE-Aufwendungen waren in Sparten mit dem höchsten Umsatzwachstum wie Pharmazeutika und Anstriche (Farben und Lacke) konzentriert. Die pharmazeutische Sparte ist auch eine der profitabelsten Sparten, wie beispielsweise der über Eins liegende Quotient „Verhältnis Pharma-Gewinn zu Gesamtgewinn und Pharma-Umsatz zu Gesamtumsatz des Unternehmens“ deutlich macht. Nur in sehr wenigen anderen Sparten war eine Rentabilität oberhalb des Durchschnitts feststellbar. Dazu gehören Sprengstoffe für ICI, Färbemittel und Feinchemikalien für BASF und Alkaline und Peroxide für Solvay.

## **Analyse der CIS Daten**

Ergebnisse stehen für maximal 1938 Chemieunternehmen aus allen 13 Ländern zur Verfügung, in denen der CIS durchgeführt wurde. Aufgrund von Erhebungsproblemen in einigen Ländern gelten die Ergebnisse für maximal 1637 Unternehmen, von denen 1027 (62,7 Prozent) mindestens eine Innovation in der Zeit zwischen 1990 und 1992 eingeführt haben. Für diese Unternehmen ist bekannt, in welchen Sparten der chemischen Industrie ihre Hauptaktivitäten angesiedelt sind. Die Unternehmen stammen aus bis zu neun Ländern: Belgien, Frankreich, Deutschland, Irland, Italien, Luxemburg, die Niederlande, Norwegen und Großbritannien. In einigen Fällen wird Frankreich wegen



fehlender Daten ausgenommen und es verbleibt eine 8-Länderstichprobe. Ergebnisse liegen für die dreistellige NACE-Klassifikation der Wirtschaftszweige vor: Chemische Grundstoffe, Agrochemikalien, Farben und Lacke, Pharmazeutika, Seifen und Reinigungsmittel, andere chemische Produkte und Kunstfasern. Alle hier dargestellten Ergebnisse basieren auf Analysen, die sich auf ungewichtete Erhebungsdaten stützen. Wegen der Dominanz der italienischen Unternehmen in der Gesamtstichprobe sind die Ergebnisse mit entsprechender Vorsicht zu interpretieren (italienische Unternehmen machen 40,8 Prozent aller Chemieunternehmen der gesamten CIS-Stichprobe aus).

Die Daten zeigen, daß es eine positive Korrelation zwischen der Innovationseinführung und der Unternehmensgröße gibt. Nur knapp die Hälfte von Unternehmen mit weniger als 50 Beschäftigten innoviert, während es bei Unternehmen von 50 bis 499 Beschäftigten 68 Prozent sind und bei Unternehmen mit mehr als 1000 Beschäftigten 95 Prozent. Das größenspezifische Innovationsverhalten unterscheidet nur geringfügig in den einzelnen Zweigen der chemischen Industrie. Vorrangiges Ziel der Chemieunternehmen aller Länder (und in allen Sparten) ist es, innerhalb ihrer lokalen Märkte zu expandieren und dort ihre Marktanteile zu konsolidieren. Nächstwichtig ist die Verbesserung der Produktqualität. Mit den Innovationen wird aber auch eine Strategie der Kostenführerschaft angestrebt, d.h. man bemüht sich im Preiswettbewerb mitzuhalten. Mehr als 50 Prozent der Unternehmen strebt mit Innovationen an, Lohnkosten zu senken und den Materialverbrauch zu vermindern. Diese Strategie ist besonders bei der Herstellung chemischer Grundstoffe wichtig. Die Relation von FuE-Aufwendungen für Produktinnovationen und für Verfahrensinnovationen läßt sich als Indikator für den innovativen Charakter der Entwicklung von chemischen Spezialitäten verwenden. Beinahe 78 Prozent der Unternehmen geben mehr als 50 Prozent des FuE-Budgets für Produktinnovationen aus. Dabei ist die Konzentration auf Produktinnovationen am stärksten in den Sparten Agrochemikalien und Farben/Lacke und am schwächsten bei chemischen Grundstoffen.

Die Wirkung zunehmender Globalisierung von Märkten der chemischen Industrie läßt sich anhand der CIS-Daten schätzen. Geht man von der Bedeutung aus, die die Unternehmen neuen Märkten innerhalb Europas im Vergleich zu Nordamerika beimessen, kann man die Präferenz für globale Märkte feststellen. Abgesehen von den pharmazeutischen Unternehmen, die überwiegend global operieren, hängen die Ergebnisse sehr stark von der Unternehmensgröße ab. So erachten beispielsweise nur 11,1 Prozent der Unternehmen mit einem Umsatz von weniger als 0,5 Millionen ECU die Schaffung von neuen Märkten in Nordamerika als wichtig oder sehr wichtig. Bei Unternehmen mit Umsätzen über 500 Millionen ECU sind dies bereits 29,7 Prozent.

Die CIS-Daten lassen auch Aussagen über das Kooperationsverhalten der Unternehmen zu. Kooperation ist besonders häufig in FuE-intensiven Sparten anzutreffen (pharmazeutische und agrochemische Produkte), obwohl sie auch eine große Rolle bei der

Herstellung chemischer Grundstoffe spielt. Interessanterweise hat die Kooperation mit öffentlichen Forschungseinrichtungen eine größere Bedeutung als die mit Konkurrenten.

Die Innovationsintensität wird im CIS als der Prozentsatz vom Umsatz gemessen, der insgesamt für Innovationsaktivitäten und für FuE aufgewendet wird. Für die gesamte Stichprobe, einschließlich der Nichtinnovatoren, zeigt die FuE-Intensität in Abhängigkeit von der Unternehmensgröße einen U-förmigen Verlauf. Sie sinkt von 3,5 Prozent für Unternehmen mit weniger als 50 Beschäftigten auf 2,9 Prozent für Unternehmen mit 250 bis 499 Beschäftigten und steigt dann auf 6,1 Prozent für Unternehmen mit über 1000 Beschäftigten. Im Gegensatz dazu ist die Innovationsintensität für Unternehmen mittlerer Größe (500 bis 999 Beschäftigte) am höchsten. Die FuE-Intensität hängt von der Sparte ab. Sie reicht von 2,2 Prozent für Kunstfasern bis zu 3,1 Prozent für sonstige chemische Erzeugnisse. Eine Ausnahme bildet die pharmazeutische Industrie mit einer durchschnittlichen FuE-Intensität von 5,6 Prozent.

Eine Analyse der Innovationskosten (als Prozentsatz der Gesamtkosten) nach Sparten weist die höchsten Innovationskosten für Agrochemikalien aus, die höchsten Patent- und Lizenzkosten fallen in der pharmazeutischen Industrie an.

Der Innovationsoutput der 760 innovierenden Unternehmen kann anhand des Prozentsatzes vom Umsatz gemessen werden, den diese Unternehmen mit einem signifikant geänderten neuen Produkt am Markt erzielen. Eine lineare Regressionsanalyse zur Überprüfung der Beziehung zwischen FuE-Aufwendungen und dem Umsatzanteil signifikant geänderter neuer Produkte zeigt einen Anstieg dieses Anteils mit steigenden FuE-Aufwendungen (die Elastizitäten wurden anhand der natürlichen Logarithmen der Variablen berechnet). Je nach Sparte reichen die geschätzten Elastizitäten für die jeweiligen Stichprobenmittelwerte für Umsatz und FuE-Aufwand von 0,43 für Agrochemikalien bis zu 0,74 für sonstige chemische Erzeugnisse, d.h. 1 ECU FuE-Aufwand führt bei Agrochemikalien zu 0,43 ECU Neuproduktumsatz. Bei steigenden FuE-Aufwendungen nimmt der Neuproduktumsatz also unterproportional zu. Bezieht man den Neuproduktumsatz auf die Beschäftigten, dann errechnet sich eine Elastizität von 1,00, d.h. der Innovationsoutput wächst proportional mit der Unternehmensgröße (gemessen in Beschäftigten).

Bestehende Unterschiede in der FuE-Innovationsproduktivität zwischen Ländern wurden anhand eines Regressionsmodells mit einem linearen und quadratischen FuE-Ausdruck geschätzt. Mit dieser Modellspezifikation lassen sich abnehmende Zuwächse abschätzen. Eine abnehmende FuE-Innovationsproduktivität von FuE-Aufwendungen konnte für Italien, Spanien, Irland und Norwegen festgestellt werden, während anhand der Daten für 134 deutsche Unternehmen eine zunehmende FuE-Innovationsproduktivität ermittelt wurde. Nicht schlüssig sind die Ergebnisse für Belgien, Dänemark und Portugal. Schätzungen für die einzelnen Zweige der chemischen Industrie weisen abnehmende FuE-Innovationsproduktivität für fünf Sparten nach. Nicht signifikant sind die Ergebnisse für Kunstfasern und Agrochemikalien. Dies deutet auf

eine abnehmende FuE-Innovationsproduktivität in Europa hin, von den Ergebnissen zunehmender FuE-Innovationsproduktivität der chemischen Industrie in Deutschland einmal abgesehen.

Schließlich wird ein Logit-Modell verwendet, um die Faktoren zu untersuchen, die die Strategie beeinflussen, ob ein Unternehmen als Produktinnovator agiert oder nicht bzw. die Voraussetzungen für eine Prozeßinnovationsstrategie erfüllt oder nicht. Ein Unternehmen wird als Produktinnovator definiert, wenn der mit geringfügig oder signifikant geänderten neuen Produkten erzielte Umsatzanteil mehr als 30 Prozent beträgt. Anhand eines zweiten Logit-Modells wurden die Determinanten des Prozeßinnovators überprüft. Ein Prozeßinnovator ist definiert als Unternehmen, dessen Anteil von FuE-Aufwendungen für Prozeßinnovationen mehr als 25 Prozent beträgt. Die Signifikanz der geschätzten Parameter läßt eine deutliche Einflußgrößenstruktur erkennen. Zwei Faktoren beeinflussen die Wahrscheinlichkeit, ein Produktinnovator zu sein: die Bedeutung, die der Verbesserung der Produktqualität als Innovationsziel beigemessen wird, und die Effektivität, die dem Zeitvorteil für die erfolgreiche Aneignung des Innovationsvorteils im Wettbewerb zugeschrieben wird. Die Wahrscheinlichkeit eine Strategie der Prozeßinnovation zu verfolgen wird durch den Exportanteil des Unternehmens und eine Präferenz für die Schaffung von neuen Märkten in Japan erhöht. Beides sind Indikatoren, die auf eine Präferenz für den Preiswettbewerb schließen lassen. Außerdem beeinflußt eine Präferenz für die Reduzierung des Energieeinsatzes das Auftreten des Prozeßinnovators positiv.

### **Schlußfolgerungen**

Die Bewertung der Daten der Innovationszählung, die anhand einer Auswertung der Geschäftsberichte gewonnen wurden, hat eindeutige Innovationstrends aufgezeigt. Die Schwerpunkte der Innovationsanstrengungen - ohne Pharmazeutika - liegen im Bereich von chemischen Spezialitäten, Farben/Lacke und Kunststoffen. Dies unterstreicht auch die generelle Strategie der Unternehmen, den Umsatzanteil von innovativen Produkten zu erhöhen. Die CIS-Ergebnisse bestätigen weitere Trends. So wird beispielsweise die Bedeutung einer Strategie der Kostenführerschaft deutlich, insbesondere im Bereich der chemischen Grundstoffe. Dies gilt ebenso für die zunehmende Bedeutung von FuE-Kooperationen und den Export als Strategien für erfolgreiche Kostensenkung durch Prozeßinnovationen.

# 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, the total cost of an innovation is significantly higher in German than in Japanese firms--due to longer innovation periods.<sup>1</sup> Because of such factors, concern about the innovative performance of European companies abounds. The innovative capabilities of individual companies' have thus become one of the most decisive factors for their successful competition.

Structural changes are currently under way within Europe's chemical industry, an industry where concentration on innovative lines of business is of major importance. This study illustrates how nine selected European chemical companies have been able to maintain their high levels of innovation. At the same time, this study reveals the relevant innovative and corporate strategies now dominating Europe's chemical industry. Furthermore, the study uses data from the Community Innovation Survey (CIS) to describe and explain the differences between innovative performance across firms within the European chemical industry. In order to accomplish these aims, this study uses a broad interpretation of the term, innovation. We include the entire innovation process--which ranges 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 marketplace. The concept of something being "new" utilizes the so-called relative novelty definition. This definition includes any company-oriented novelties--meaning that even a renewed procedure bought by a company (e.g. taking out a license) constitutes an innovation for this particular company (Albach 1994, pp. 50-54; and for the chemical industry in particular, see Schmidt 1991, p. 7).

Most innovations in the chemical industry originate from internal sources (i.e. mainly from company-owned R&D departments). Decisions concerning the orientation of these R&D activities, as well as concerning the allocation of R&D resources and capacities, are made within the framework of the respective technological and innovative strategies chosen by the corporation.

---

<sup>1</sup>For a discussion of problems of culture and technical innovation of see e.g. Albach (1994). See Acs and Audretsch (1990) in particular for an analysis of innovation in the US industry.

## 2 The Chemical Industry

### 2.1 Products and Industry Structure

The chemical industry<sup>2</sup> is the third largest manufacturing industry in the EU and is definitely an economic sector which is facing an unparalleled challenge regarding its innovative activities. The industry is composed of all companies which produce their products exclusively or primarily by the conversion of substances. The goal of chemistry, in this definition, 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 materials (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 (Amecke 1987, p. 13).

The chemical industry differs from other industries primarily through the heterogeneity of its products. As a result, the individual line sectors of the industry are subject to completely different technical/scientific conditions and R&D situations. Thus, Schulze

---

<sup>2</sup> For a description, data, and analyses of the chemical industry, see e.g. the following publications: European Commission (ed.), *Panorama of EU Industry 95-96*, Luxembourg, 1995, 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., Klotten, N., *Gutachterliche Stellungnahme zu der Preispolitik auf dem Farbstoffmarkt in der EWG in der Zeit von 1964 bis 1967*, Tübingen, 1973; Reader, W.J., *Imperial 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.

and Weiser (1982, p. 6) are able to describe the chemical industry as a sum of several individual lines of industry.

Another characteristic of the chemical industry is that the majority of the products (approximately 65 percent) are intermediate products and are delivered mainly to 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 (European Commission 1995, Panorama of EU Industry 95-96, p. 6-5). Other major customers of the chemical industry are automobile manufacturers, the construction industry and agricultural industries.

A crude method commonly used for the classification of chemical products is the product-group matrix (see Figure 2.1). Four product groups are distinguished, according to two dimensions: production quantity and the level of differentiation. Each of these groups exhibits specific characteristics that need to be considered when undertaking strategic planning.

**Output**

		<b>low</b>	<b>high</b>
high	<b>Basic Chemicals</b>	Process development and improvement and only some product developments	<b>Industrial Chemicals</b>
			Process developments and improvements and only some product developments
low	<b>Fine Chemicals</b>	Product and process developments and improvements	<b>Speciality Chemicals</b>
			Product developments and improvements and only some process developments
		<b>low</b>	<b>high</b>
		<b>Degree of Differentiation</b>	

Source: Schmidt 1991, p. 150.

**Figure 2.1 Product-Group Matrix**

The second conceptual model of interest for the study of the chemical industry is the model of the product life cycle. 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 life cycle 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 and toward the end of the product life cycle the run of the curve begins to slope down.

The product-group matrix permits conclusions to be drawn concerning the business concentrations within the individual product groups. Base chemicals are produced by the major companies because of their high degree of capitalization. Fine chemicals and specialized products are produced by medium and small firms. Table 2.1 illustrates that the chemical industry is fairly concentrated--although a certain balance between major companies and smaller firms prevails. For instance, while the 10 leading EU-companies hold 48.6 percent of the entire industrial turnover; the five leading ones represent 32.6 percent of the gross sales (Panorama of EU Industry 95-96, p. 6-5).

**Table 2.1 Concentration of the Chemical Industry within the European Union**

Total Employees	Total Companies	% of all Companies	% of all Employees	% of EU-Sales
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	79.0

Source: Panorama of EU Industry 95-96, p. 6-6

## 2.2 Typical Life Cycles: Two Examples

Products, technologies, and industries can be described by their positions 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 the manufacturing industry reached a mere 2 percent

(Panorama of EU Industry 95-96, p. 6-5). This is primarily due to the substitution of traditional materials--such as wood, steel and glass--by chemical products. This development was only made possible through the continuous introduction of new products and procedures. Since this has always called for high research expenses, the chemical industry is considered to be extremely R&D-intensive.

Some authors<sup>3</sup> see the development of the chemical industry as occurring in waves triggered by certain basic innovations. According to Franck (1983), the following innovations constituted revolutionary basic innovations: the production of mineral fertilizer 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 (1987) and the DRI Europe (Panorama of EU Industry 95-96, p. 6-8) argue, however, that the potential for further development of basic innovations is exhausted. Despite increasing R&D expenses (EU average at 5 percent of gross sales), the chemical industry is currently in a phase with little innovative opportunities. Whether or not the development of gene technology will be able to instigate a new upsurge in the chemical and pharmaceutical industries remains to be seen.

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

Our next example is firm-specific, and relates to the BASF portfolio of polymeric materials. Figure 2.3 illuminates the positions of various polymeric materials within a 10 year life cycle. Performance is defined here as market performance--the annual growth in gross sales over the 10 year period. The circles indicate the market volume of the particular material. The black circles represent specialty polymeric materials, whereas the white circles indicate standard 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 advises firms to invest R&D in emerging technologies, specialty chemicals and in basic innovations in their respective areas of competence.

---

<sup>3</sup> See Mensch (1979); Franck (1983); Ayres (1988).



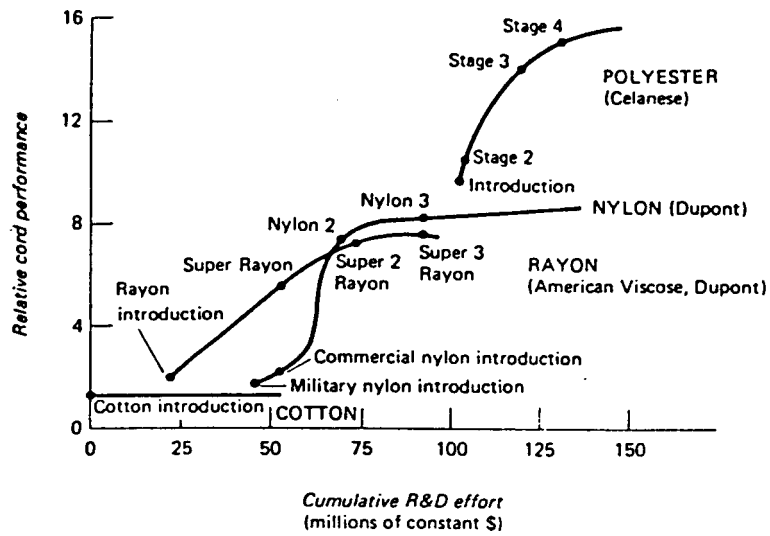


Figure 2.2 Life Cycles for Different Processes for the Manufacture of Cord for Tires (Source: Ayres 1988, p. 104)

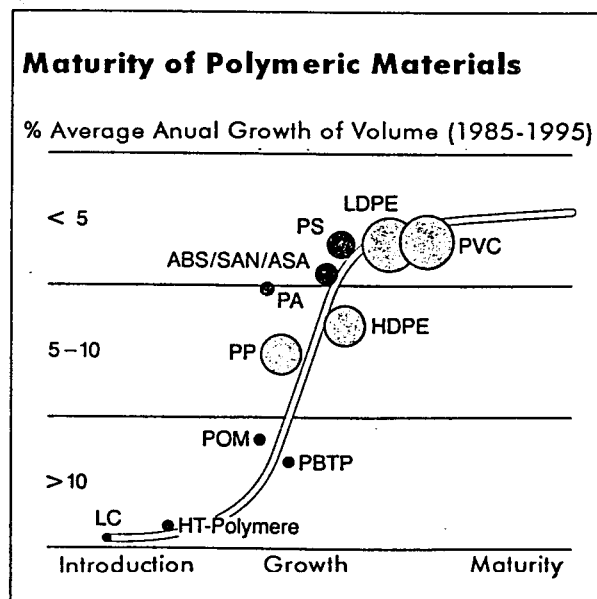


Figure 2.3 Stage of Product Life Cycle for Various Polymeric Materials (Source: Quadbeck-Seeger 1995, p. 5)

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 R&D resources devoted to product development can be explained by the above statement--innovations in a specialized industry revolve almost exclusively around products. The fact that these product innovations are often nothing more than product variations and further developments of existing products (called “incremental innovations”) is substantiated by the large (and slightly increasing) amounts spent for R&D expenses for development, as 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 (1994), pp. 38-39

### **3 Measurement of Innovation Trends**

#### **3.1 The Measurement Approach**

Nine European chemical companies were selected as subjects for our investigation (which covered a ten year time period). The goal of the selection process was to choose a wide range of chemical lines in order to insure a certain diversity in strategic orientation. Company size was thus also a decisive factor in the selection of the companies.

The annual reports of the respective companies supplied the relevant basic data. The following report items were investigated:

- Product and process innovations, which are then described in detail using a specially designed classification system;
- Quantitative data regarding R&D activities, such as R&D expenditures and the number of employees involved in R&D;
- Quantitative data regarding corporate success and growth;
- Qualitative data regarding the strategies pursued by the divisions of the various firms.

#### **3.2 Selection of the Companies to be Investigated**

As mentioned above, the selection of the companies to be investigated was made according to size and line 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, nine 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 gross sales (this ranking causes certain distortions, since the percentages of income from chemicals may vary in the individual cases; e. g. ICI shows a higher engagement in the chemical line than Sandoz).

By analyzing their corporate profiles and through considering the availability of data, such as annual reports, we selected nine of the original 15 companies as appropriate for this study (see the last column in Table 3.1). Bayer and ICI represent big and highly diversified companies, while Ciba-Geigy and Sandoz are typical of more specialized firms. 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 concentrated in the central areas of a company, is usually the result of decades of R&D and a component of the corporate

history. For further information, brief characterizations of the companies under investigation are included in Appendix 9.1.

**Table 3.1 The 15 Leading European Chemical Companies - 1992**

Company	Country	Gross Sales in million ECU	Staff Size	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	no
Sandoz	CH	7 935	53 360	yes
Akzo	NL	7 414	62 500	yes
Norsk Hydro	N	7 236	34 036	no
Roche Holding	CH	7 129	56 335	no
Smithkline Beecham	UK	7 091	53 700	no
Henkel	D	6 987	42 244	yes
Solvay & Cie	B	6 125	45 350	yes
Glaxo Holdings	UK	5 801	37 083	no
L'Oreal	F	5 489	31 908	no

Source: European Commission (1994a), Panorama of EU Industry 1994, p. 6-7. The following abbreviations are used: B=Belgium, CH=Switzerland, D=Germany, F=France, NL=Netherlands, N=Norway, and UK=United Kingdom.

### 3.3 Annual Reports as a Source of Information

Annual reports are required by law to represent the true economic situation of their companies. This also applies to expected corporate developments. Since the prospective developments of research-intensive companies, such as chemical companies, depend on R&D, German law also requires these firms to issue periodic R&D reports. The German chemical association therefore recommends the declaration of data concerning each of the following: (1) R&D areas and R&D facilities, (2) R&D personnel and R&D expenditures, (3) the relevant results of R&D activities, and (4) the main R&D objectives (Graumann 1993, p. 194). Germany's major chemical companies comply with these recommendations. In other countries, most annual reports are less detailed.

Usually, the amount of money expended on R&D can be derived from the annual reports, along with data concerning gross sales, balance-sheet totals, annual net earnings, and the respective operating results. The most important source of information for this study, however, is the status report--which is the main supplier of qualitative data concerning corporate and innovative strategies, including data on the major results and goals of R&D activities. This makes the status report the primary source of information for our method of innovation counting.

### 3.4 Indicators of Innovative Activity

**Indicators for the Evaluation of Innovative Activities** The quantitative evaluation of corporate innovative activities is only made possible through the assessment of “innovative indicators.” These indicators, in the form of “representative variables,” depict the unobservable variable of “innovative activity” more or less accurately. Because of the complex diversity involved in the innovative process, the indicators are split up into input indicators and output indicators. Typical input indicators include the number of R&D personnel or the amount spent by a firm on R&D. 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 Based on Research Expenditures** Several prior studies in this area have utilized the input indicators R&D expenditures and R&D personnel. The indicator of R&D personnel, however, has certain disadvantages. In companies with capital-intensive R&D, the relevant R&D expenditures are easily underestimated; while in companies with personnel-intensive R&D, an overestimation of these activities takes place. In addition, due to employment conditions and personnel policies in large firms, R&D personnel can only be adjusted to changed R&D strategies after a certain time-lag. An additional advantage to using R&D expenditures versus the number of R&D personnel is that the incorporation of outside services (R&D services carried out on order by third parties) skews the companies R&D personnel figures. By utilizing the input indicator of R&D expenditures, we feel the innovation input can thus be rated in a more comprehensive manner.

**R&D (Expenditures) Intensity** may be calculated two ways: (1) by dividing total R&D expenditures by gross sales, or (2) by dividing total R&D expenditures by the balance-sheet total. The sales-related R&D intensity is the indicator more commonly used than the R&D intensity relating to the balance-sheet totals. Due to the stability and size of denominator the latter fluctuates less than the former, that is, it shows less dependence on product market swings (see Schwitalla 1993, p. 225).

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

**Output Indicators for the Evaluation of Research Performance** The best known and most accessible R&D output indicator 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 a poor reflection of the quality of the underlying innovations, since only a small number of patents are actually put to economic use. Second, the inclination towards patenting varies greatly among companies and lines of business. In some cases, inventions are never patented because other strategies, such as secrecy or an early market introduction, are given priority. Our study uses 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 Performance** Corporate performance is generally cited in terms of profitability and cash-flow analysis. This study uses the net profit ratio, as one of the most commonly used financial ratios, and as an analysis of the operating result. The net profit ratio is defined as follows:

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

An examination of the operating result is significant insofar 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 characterize corporate growth by means of the growth rates of annual sales, 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. The information concerning process and product innovations in the annual reports was simply not detailed enough. The number of innovations under investigation was also too small for a meaningful classification into the very specialized product groups of the SITC or NACE systems. As a result, new classifications were developed during the course of the evaluation. These classifications were based on the common categories used by the SITC, NACE, and found in related literature.

The new classification system was developed in connection with a pilot study. It was then further refined during 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 system contains nine key groups, some of which are divided into sub-groups. We are thus enabled to undertake both a significant investigation of the material at hand and an identification of certain innovative trends. In addition, innovations are divided according to whether they are product or process innovations, and records are kept concerning possible ecopolitical innovations.

### **The Classification System:**

- 0 Environmental Technologies:** This category primarily includes recycling technologies. These constitute a relatively new sphere of operation within the chemical industry, where repeated innovations are recorded, but do not fit into the traditional classification for chemical processes and products. This group also includes recycling technologies that are used for the recovery of precious raw materials (such as platinum from catalyzers) and are not ecopolitical in nature.
- 1 Basic Organic Materials:** Category No. 1 contains chemical elements and intermediate products which are produced in large quantities and/or manufactured from crude oil, natural gas or coal. They include methanol, ethane, benzole, butadiene, chloroethylene, and unvulcanized rubber.
- 2 Basic Inorganic Materials:** Category No. 2 includes inorganic elements manufactured in large quantities and needed as source materials for various syntheses, such as ammonia, soda and sulfuric acid.
- 3 Plastics:** Because of the complexity and heterogeneity of this subject, a further sub-division was attempted. However, the partiality and insufficiency of detailed information in the annual reports was a problem. Finally, we chose to create the following subgroups:
  - 30 Plastics:** Plastics that do not fit into either 31 or 32.
  - 31 Traditional Mass-produced Plastics:** Such as polyvinyl chloride, polyethylene, polystyrene, polypropylene, including any new developments related to mass-produced plastics.
  - 32 Special Plastics:** Plastics which are not based on traditional synthetic substances, such as polyetherketones, polyester resins, polysulfones, polyurethane, polyacetals, polycarbonates, and copolymers.

- 4 **Synthetic Fibers:** This category contains all synthetic fibers including fibers based on natural substances, such as cellulose (viscose, acetates, etc.). Its major component, however, consists of polyamide and polyester fibers.
- 5 **Paints and Varnishes:** Category No. 5 consists of both organic and inorganic colorants. Besides paints and varnishes, various coatings which are used as architectural coatings, electrical insulation, or by the automobile industry were also assigned to 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 **Specialty 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, Specialties for the Printing Industry**
  - 85 **Specialties for Photographic Purposes**
  - 86 **Specialties 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, and industrial gases.
- 9 **New Materials:** The definition of this category is particularly problematic, since numerous special plastics would have to be included. In order not to confuse the 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 of the innovation counting, the companies' levels of success and their financial ratios. The results of the innovation counting are examined separately for the individual lines of business. The most innovative lines are identified, as are the exemplary technological trends dominating the innovative activities in those lines. The extent of ecopolitically motivated innovations is also investigated, along with any technological developments in the area of environment protection.

This study investigates the individual lines of business concerning their respective mean values for the past ten years. It also describes significant tendencies that may have appeared during the investigation period (1984 - 1993), i. e. those lines whose innovative frequency was subject to change during the course of the study. This is done by comparing 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 this study's 1,299 recorded innovations suggests that the areas of specialty chemicals, paints and varnishes, and plastics comprise the most innovative fields within the chemical industry (detailed results are in Table 4.1). Comparison between this study and the pilot study (see Table 4.1, Column 3) shows extensive congruence between the results of both. The following section explores and evaluates the innovative tendencies of the chemical industry by lines of business, beginning with the most innovative.

**Specialty Chemicals** Evaluation of the subdivisions within 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 often based on the further development 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				
		Innovative Share	Innovative Share	Share of Product/Process Innovations		Share in Ecopolitically Motivated Innovations		
				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
	<i>Sum Plastics</i>	<i>17.7</i>	<i>15.7</i>	<i>91.7</i>	<i>8.3</i>	<i>7.8</i>	<i>7.0</i>	<i>17.6</i>
4	Man-made fibres	3.7	3.2	73.8	26.2	7.1	0.0	27.3
5	Paints and 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
	<i>Sum Specialities</i>	<i>19.3</i>	<i>27.9</i>	<i>95.0</i>	<i>5.0</i>	<i>11.6</i>	<i>11.6</i>	<i>11.1</i>
9	New Materials	4.4	0.5	85.7	14.3	0.0	0.0	0.0
	<b>Sum of all Innovations</b>	<b>100</b>	<b>100</b>	<b>90.3</b>	<b>9.7</b>	<b>16.6</b>	<b>13.5</b>	<b>45.2</b>

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 petrochemicals results from the substitution of drilling aids based on mineral oil with those based on fatty chemicals (biologically decomposable esters) or the introduction of environment friendly fuel additives.

The majority of innovations connected with specialty 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 specialty chemicals (see product group matrix, Figure 2.1).

**Paints and Varnishes** 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. Analogous 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 colors 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 enameling). Again, polymers played a very important part in the development of these varnishes. A still greater potential for development than solvent-free varnishes, however, lies in coating powders and multicomponent systems--such as with epoxy-amino systems (see Hoechst, Annual Report 1991, p. 9).

**Plastics** Our investigation showed an innovative share of approximately 16 percent for the field of plastics, which places them in the third position. When recording these innovations, it was attempted to split the plastics group up into two subgroups. Such a classification, however, turned out to present certain problems. The area of plastics is extremely diverse and the information in the annual reports usually is not sufficient for such precise classification. Yet, there is a distinct difference concerning the innovative share between the traditional mass-produced plastics and the newly developed specialty plastics. The fact that the innovative share of the traditional mass-produced plastics is more than 10 percent higher for process innovations than that of specialty plastics confirms the hypothesis of the technological life cycle model, which posits that the more "mature" lines of business will show a higher rate of process innovation.

The development of polymerization catalyzers was very important for the mass production of plastics. A new class of metal-based catalyzers capable 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 (see *Chemische Industrie* 10/92, p. 29). 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 fiber material immersed in a polymer matrix and show properties unknown in homogenous material. New developments in the fiber industry, such as carbon fibers and aramid fibers (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 among the most R&D-intensive lines of business and show similarities to the R&D of pharmaceuticals. During the course of the investigation, the extremely low share of biotechnologically manufactured plant protectives became noticeable. Only Ciba-Geigy introduced two such products. In research, however, biotechnology (gene technology) plays a vital role. This observation coincides with the S-curve theory. The development of gene technology is at an early stage. This leads to the conclusion that a rapid growth in biotechnologically manufactured products is to be expected within the next few years. Accordingly, Ciba-Geigy aims at having introduced ten products on a biotechnological basis by the year 2000. ICI also describes their biotechnological engagement in plant protection as very intensive, complex, and as “very long-term.” (see ICI, Annual Report 1988, p. 10). 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 primarily due to innovations introduced by Henkel. In fact, 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 specialty chemicals.

For detergents, priority was given to the development of environmentally 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-aluminum silicates that belong to the zeolites (brand name: Sasil). Furthermore, there is a tendency

towards materials based on renewable resources, such as starch and/or fat. The tensides developed by Henkel on the basis of alkyl polyglucosides serve as a relevant example (see Henkel, Annual Report 1990, p. 13).

**Synthetic Fibers** This line of fibers accounts for a mere 3.2 percent of all innovations and, with the exception of high-tech fibers, ranks among the more mature industries. The generally low innovative rate and a relatively high share in process innovations (26.6 percent) conforms to the expectations of the technological life cycle model for mature industries.

The fibers made from polyaramides represent an interesting new development and are characterized by extreme stability. Besides these fibers, extremely temperature resistant fibers such as fibers from polybenzimidazole or fibers based on polyacrylonitrile were specially developed for industrial use in the aviation and construction industries in order to substitute for asbestos (see Hoechst 1993, *Neue Wege finden*, p. 83). In addition, heavy duty fibers 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 fibers, 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 category, 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 in these categories. This is primarily 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 (see Hoechst 1993, *Neue Wege finden*, p. 104).

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

**New Materials** The very low share (0.5 percent) of new materials in the investigation can be explained by our classification of the modern polymer compounds and composite materials in the category of special plastics. Ceramic materials and special glasses, however, belong to this category. Ceramic materials offer a multitude of applications, thanks to their hardness and 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 attention to possible changes in innovative intensity.

The results are documented in Table 4.2. The large innovative share increases in the areas of environmental technologies and products related to information technology (specialties) is due to the ever-growing economic significance of these industries. The extent of the changes that occurred in the fields of plastics, agrochemicals and preservatives/cleaning materials is difficult to explain, however, since the conditions involving R&D and production were not subject to significant changes during the ten years in question.

One very noticeable finding concerns the large decrease in the total number of innovations reported. While 290 innovations were reported in 1984/85, only 202 were reported in 1992/93. Perhaps, this can be attributed to the major crisis which the chemical industry experienced (beginning in the early 1990s). This decline might also be seen as an indicator of the chemical industry's increasing inability to produce innovations. This would fit with the thesis of the chemical industry finding itself in the maturity phase of its life cycle.

## **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. We reveal which of each companies' lines of business are particularly innovative and identify which lines of business exhibit exceptionally large rates of growth. These findings are used to explain the differences in the gross sales and rates of return of the individual companies.

### ***4.2.1 A Comparison of R&D Input Indicators***

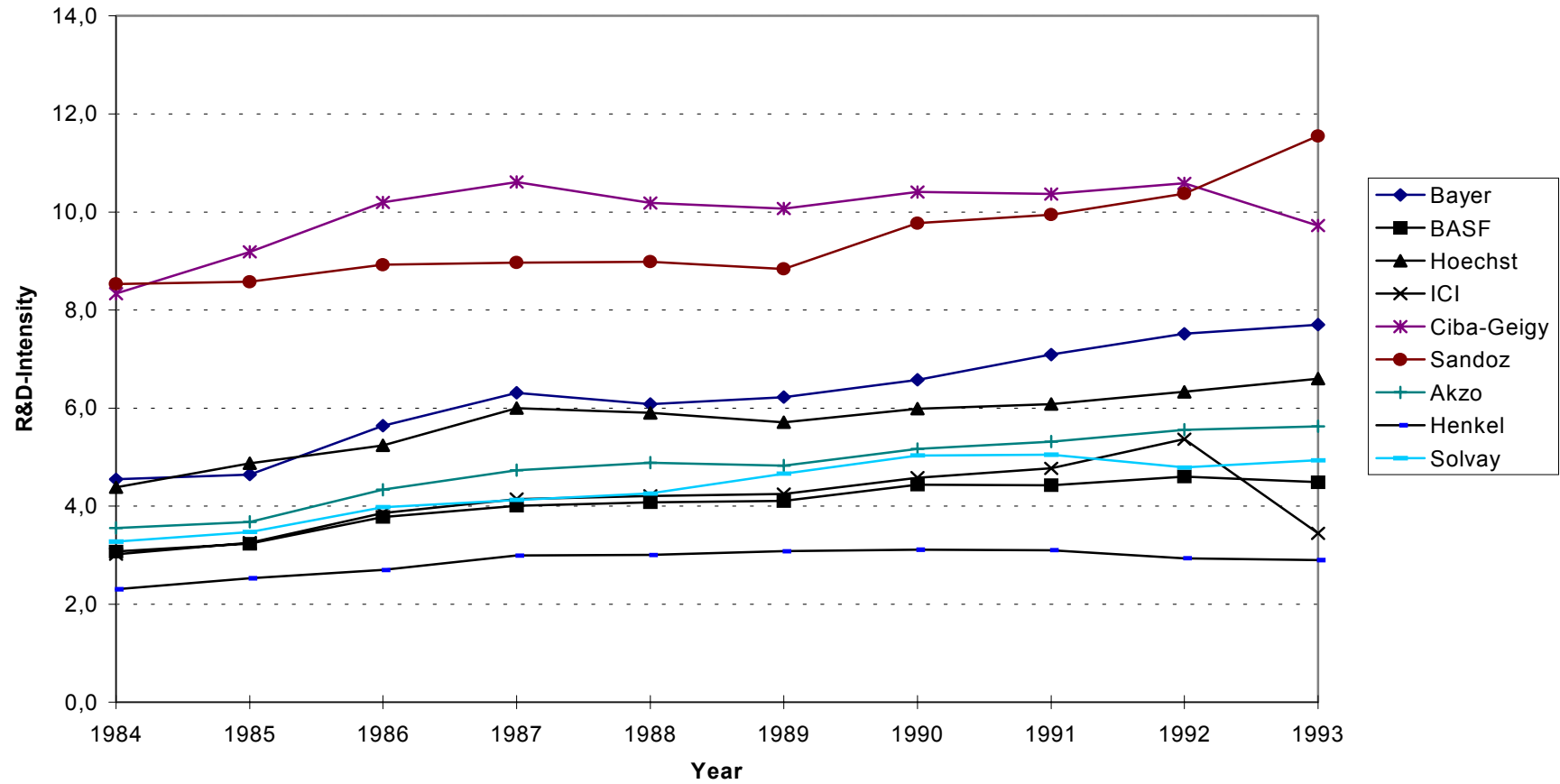
**Comparison of R&D Intensity** This section initially examines R&D expenditures relative to sales. It then moves to an analysis concerning percentages of R&D personnel, as compared to total personnel. We distinguish these two measurements as R&D expenditure intensity and R&D personnel intensity, respectively.

**Comparison of R&D Expenditure Intensity** Figure 4.1 illustrates the recent development of the R&D expenditure intensities of the nine companies in this study. Almost all of the companies show increasing R&D expenditure intensities. This may be due to an increased orientation towards the R&D-intensive areas of pharmaceuticals and specialty chemicals, but it could also be the result of decreasing R&D productivity.

**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
	<i>Sum Plastics</i>	<i>55</i>	<i>19.0</i>	<i>16</i>	<i>7.9</i>
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	Miscellaneous	22	7.6	13	6.4
	<i>Sum Specialities</i>	<i>82</i>	<i>28.3</i>	<i>51</i>	<i>25.2</i>
9	New Materials	0	0.0	0	0.0
	<b>Sum of all Innovations</b>	<b>290</b>	<b>100</b>	<b>202</b>	<b>100</b>

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





The reasons for these differences in R&D intensity are mainly to be found in the individual corporate profiles. These differences, with respect to innovative strategies, are difficult to portrayed given the data at hand. The vast increase of Bayer, for example, is partially due to Bayer's goal of increasing their pharmaceutical share of gross sales by 30 percent by the year 2000.

Figure 4.1 identifies four groups of companies whose curves show similarities. The two Swiss companies, Sandoz and Ciba-Geigy, exhibited the highest R&D expenditure intensities. This is primarily due to their strong engagement in the extremely R&D-intensive fields of pharmaceuticals and agrochemicals. In 1993, for example, Sandoz spent 18 percent of their gross income from pharmaceutical sales on R&D connected to pharmaceuticals. On average, European companies spend around 5 percent of their turnover on R&D (Panorama of European Industry 95-96, p. 6-5).

Another group includes Bayer and Hoechst, whose R&D intensities were similar until the late 1980s. This is due to their similarly structured product ranges and their comparable corporate sizes; both companies show strong engagement in the fields of pharmaceuticals, polymers and agriculture. Remarkable in this context is the fact that not only their R&D expenditure intensities drifted apart in the beginning of the 1990s, but also their return on sales (see Figure 4.1). The lower R&D expenditure intensity shown by Hoechst is primarily due to a large increase in gross sales--as a result of acquisitions, such as Celanese.

The largest economic group includes BASF, ICI, Akzo, and Solvay. The R&D expenditure intensities of these companies range from 3 to 5 percent. These companies are fairly diverse, i. e. their product ranges include raw materials and basic chemicals, as well as pharmaceuticals. Akzo, for instance, is still very active in the production of fibers, while Solvay concentrates on basic chemicals and mass-produced plastics--however, they are both very much engaged in the production of pharmaceuticals. The vast decrease in R&D expenditure intensity shown by ICI in 1992 is the result of their having split off their lines of pharmaceuticals and agriculture.

The lowest R&D expenditure 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 gross sales.

**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	Pharmaceuticals Agriculture	Polymers Agfa-Gevaert	Industrial Chemicals
BASF (as of 1991)	Agriculture Consumer Goods	Chemicals Colorants/ Refining Products	Gas and Oil Plastics/Fibers
Hoechst (as of 1986)	Pharmaceuticals Agriculture		Polymers Technics Chemicals/Paints Fibers/Foils
ICI	no data supplied		
Ciba-Geigy (as of 1991)	Pharmaceuticals	Agriculture	Industry
Sandoz	Pharmaceuticals	Seeds Agrochemistry	
Akzo	no data available		
Henkel	no data available		
Solvay	no data available		

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

An R&D share of a line of business that exceeds the respective sales share indicates that the line of business is an R&D-intensive one. R&D-intensive fields include pharmaceuticals and agrochemicals. Lines such as mass-produced plastics and fibers exhibit a lower R&D intensity.

Applied to the S-curve model, the results from Table 4.3 illustrate a larger innovative potential for pharmaceuticals and agrochemicals, since companies with knowledge of the S-curve tend to invest more in 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. For example, 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 do not differ so much in the number of R&D personnel, but in their total number of employees. This is confirmed by comparing the share of salaries and wages to gross sales (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. This is surprising, since their production is not very personnel intensive and should indicate a high R&D personnel intensity. Furthermore, their R&D expenditure intensity conforms to the mean value for that particular line of business. Perhaps, the reasons for this contradiction lie in their extremely capital-intensive, yet barely personnel-intensive R&D.

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

One additional explanation for these discrepancies may be the diverging classification criteria used by the individual companies when assessing R&D personnel.

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

Company	R&D Personnel-Intensity (%)	Share of Salaries and Wages as Percent of Gross Sales (%)
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 Output Indicators

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 specialty chemicals). Allocations are based on the classification system established in the study, not on the categorization of the individual companies. See Table 4.6 for a detailed evaluation.

The order of precedence once again illuminates the differing corporate profiles. The large percentage of plastics, specialty chemicals and paints/varnishes is noticeable. Agrochemicals, despite being one of the most R&D-intensive fields, rank only third, however, this is partially due to their lower share of gross sales. As a result of inconsistent line definitions (share of sales according to the companies' classifications, and innovative shares according to the classification system established in the present study), an actual weighing of innovative shares against their share of sales was not feasible.

**Table 4.5 Ranking of Innovative Core Activities by Individual Companies**

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

The innovative core activities of the individual companies also explains the different R&D expenditure intensities shown in Figure 4.1. BASF, for instance, has their innovative core activities in paints/varnishes and in mass-produced plastics. The R&D expense intensity for paints/varnishes at BASF amounted to a mere 2.68 percent in 1988 (Rohe 1989, p. 20), a figure much lower than the company's total R&D expenditure intensity of 4.1 percent.

**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	<b>2.3</b>
1	Basic Organic Chemicals	3.7	2.8	3.7	6.6	0.0	0.0	8.5	1.3	9.6	<b>3.5</b>
2	Basis Inorganic Chemicals	0.0	0.0	3.7	2.2	0.0	0.0	0.7	0.0	1.9	<b>0.5</b>
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	<b>0.5</b>
31	Traditional Mass Produced Plastics	0.7	14.2	4.9	0.0	0.0	0.0	0.0	0.0	19.2	<b>4.0</b>
32	Special Plastics	16.7	11.9	19.8	11.0	14.0	1.3	0.7	0.6	34.6	<b>11.2</b>
	<i>Sum Plastics</i>	<i>18.6</i>	<i>26.5</i>	<i>24.7</i>	<i>12.1</i>	<i>14.6</i>	<i>1.3</i>	<i>1.3</i>	<i>0.6</i>	<i>53.8</i>	<i>15.7</i>
4	Man-made fibres	3.3	2.4	9.9	2.2	0.0	1.3	10.5	0.0	0.0	<b>3.2</b>
5	Paint. Varnishes	23.8	34.4	16.0	24.2	29.9	27.6	41.2	2.5	0.0	<b>24.9</b>
6	Agrochemicals	10.4	4.7	14.8	16.5	24.4	21.1	15.7	0.0	11.5	<b>11.8</b>
7	Maintenance Products	3.3	4.7	2.5	3.3	2.4	3.9	3.3	53.1	1.9	<b>9.5</b>
81	Glues and Adhesives	3.7	2.0	0.0	3.3	5.5	1.3	0.7	23.1	0.0	<b>5.1</b>
82	Petrochemical Additives	0.0	2.8	1.2	1.1	0.0	0.0	0.0	2.5	0.0	<b>1.0</b>
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	<b>4.2</b>
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	<b>3.4</b>
85	Chemicals for Photographic Purposes	13.0	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0	<b>2.9</b>
86	Chemicals for IT	2.2	2.4	1.2	1.1	0.0	0.0	0.0	0.0	0.0	<b>1.1</b>
87	Chemicals for Construction Ind.	1.1	0.0	0.0	2.2	0.0	9.2	0.7	3.8	5.8	<b>1.7</b>
88	Plastic Additives	0.0	2.0	0.0	3.3	6.1	3.9	2.0	0.6	0.0	<b>1.9</b>
89	Miscellaneous	5.6	3.2	6.2	12.1	10.4	1.3	11.1	5.0	9.6	<b>6.7</b>
	<i>Sum Specialities</i>	<i>34.2</i>	<i>22.5</i>	<i>16.0</i>	<i>26.4</i>	<i>28.7</i>	<i>43.4</i>	<i>17.0</i>	<i>39.4</i>	<i>15.4</i>	<i>27.9</i>
9	New Materials	0.7	0.0	1.2	1.1	0.0	0.0	2.0	0.0	0.0	<b>0.5</b>
	<b>Sum of all Innovations</b>	<b>269</b>	<b>253</b>	<b>81</b>	<b>91</b>	<b>164</b>	<b>76</b>	<b>153</b>	<b>160</b>	<b>52</b>	<b>1299</b>

Another very interesting item is Henkel's concentration on preservatives and cleaning agents--more than 50 percent of total sales. This line of business seems to require a minimal R&D expenditure intensity, a theory which would explain Henkel's low total R&D intensity. As for Sandoz, their high share of preparing agents for textiles and leathers exceeds even their innovative shares of paints/varnishes and agrochemicals.

The intended evaluation of the companies' strength--related to their reported innovations--could not be carried out. During the course of the investigation it was discovered that the various companies' inclination to accurately report their innovations varied 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 that their product ranges differ considerably, while this study was not in a position to consider anything but their chemical fields. Thus, the innovative shares shown in Table 4.6 refer only to the companies' chemical activities in accordance with the classification definition underlying the study.

#### ***4.2.3 Growth in the Individual Lines of Business***

Table 4.7 categorizes the individual lines of business according to the development of their gross sales from 1984 to 1993. The categories used are: growing, fairly constant, and declining. We adopted the companies' own definitions of their individual lines of business for this table.

Growth in pharmaceuticals and/or consumer-related business lines, such as cosmetics (Henkel) or consumer goods (BASF), are 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, fibers and agriculture, on the other hand, are on the decline. Two of the companies under investigation suffered further decreases in sales in the areas of raw materials/energy (BASF) and petrochemicals (ICI). The consistency of Sandoz's lines is also worth noticing.

The conformity between R&D expenditure intensity and sales growth for the individual lines of business is remarkable. A positive correlation between R&D intensity and sales growth has, thus, been established, except where agriculture is concerned. Although agriculture ranks among the most R&D-intensive lines of business, it does not belong to the lines whose sales are expanding. This is partially due to the declining sales of fertilizers. Innovations, on the other hand, are to be found in the area of agrochemicals, i. e. insecticides, herbicides, etc., while the high degree of R&D intensity can be attributed, at least in part, to strict environmental regulations.

**Table 4.7 Growth Trends by Individual Lines of Business**

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

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

The data found in Table 4.7 is directly related to the product life cycle model--it is in this model that the stages of maturity are identified through growth in sales. Accordingly, those lines of business that show growing gross sales--pharmaceuticals, paints and varnishes, etc.--are placed at an earlier stage of maturity than the areas of fibers or chemicals.

**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 Sales	Return on Sales	Return on Equity	Return on Total Assets	Return on Operating Profit	Increase in Sales	Increase in R&D-Expenditure	Increase in Balance Sheet Total	Increase in Employment	Increase in 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



#### ***4.2.4 Corporate Performance 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 for the individual companies largely depends on the respective corporate profiles. See Table 4.9, Column 2, for the most profitable fields. It is not surprising that the companies who are the most successful are those whose sales originates largely from the lines shown to be the most profitable in Table 4.9. The companies with profitable pharmaceutical lines were the most successful. Furthermore, it should be mentioned that:

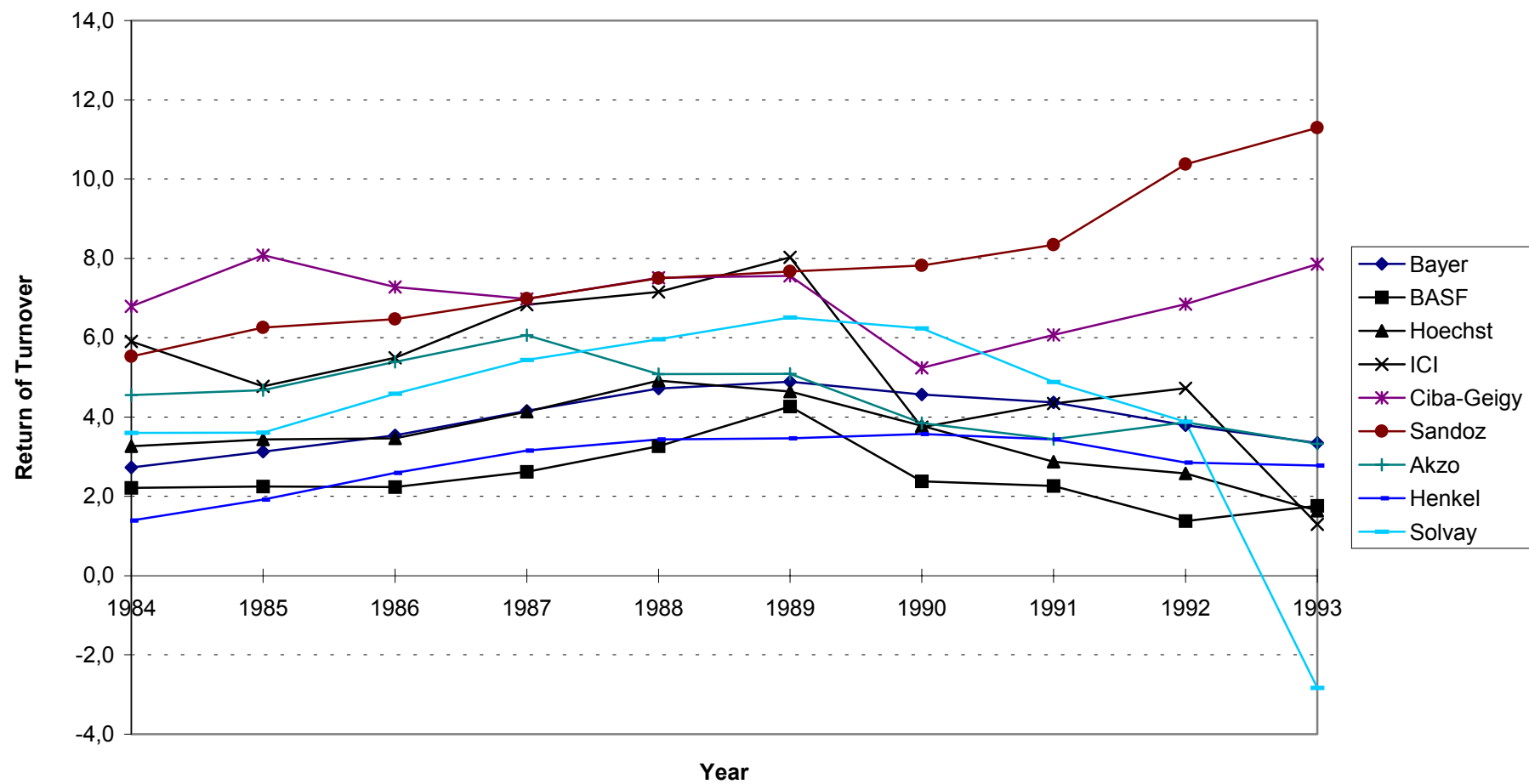
- the two Swiss companies, Ciba-Geigy and Sandoz, were able to achieve sales growth at a time when most companies were suffering a decline in their return on sales. This is probably due to their strong orientation towards pharmaceuticals and specialty chemicals. Sandoz is also strongly represented in markets related to 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 pharmaceuticals, part of the specialty 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 earnings exceeding the share in sales of a particular field reflects an above average contribution towards the corporate performance. More or less balanced shares reflect an approximate equivalence of return on sales (where return on sales is defined as the quotient from the operating result and total sales) for this particular line of business and for the total return on sales of the company.

Pharmaceuticals are by far the most profitable lines of business. The 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 a portion of their finishing products (varnishes). However, most of these results refer to the period of 1988 - 1993, a period which coincided with the severe recession that affected the chemical industry, so distortions may have occurred.

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.

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



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

Company	Share in Operating Earnings Larger than Sales Share	Share in Operating Earnings and Sales Share more or less Equal	Share in Operating Earnings Smaller than Sales Share
Bayer (as of 1988)	Pharmaceuticals	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)	Pharmaceuticals	Agriculture Chemicals and Paints Fibers/Foils	Polymers Technics
ICI (Various Periods of Time)	Pharmaceuticals Explosives	Petrochemistry/Plastics Varnishes and Paints Chemicals	Agriculture fibres
Ciba-Geigy (as of 1988)	Pharmaceuticals	Agriculture	Industry
Sandoz	no data available		
Akzo	Pharmaceuticals	Chemicals	Fibres Paints/Varnishes
Henkel	no data available		
Solvay	Pharmaceuticals Alkalines Peroxides	Plastic Processing	Plastics

### 4.3 Limitations and Conclusion

The main limitation we have found when undertaking research of this nature is the complete lack of obligatory definitions concerning the classification of expenses related to R&D. The so-called "Frascati-manual," published by the OECD merely documents relevant recommendations (see Schwitalla 1993, p. 101, and Kuhn 1992, p. 107). Since research-oriented chemical companies are considered to be dynamic and expansive, the companies are interested in reporting maximum R&D expenditures. According to Amecke (1987, p. 31), many chemical companies declare R&D expenditures which are of an exclusively defensive nature, such as toxicological examinations of already existing products, or advice on application problem solving--which should, in fact, be considered as sales-related activities.

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

Despite the uncertainties described above, our analysis found plausible figures and tendencies. Schwitalla (1993, p. 272) and Graumann (1993, p. 185), who both investigated the annual reports of German companies, came to the conclusion that these annual reports contain R&D data of a surprisingly high quality--particularly concerning R&D expenditures.

Several limitations were encountered in connection with the innovation counting. These are primarily due to the differing degrees of information available in the annual reports. Because of the companies' varying tendencies to report their innovations, it was impossible to evaluate and compare the companies' levels of innovativeness. Another problem was the imprecise information distributed by the firms. Much of the information regarding innovations is little more than advertising. 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 classification extremely difficult. This is especially true in the area of plastics, where categorization according to chemical criteria is not clear-cut--it was impossible to differentiate between mass-produced plastics, further developments based on them, and/or special plastics.

Innovation counting was further hampered by entire new product lines being introduced, instead of an exact number 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 innovations were often, in fact, improvements with no change of name (or sometimes individual products in 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 description of the innovative trends prevailing in the chemical industry. This is confirmed by the large degree of conformity between this study and the prior pilot study (innovation counting on the basis of information taken from the magazine "Europa Chemie").

The most noticeable finding of these studies is the interdependence of R&D expenditure intensity and return on sales. 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, suggests that the level of R&D expenditure intensity is extremely dependent on the respective corporate profile--i.e., it also illustrates which lines of business the company in question engages in. Thus, the interdependence concerns corporate profile, R&D expenditure intensity and return on sales. The evaluation utilizing lines of business has

shown that the R&D-intensive lines are those lines which produce the best sales growth and return on sales.

These connections serve to validate the assumptions of the S-curves and the product life cycle model. Thus, it was shown that companies tend to spend particularly large sums in business lines with a high potential for growth and profit (such as pharmaceuticals). 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 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. fibers or basic chemicals).

The evaluation of the innovation counting illustrates the companies' tendencies to move toward specialty chemicals and/or paints and varnishes (which resemble the specialties in many ways).

## **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 Database**

The following section introduces several basic innovation and corporate strategies of major importance to the future development of the European chemical industry. It describes the underlying conditions currently influencing corporate strategies. In addition, this section examines the companies' reactions to the developments identified in the previous section. In order to relate our analysis of the nine large European chemical firms to the CIS database, we will pretest some of the propositions developed later in this section. Unless other sources are explicitly stated, the utilized data originates from the respective annual reports and from the CIS database.

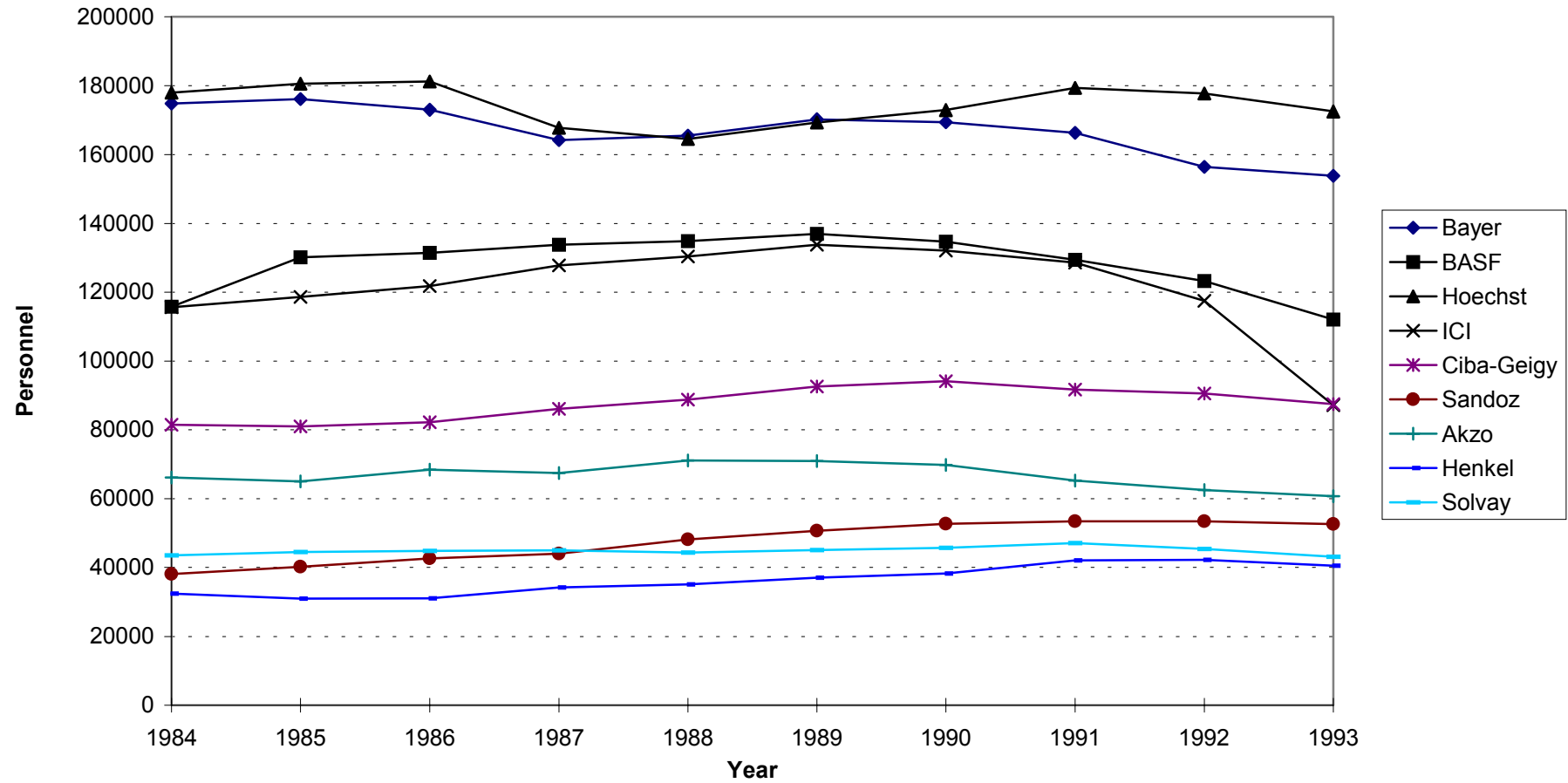
#### ***5.1.1 Changed Conditions in Europe***

A major structural crisis gripped the European chemical industry in the early 1990s. The industry reacted to this crisis with a series of structural adjustments and rationalization measures, which resulted in considerable manpower reductions. The extent of these reductions is shown in Figure 5.1. In early 1995, the total number of personnel employed in the European chemical industry was approximately 255,000 less than in 1991--a decrease of 14 percent (Economist 1995, p. 69).

The reason for these structural problems, some of which still exist today, are primarily due to the considerable cost disadvantages European producers of mass products (such as base materials, plastics, fertilizers and fibers) experience when compared with producers outside of Europe. These cost disadvantages result from higher costs for raw materials, labor and environmental protection. A significant factor related to the competitive disadvantage is the high cost of labor. As shown in Table 5.1, there is a broad variation of these costs, even within Europe. An additional factor is the geographic shift in the production of chemicals in order to be closer to major customers. The exodus of the textile industry to the Far East is the result of the increased production of synthetic fibers in that area (see Amecke 1987, p. 37). A similar danger prevails in R&D-intensive fields, such as in the production of very high-grade chemicals for microelectronics.

The Middle East countries in particular (and also Mexico), have a supply of raw materials for a large number of base chemicals and mass-produced plastics at their disposal at keen prices that have no competition whatsoever. These countries aim to produce methane- and methane-based petrochemicals (normally by-products in the production of crude oil that need to be burnt off) in large plants at low operating costs

Figure 5.1 Employment for Large Chemical Firms, 1984-1993



and thus achieve significant competitive advantages (see Riemann 1993, p. 18). The world market share of ethylene glycols for Middle Eastern countries is expected to rise from 12 percent in 1991 to 20 percent in 2000. Western Europe will become a net importer of petrochemicals and standard plastics, a development which, in the long run, will become evident for high-grade plastics as well (see Fond der Chemischen Industrie 1993, p. 14).

**Table 5.1 Chemical Labor 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, 6 October 1995, p. 24

The 1980s were characterized by the increasingly higher expenses necessary for compliance with environmental standards. Because of this, the environmental costs for German chemical companies amounted to 6.4 billion DM (or 4 percent of their 1990 sales), which represents a 25 percent increase when compared with the previous year (Riggert 1992, p. 9). These costs have now been successfully cut in half. In 1994, Bayer invested a mere 330 million DM--approximately half of their environment protection investment in 1990 (Frankfurter Allgemeine Zeitung, 12 July 1995, p. 22).

As a result of the situation described above, 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 members of these complex production links become unprofitable and the remaining firms lose what little cost advantages they have left (see Fond der Chemischen Industrie 1993, p. 13).

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 identifies those areas of R&D which will be of major importance in the future (Chemical Industries Association 1995, pp. 71-82). By reviewing all fields related to chemicals, the following list of priorities and promising technologies was created:

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

Japanese and American companies engaged in the R&D of these promising fields receive government incentives 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, 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 in 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, creates vast competitive disadvantages for German companies. At the same time, it impedes market access for medium-sized and small companies (see Chemische Industrie 4/94, p. 16). The poor social acceptance of chemical research reflected in such laws has led to research in the more-promising fields being increasingly shifted abroad, for instance to the USA and Japan.

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

### ***5.1.2 The Main Strategies Driving Innovation: Cost Leadership and Specialization***

Our strategy so far has focused on nine large European chemical firms. For a more complete statistical analysis, we will use the CIS database at this juncture, in order to explore the European situation more systematically<sup>4</sup>. However, due to the lack of data for some countries and sectors of the industry, the analysis focuses on the CIS 6-country sample which includes: Belgium, Germany, Ireland, Italy, Luxembourg, the Netherlands, Norway, and the United Kingdom.

Two broad lines of strategic research are of interest with respect to the chemical industry. The first group follows 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 in the chemical industry.

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

We see in Table 5.2 that the large firms<sup>5</sup> are located in the industry sectors of basic chemicals (24.1), soap and detergents (24.5), and man-made fibers (24.7).<sup>6</sup> The percentage of firms in these sectors in the highest earning categories (no. 4 and 5) is high--15 percent or more.

Paints and varnishes (24.3) and other chemical products (24.6) have 50 percent or more of their firms in the lower earning groups, 1 and 2. Agrochemicals is between these two groups with 44.4 percent of the firms falling into the middle category.

---

<sup>4</sup> The questionnaire of the CIS and a summary of descriptive statistics are published in Albach et al. (1996). An overview on the CIS and its organization is given in European Commission (1994b), Innovation.

<sup>5</sup> Size is measured as annual sales in thousand ECU. The size distribution is based on five sales groups.

<sup>6</sup> The pharmaceutical industry is included for the purpose of comparison, but will not be further discussed in the context of the tables (except for Tables 6.14 and 6.16).

**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)					Total Number of Firms
	1 (0-499)	2 (500-9,999)	3 (10,000-99,999)	4 (100,000-499,999)	5 (500,000+)	
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.

These results are expected because the production of basic chemicals requires considerable amounts of capital, which usually can be raised only by large firms. The manufacture of paints and varnishes, on the other hand, is often feasible as specialty production--a lower volume can be marketed profitably by providing a range of products. This is an environment where cost leadership strategies based on capital intensity are not a necessary condition for the survival.

**Cost Leadership** The strategy of cost leadership is primarily pursued in areas where price is the decisive competitive feature. According to the Technological Life Cycle Model, this is often the case with products where product innovations do not play an important role. This applies to mass-produced plastics and base chemicals, but is also partially true for certain sectors of specialized chemistry (see *Chemische Industrie* 8/89, p. 28).

The availability of low-priced raw materials and the attainment of a high market share (for better use of economies of scale) are of vital importance in achieving cost advantages. Stronger efforts toward concentration were thus made by the European chemical industry during the past few years. Efforts toward strategic concentration concerning the individual companies' core areas and tendencies to form strategic alliances were also observed.

Thus, BASF acquired ICI's European polypropylene branch and, in turn, sold their Plexiglas line to ICI. As far as synthetic fibers are concerned, BASF formed a joint venture with Allied Signal in order to concentrate on the production of nylon-6. With polyester fibers, 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 as a goal of innovative activities. This is plausible because goals are part of the corporate strategy and the goal of lowering production cost is at the core of a cost leadership strategy. More than 50 percent of the firms in the sample pursue the goals of reducing their wage costs and material consumption.<sup>7</sup>

Reducing energy consumption is of particular importance for the production of basic chemicals since a significant percentage of their costs are related to energy usage. For 16 percent of these firms, reducing energy consumption is regarded as crucial. The situation is different for the producers of agrochemicals and paints and varnishes. For the former, only 4 percent regard reducing the consumption of energy as crucial. For the latter, 8

---

<sup>7</sup> 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.

percent of the firms feel this way. Thus, a strategy of cost leadership through the reduction of energy consumption is primarily pursued in the field of basic chemicals.

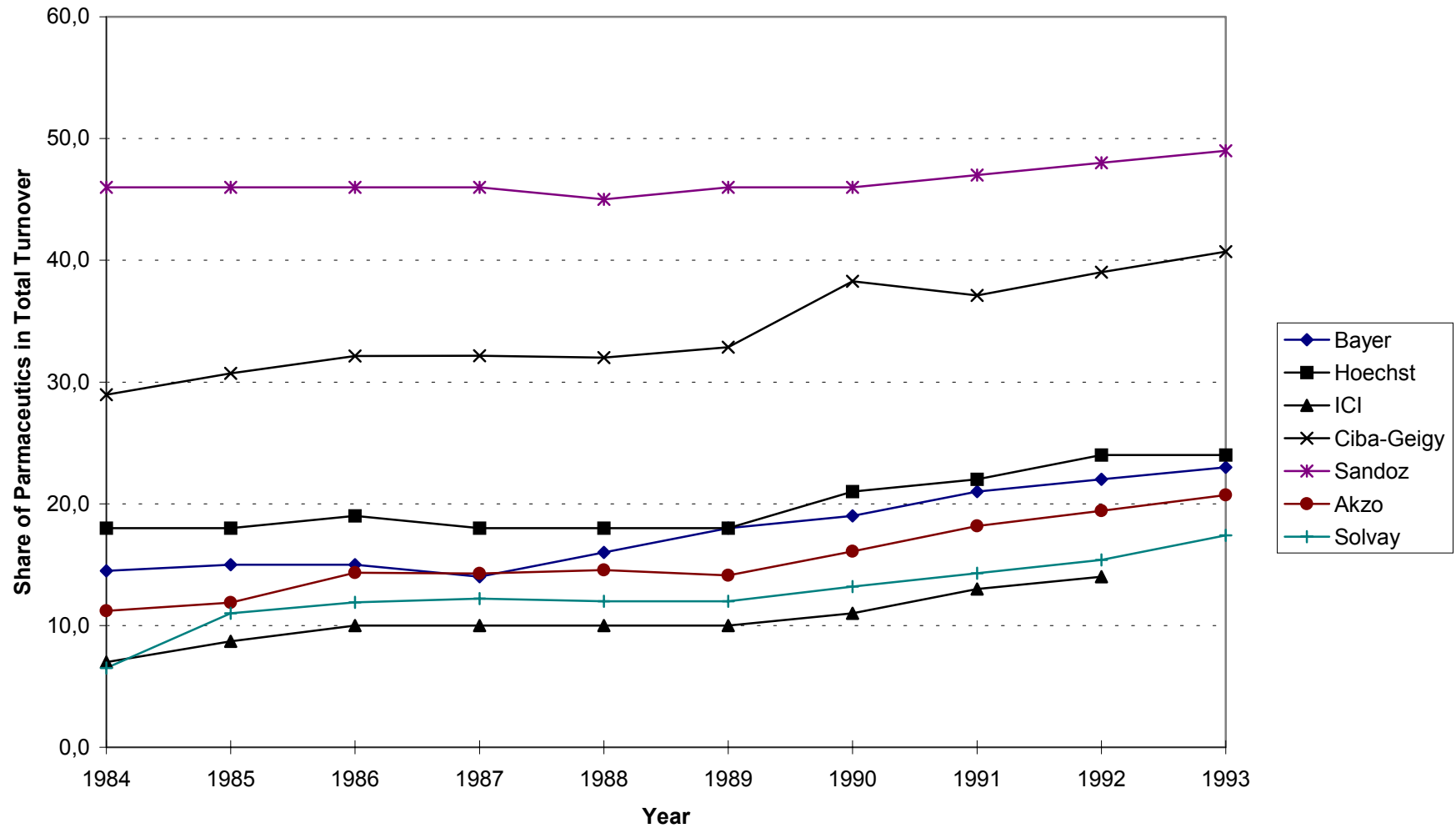
**Specialization** The strategy of specialization constitutes an attempt on the part of the chemical companies to escape from the price competition dominating the market for mass products. For the chemical industry, specialization is an orientation towards specialties--barring above the mentioned exceptions--i. e., concentration on the companies' part on certain mass products with the aim of securing cost advantages. Specialties are characterized by 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 fibers (Sandoz). As a rule, these products are highly refined 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 they pursued in greater detail. These strategies were focused on the concentration on high-value-added, market-intensive products (especially with Akzo). Any specialization trends followed were always pursued at the expense of mass production. As a result, Akzo decreased their fiber production from 52 percent of their 1963 sales 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 1969 sales to almost 25 percent in 1993. In order to continue this development, Akzo acquired the Swedish company, Nobel Industries AB, in 1993.

This trend towards specialization can easily be explained by examining the pharmaceutical lines of the companies. As shown in Figure 5.2, almost all of the companies in the study were able to increase the percentages of pharmaceuticals in their total sales. 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 of success, as BASF proved with their commitment to advanced composites. Having purchased a branch specializing in advanced composites from Celanese Corp in 1985, BASF was forced to discontinue their activities in 1992 due to unsatisfactory demand. In their efforts to appeal to the ultimate consumers, 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, e.g. for the exact mixing of varnishes and paints is offered. ICI offers its customers a computer-aided optimization system for explosions.

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



Based on the information concerning the innovative firms in the CIS sample, we can use responses to questions 10.c)i-ii of the CIS (see Albach et al. 1996 for the CIS questionnaire) to gain an understanding of how firms are investing in product innovation and in process innovation (measured as the share of their total R&D expenditures). As Table 5.3 illustrates, 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 or more for process innovation. One interpretation of this is that firms concentrate on specialized products. This is underlined by the fact that manufacturers of basic chemicals and man-made fibers concentrate on investments in process innovation which directly support their products.

Tables 5.4 and 5.5 are based on the R&D expenditures for product innovation and for process innovation. They demonstrate the different routes to specialization traveled by the various sectors of the chemical industry. For example, more than 60 percent of the manufacturers of agrochemicals and of paints and varnishes allocate a minimum of 75 percent of their R&D budgets to product innovations. Only 30.8 percent of the basic chemical producers do this, however, and the profile of firms producing man-made fibers is different still. Here only 16 percent of the producers spend 75 percent of their R&D budgets on product innovations. Instead, more than 15 percent of the manufacturers of basic chemicals and man-made fibers spend 75 percent or more on process innovations.

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

### ***5.1.3 Concentration on Key Areas***

In almost all of the annual reports studied, the concentration on key areas and/or key competencies was central. The stated goals were the achievement of a strong market position and the concentration on areas with a high synergistic effect. These are strategies that the companies actually realize with great consistency. Thus, ICI split off all bio-areas (mainly pharmaceuticals and agriculture) and integrated them into the newly-founded subsidiary company called Zeneca. Greater flexibility and effectiveness for both companies were the stated reasons for this step. However, this also means the end of risk sharing for the individual bio and chemical lines-- in the past, this was a feature of special importance for the chemical lines.

**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 (percentages of the 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	98	74	242	323	737
Total	13.3	10.0	32.8	43.8	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 (percentages of the 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 Total	352	184	119	82	737
	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.

Sandoz, on the other hand, took the opposite approach and decided in 1995 to abandon all lines of business not connected with pharmaceuticals and/or nutrition. They are now focusing exclusively on pharmaceuticals and nutrition, since health is the common denominator of both businesses. Profits are to be used for further investments in gene technology and to finance new acquisitions in the areas of pharmaceuticals and nutrition (Frankfurter Allgemeine Zeitung, 28 March 1995, p. 21). This restructuring effort could be regarded as a step leading towards the merger of Sandoz and Ciba-Geigy (announced in early 1996). The new firm, Novartis, is seen as an effort to focus on core competencies in agrochemicals, pharmaceuticals, and nutrition. In a similar move, Hoechst decided to take equally drastic measures and divested their profitable cosmetics line (e. g. Jade and Schwarzkopf), because it was not part of their key area of concentration.

#### ***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 a new development in the chemical industry. Not only co-operation between companies, but co-operation between companies and academic institutions is of major importance now, especially where basic research is concerned. As a rule, strategic alliances are formed to pursue one of the strategies described above.

Co-operation in the area of production usually aims at the concentration of production capacities in order to increase cost efficiency, largely in connection with the strategy of cost leadership. The annual reports supply numerous examples of 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 consolidated their respective PVC activities into a joint venture.

A particularly interesting example of 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 sales of 3 billion DM and approximately 8,000 employees, is the second largest producer of plant protectives world-wide, after Ciba-Geigy (Chemische Industrie 3/94, pp. 28-32). The objective of this co-operation is the achievement of "critical size" in the generally shrinking market for plant protectives, allowing the new venture to meet the challenges of both innovative and price competition.

The importance of co-operation is ever-increasing, especially in the R&D sector. According to the FAST study (1991, p. 32), this is not due to increasing R&D expenses, but the realization that co-operation enables individual companies to enter new markets, to quicken innovation development, and to recognize technological potentials at an earlier stage. Hoechst AG's increased number of co-operative agreements, from 230 to 380 in the past ten years, is indicative of the dimensions of this trend (Chemische Industrie 1/92, p. 38).

The CIS has explored co-operative arrangements involving R&D activities (question number 11: "Did your enterprise have any co-operation arrangements on R&D activities with other enterprises or institutions in 1992?"). For the overall sample of firms of the European chemical industry, 43.4 percent of the firms which responded to the question reported such arrangements.<sup>8</sup> For the 8-country sample this fraction is with 35.5 percent lower. This might be due to the fact that the larger sample has a sampling bias towards innovative firms (e.g. the Greek and Portugese sample includes only innovative firms). Table 5.6 illustrates for the 8-country sample how the use of co-operative arrangements varies regarding the sectors. The highest intensity of R&D co-operation is found within the agrochemical sector and the lowest in soap and detergents.

Information concerning the positions of the co-operative partners is also provided in the CIS.<sup>9</sup> To check the intensity related to position, we have computed the occurrences of three major types of arrangement: (1) co-operation with competitors, (2) co-operation in the form of research joint ventures, and (3) co-operation with universities, government labs, and other research institutes. The results are shown in Table 5.7. A pattern similar to the previous table emerges. Again, the agrochemical sector exhibits the highest intensity of co-operation in all three areas. The likelihood of one or more co-operative arrangements existing in any one of the three major types for any one of the seven positions is 85.7 percent<sup>10</sup> for agrochemicals. At first glance, the intensities for basic chemicals and man-made fibers are somewhat surprising. These sectors of industry rely heavily on co-operative arrangements with universities, government labs, and other research institutes.

---

<sup>8</sup> It should be recognized that of the 1,938 firms, 34.9 percent provided no information. They are the "missing values." 28.2 percent said that they do apply such arrangements whereas 36.8 percent have no co-operation arrangements.

<sup>9</sup> Seven locations are distinguished. Inside Europe, these are: regional, national, E.C., and non-E.C. Outside Europe: U.S.A., Japan, and other.

<sup>10</sup> This overall percentage is not included in Table 5.7.

**Table 5.6 Percentage of Firms Utilizing R&D Co-operative Arrangements by Segment of Industry (percentages of the 8-country sample)**

Industry Segment (NACE)	Firm has Co-operation Arrangements on R&D		
	Yes	Number of Valid Cases	
	Percent	No. of Firms	
Basic Chemicals (24.1)	43.8	98	224
Agrochemicals (24.2)	52.6	9	19
Paints, Varnishes (24.3)	15.6	14	90
Pharmaceuticals (24.4.)	45.3	92	203
Soap and Detergents (24.5)	17.9	17	95
Other Chemical Products (24.6)	33.0	75	227
Man-Made Fibres (24.7)	33.3	9	27
Total No. of Firms		314	885
Total Percentage	35.5		100.0

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.	
	Percent	No. of Firms	Percent	No. of Firms	Percent	No. of Firms
Basic Chemicals (24.1)	17.6	15	23.1	9	71.8	61
Agrochemicals (24.2)	50.0	4	40.0	2	75.0	6
Paints, Varnishes (24.3)	0.0	0	33.3	2	50.0	7
Pharmaceuticals (24.4.)	31.4	16	20.0	5	66.7	34
Soap and Detergents (24.5)	12.5	2	0.0	0	50.0	8
Other Chemical Products (24.6)	12.7	9	12.5	2	64.8	46
Man-Made Fibres (24.7)	16.7	1	0.0	0	83.3	5
Firms with Specific Arrangement:						
- Percentage of Firms	18.7		20.6		66.5	
- Number of Firms		47		20		167

Note: The table counts by segment of industry the number of firms applying a specific co-operation arrangement. 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 concerning the extent of globalization of certain chemical companies can be drawn from the layouts of their annual reports, which, as a rule, present detailed accounts of regional developments (regions such as Europe, North America, Latin America and Asia). The trend towards globalization reveals itself in:

- corporate efforts to *achieve additional and increased rates of sales outside of 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 closer to major customers*, and/or *areas with more favorable R&D conditions* (such as the USA, in regards to gene technology).

The Swiss companies and ICI rank as the most geographically-diversified companies. Together, Ciba-Geigy and Sandoz account for approximately 40 percent of the total European sales and for about 30 percent of the North American ones. Solvay and Akzo 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 through acquisition, as was the case with the latest Hoechst acquisition. Hoechst purchased the American company, Marion Merrell, 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 developed in an even more dynamic manner than the foreign share of sales. The majority of the companies actively engaged in gene technology carry out their research in the USA, while numerous companies prefer to make Japan their location for material research. Apart from the legal framework, contact with leading academic research facilities in the respective fields is an important factor in the choice of R&D location.

Bayer, for instance, established their new pharmaceutical research center (Miles Laboratories) in West Haven (USA), while their new plant protection research center was built in Yuki (Japan). Although Europe, with 70 percent of total R&D expenditures, is still their strongest R&D location, Bayer plans to expand its US and Japanese facilities. 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 emphasizing photoresisters in the USA, while Japan is utilized as the best possible location for developing new liquid crystal systems for large screens. For ceramic superconductors, the company decided on Germany as their preferred location (Chemische Industrie 1/92, p. 38).

To test the trend of increasing globalization of markets, we once again used the CIS data (question 5, "objectives of innovation"). The firms chosen had all rated a presence in the global market as "very significant" or "crucial." We then grouped the firms according to the size of their annual sales. The following pattern emerges, as demonstrated in Table 5.8. Fifty to sixty percent of the small and medium sized firms view the creation of national markets as important, whereas for the largest firms (sales of more than 50 million ECU) only 40.6 percent perceive the importance of creating new national markets. For the creation of new markets within Europe, a U-shaped relationship holds--the smaller firms (64.9 percent) and the largest firms (59.4 percent) perceive this as an important objective. The range of the groups in between 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**

Despite the partially differing information in the corporate profiles, a few common features concerning corporate and innovative strategies can be established, particularly when CIS data is used to complement the study and serve as a measurement of regularities in the whole industry. It is obvious that the investigated companies operate under similar competitive conditions. The fact that the companies concentrate on certain mass products, thus rendering a strong market position, was particularly noticeable. All the companies studied are also involved with highly refined products.

This portion of the study clearly reflects the trends already established within the framework of the innovation counting approach. The strong shifting of sales shares from mass products to highly refined products indicates how drastically the companies carry out their restructuring processes. The annual reports confirm this and include many examples of capacity reductions concerning mass products. In the area of highly refined products, however, numerous acquisitions, some of them outside of Europe, were recorded. This demonstrates an increasing globalization of corporate activities. This globalization is further accelerated by the barriers to innovation prevalent in many European countries. How this is reflected in the CIS database will be investigated in detail in the next section.



**Table 5.8 Importance of the Globalization of Markets According to Firm Size (Based on the Objective "Creation of New Markets"; as a percentage of the 8-country sample, pharmaceutical industry excluded)**

Importance of Creating New Markets:	Size Group by Sales (thousand ECU)				
	1 (0-499)	2 (500-9,999)	3 (10,000-99,999)	4 (100,000-499,999)	5 (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 firms chosen had ranked the creation of new markets as "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.<sup>11</sup> The total number of firms classified (according to NACE 24) in the chemical industry is 1,938. These firms are ranked according to sales, employees, and R&D. They are distributed throughout the studied countries as follows (Table 6.3). The largest number of participants came from Italy (with 791) and the fewest from the U.K. (with nine firms). This large difference in participation should be kept in mind when examining the statistical results. According to Eurostat (1996, p.1), the data for 10 of the countries is comparable. Data from Greece, Portugal, and the U.K. is not comparable. The Greek and Portuguese data includes only information on those firms which undertook innovations and the number of U.K. firms is very small. Furthermore, some of the answers to CIS questions in the data for France are missing (such as the figures for R&D expenditures).

For the type of intra-industry analysis we are undertaking it is important to analyze the industry according to their main product groups. This is because firms engaged in innovative activities exhibit significant differences, which relate to these groups. Our analysis will focus on the comparison of the 13 countries and the seven product groups representing the major sectors of the chemical industry.<sup>12</sup>

### **6.2 Organizational Characteristics Effecting Innovation**

#### **6.2.1 Objectives of Innovation**

The objectives for innovative activity are important in two ways. First, they are part of the corporate strategy and they influence the way firms organize their innovation activities. Second, if environmental changes outside the firm require innovation by the firm, the preferences of employees may change, thus, the innovation objectives of the firm will also change.

---

<sup>11</sup> The latest Eurostat corrections regarding the CIS were dated March 7, 1996.

<sup>12</sup> Since the whole CIS venture might be regarded 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. For the intra-industry analysis, we use an 8-country sample including Belgium, Germany, Ireland, Italy, Luxembourg, the Netherlands, Norway, and the United Kingdom. Whenever data for France is available, we use a 9-country sample.

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

Country	Firm Size by 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 Industrial Sector**  
(in absolute numbers and percentages)

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 of the 3-digit NACE classification is smaller than the overall sample.

**Table 6.3 Descriptive Statistics for Sales, Employees, and R&D of the Firms in the CIS Sample by Country, 1992**

Country	BEL	DK	ESP	FR	GER	GR	IRL	ITL	LUX	NL	NOR	P	UK
<b>Sales in thousands of ECU</b>													
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
Sales per Employee	232	135	161	230	139	71	201	227	314	264	300	122	83
<b>Employees</b>													
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
<b>R&amp;D in thousands of ECU</b>													
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

Jewkes, Sawers, and Stillerman (1969) and other researchers interested in innovations<sup>13</sup> 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 firm's innovative effectiveness is neither cost nor the technical knowledge required. Rather, the main limitation seems to be the firm's ability to recognize needs and demands in their external environment. This ability (or inability) is determined by the firm's innovative objectives. 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 of firms in the chemical industry. We will also illustrate how these objectives vary across firms and across countries. The CIS (section III) provides a subjective evaluation of a firm's innovative objectives--ranging from 1, which refers to "Insignificant," to 5, for "Crucial." Possible objectives for innovation 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, in order to determine which objectives are the most important in which countries. To accomplish this, we use the same graphic ranking device which was applied by ZEW Mannheim in their analysis of the German innovation survey (see Felder, Harhoff, Licht, Nerlinger, and Stahl 1994).

To check the appropriateness of the items in the CIS, with respect to the objectives of innovation, we utilized factor analysis.<sup>14</sup> Table 6.4 indicates that the factor loadings, based on principal component analysis with a varimax rotation, exhibit a structure similar to the items 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 industrial sector. The factors were ranked, based on the overall mean for the variables of this factor. The ranking for all countries points to the "extension of local markets" as the most important bundle of innovation objectives. The black circles "•" indicate the three most important objectives and the white circles "o" the three least important ones. Increasing and maintaining market share is the crucial objective for innovative efforts in the European chemical industry. Of similar importance is the improvement of product quality by means of innovation. Creating new markets in Japan is the least important goal.

---

<sup>13</sup> See e.g. Albach (1994) for recent case studies concerning basic innovations and covering the importance of the organization for successful innovation.

<sup>14</sup> In a "nontechnical way," meaning that we will not report the statistical properties of the analysis and that we will extract more factors than should be extracted according to the Kaiser criterium. The Kaiser criterium limits the extraction to factors representing eigenvalues greater than 1. For values of 1 or less, the use of variables themselves is statistically more appropriate.

**Table 6.4 The Structure of the Objectives of Innovation**

Variable	Mean	Std.Dev.	Process Innovation incl. environmental issues	Opening up of Global Markets	Extension of Local Markets	Product Innovation	Product Diversification
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 the Objectives of Innovation by Countries**

	All Countries	BEL	DK	ESP	FR	GER	GR	IRL	ITL	LUX	NL	NOR	P	UK
<b>Extension of Local Markets</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>3</b>	<b>2</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>2</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>1</b>
Increasing or maintaining market share	●	●	●	●		●	●	●	●	●	●	●	●	●
Creating new markets: nationally				●			●							
Creating new markets: within the European Community														●
<b>Product Innovation</b>	<b>2</b>	<b>3</b>	<b>2</b>	<b>3</b>	<b>2</b>	<b>1</b>	-	<b>2</b>	<b>2</b>	<b>3</b>	<b>2</b>	<b>2</b>	<b>3</b>	<b>2</b>
Replace products being phased out				○										
Extend product range: within main product field	●			●	●	●		●			●	●		
<b>Process Innovation incl. environmental issues</b>	<b>3</b>	<b>2</b>	<b>3</b>	<b>2</b>	<b>4</b>	<b>3</b>	<b>2</b>	<b>3</b>	<b>3</b>	<b>1</b>	<b>3</b>	<b>3</b>	<b>2</b>	<b>3</b>
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													●	●
<b>Product Diversification</b>	<b>4</b>	<b>4</b>	<b>4</b>	<b>4</b>	<b>1</b>	<b>4</b>	-	<b>4</b>	<b>4</b>	<b>5</b>	<b>4</b>	<b>5</b>	<b>5</b>	<b>4</b>
Extend product range: outside main product field				○	●	○				○		○	○	
<b>Opening up of Global Markets</b>	<b>5</b>	<b>5</b>	<b>5</b>	-	<b>5</b>	<b>5</b>	-	<b>5</b>	<b>5</b>	<b>4</b>	<b>5</b>	<b>4</b>	<b>4</b>	<b>5</b>
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 black circles “●” indicate the three most important single objectives and the white circles “○” the three least important ones.



**Table 6.6 The Importance of the Objectives of Innovation by Sub-Sectors 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
<b>Extension of Local Markets</b> Increasing or maintaining market share Creating new markets: nationally Creating new markets: within the European Community	1 ●	1 ●	1 ●	1 ●	1 ●	1 ●	1 ●	1 ●
<b>Product Innovation</b> Replace products being phased out Extend product range: within main product field	2 ●	3 ●	2 ●	2 ●	2 ●	2 ●	2 ●	3 ●
<b>Process Innovation incl. environmental issues</b> 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	3 ○ ●	2 ○ ●	3 ○ ●	3 ● ●	3 ○ ●	3 ○ ●	3 ○ ●	2 ○ ●
<b>Product Diversification</b> Extend product range: outside main product field	4	4	4	4	4	4	4 ●	5 ○
<b>Opening up of Global Markets</b> in North America in Japan in other countries	5 ○ ○	5 ○ ○	5 ○ ○ ○	5 ○ ○ ○	5 ○ ○	5 ○ ○ ○	5 ○ ○	4 ○ ○

Note: The ranking of the objectives is based on the mean value of the respective cluster of objectives. 1 represents the highest ranking. The black circles “●” indicate the three most important single objectives and the white circles “○” the three least important ones.

One exception regarding this homogeneous goal structure is France. The French firms have the highest preference for using innovative effort in order to extend the product range outside of the main product field--i. e. product diversification. Closely related to the question of the objectives of innovation is the question of how firms observe their environment in order to pursue their innovation objectives.

### 6.2.2 *Information Sources*

There is general agreement that important information leading to innovation in the chemical industry has come from basic research in chemistry. This raises the question of whether one can isolate technology-push or demand-pull factors as the major source of innovation. Empirical research states that both are important. For example, the study by Freeman et al. (1968) of 810 innovative chemical processes provided evidence that the user was the source of information for 70 percent of these innovations, whereas only 30 percent of the ideas came from the innovating firm. Von Hippel (1988) developed his theory of the locus of innovation along similar lines--that the likelihood for the success of innovation increases when it is 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 shown in 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 labeled as "other firms."<sup>15</sup> The day-to-day business of innovation may have led to the fact that science-based sources are regarded as less important. This pattern is the same across countries, as well as for the industrial sectors. The greatest importance was attributed to the variable "internal sources from within the firm" (mean score 3.7). Second, was "clients and customers" with 3.4 and the least important source was "technical institutes" (1.8). We can conclude that the locus of innovation is most commonly found within the innovating firm, but that a second important locus is certainly the customer. The CIS data for the chemical industry emphasizes the importance of a network approach when studying the sources of innovation. This is also what one sees when observing the various arrangements used by firms in their R&D co-operations (see Section 5.1.4). Further use of the network approach might help firms overcome some of the barriers to innovation.

---

<sup>15</sup> We should have labeled this factor as "external sources non-science based."

**Table 6.7 The Structure of the 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: within 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 customers	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 the Sources of Information for Innovation by Countries**

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

Note: The ranking of the objectives is based on the mean value of the respective cluster of objectives. 1 represents the highest ranking. The black circles “●” indicate the three most important single objectives and the white circles “○” the three least important ones.

**Table 6.9 The Importance of the Sources of Information for Innovation by Chemical Industry Sub-Sectors**

	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
<b>Other firms</b>	<b>1</b>	<b>1</b>	<b>2</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>1</b>
Suppliers of materials and components	●		●	●		●	●	
Suppliers of equipment								
Clients or customers	●	●	●	●	●	●	●	●
Competitors in your line of business								●
Professional conferences, meetings, professional journals		●			●			
Fairs / exhibitions								
<b>Internal sources, Patent disclosures</b>	<b>2</b>	<b>2</b>	<b>1</b>	<b>2</b>	<b>2</b>	<b>2</b>	<b>2</b>	<b>2</b>
Within the enterprise	●	●	●	●	●	●	●	●
Within the group of enterprises					○			
Patent disclosures								
<b>Science</b>	<b>3</b>	<b>3</b>	<b>3</b>	<b>3</b>	<b>3</b>	<b>3</b>	<b>3</b>	<b>3</b>
Consultancy firms	○	○	○				○	
Universities / higher education				○		○		○
Government laboratories	○	○	○	○	○	○	○	○
Technical institutes	○	○	○	○	○	○	○	○

Note: The ranking of the objectives is based on the mean value of the respective cluster of objectives. 1 represents the highest ranking. The black circles “●” indicate the three most important single objectives and the white circles “○” the three least important ones.

### 6.2.3 *Barriers to Innovation*

This section is devoted to identifying the major factors impeding innovative activity, both at the firm and country levels. Section VI of the CIS evaluates the subjective responses relating to “Factors Hampering Innovation” on a scale of 1-5. Possible factors range from economic factors, including “excessive perceived risk” and “lack of appropriate sources of funding,” 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 utilize a 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,

$\beta$  is the estimated coefficient, and

$\varepsilon$  is the stochastic disturbance, with an expected value of 0 and variance of  $\sigma^2$ .

After having checked the CIS data and run the first regressions, we recognized that the variation in the data was too small to use regression analysis in the first place. This led us to apply factor analysis, once again, in order to gain a further understanding of the structure of the impediments and factors hampering innovation. 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 to clarify 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 industrial sectors is illustrated in Tables 6.11 and 6.12. The difference between firms located in the various European countries, except for Luxembourg, is minimal. For France, no data is available. The picture becomes even clearer if we analyze by industrial sectors. 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 for the single variables are located nearer to “3,” which implies a “moderately significant” barrier to innovation.

**Table 6.10 The Structure of Factors Hampering Innovation**

Variable	Mean	Std.Dev.	Internal Implementation Risk	Financial Risk and Lack of Capital	Competitive 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 innovation potential too small	2.118	1.126	0.723	0.315	-0.006	0.207	0.199	0.068
Lack of skilled personnel	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 the availability 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 technological 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, regulations, standards, taxation	2.091	1.263	0.152	0.269	0.732	0.305	0.089	0.111
Lack of customer responsiveness 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
<b>Financial Risk and Lack of Capital</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>1</b>	-	<b>1</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>2</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>1</b>
Excessive perceived risk		●				●					●	●		●
Lack of appropriate sources of finance	●		●	●			●		●				●	●
Innovation costs too high	●	●	●	●		●	●	●	●		●	●	●	
Pay-off period of innovation too long	●	●	●	●				●	●		●			
<b>Internal Implementation Risk</b>	<b>3</b>	<b>3</b>	<b>2</b>	<b>3</b>	-	<b>4</b>	<b>3</b>	<b>2</b>	<b>3</b>	<b>3</b>	<b>2</b>	<b>3</b>	<b>2</b>	<b>2</b>
Enterprise's innovation potential too small								●		●		●	○	●
Lack of skilled personnel										●			●	
Lack of information concerning technologies										○				
Lack of information concerning markets		○				○								
Innovation too hard to control							○						○	
Resistance to change in the enterprise	○		○	○		○	○		○			○	○	
<b>Competitive Risk</b>	<b>2</b>	<b>2</b>	<b>3</b>	<b>4</b>	-	<b>2</b>	<b>2</b>	<b>3</b>	<b>2</b>	<b>4</b>	<b>3</b>	<b>6</b>	-	<b>3</b>
Innovation too easy to copy								○		○				○
Legislation, norms, regulations, standards, taxation						●	●					○		
Lack of customer responsiveness to new products and processes														
Uncertainty in timing of innovation														
<b>Lack of Opportunities for Co-operation and Technical Service</b>	<b>4</b>	<b>5</b>	<b>5</b>	<b>2</b>	-	<b>5</b>	<b>4</b>	<b>5</b>	<b>4</b>	<b>6</b>	<b>3</b>	<b>4</b>	-	<b>5</b>
- Deficiencies in the availability of external technical services		○	○				○	○		○		○		○
- Lack of opportunities for cooperation with other firms and technological institutes						○								
<b>Lack of Technological Opportunities</b>	<b>5</b>	<b>4</b>	<b>4</b>	<b>6</b>	-	<b>3</b>	-	<b>4</b>	<b>5</b>	<b>3</b>	<b>3</b>	<b>2</b>	<b>3</b>	<b>3</b>
Lack of technological opportunities	○			○					○				○	
<b>First-Mover Impediment</b>	<b>6</b>	<b>6</b>	<b>6</b>	<b>5</b>	-	-	-	<b>5</b>	<b>6</b>	<b>1</b>	-	<b>5</b>	-	<b>6</b>
No need to innovate due to earlier innovations	○	○	○	○				○	○	●				○

Note: The ranking of the objectives is based on the mean value of the respective cluster of objectives. 1 represents the highest ranking. The black circles "●" indicate the three most important single objectives and the white circles "○" 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 The Importance of Factors Hampering Innovation by Chemical Industry Sub-Sectors**

	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
<b>Financial Risk and Lack of Capital</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>1</b>
Excessive perceived risk								
Lack of appropriate sources of finance	●	●	●	●	●	●		●
Innovation costs too high	●	●	●	●	●	●	●	●
Pay-off period of innovation too long	●	●	●	●	●	●	●	●
<b>Internal Implementation Risk</b>	<b>2</b>	<b>3</b>	<b>2</b>	<b>3</b>	<b>3</b>	<b>3</b>	<b>2</b>	<b>4</b>
Enterprise's innovation potential too small							●	
Lack of skilled personnel								
Lack of information concerning technologies				○		○		
Lack of information concerning markets								
Innovation too hard to control								
Resistance to change in the enterprise		○		○		○		○
<b>Competitive Risk</b>	<b>3</b>	<b>2</b>	<b>4</b>	<b>2</b>	<b>2</b>	<b>2</b>	<b>3</b>	<b>2</b>
Innovation too easy to copy			○					
Legislation, norms, regulations, standards, taxation								
Lack of customer responsiveness to new products and processes			○		○			
Uncertainty in timing of innovation								
<b>Lack of Opportunities for Co-operation and Technical Service</b>	<b>5</b>	<b>5</b>	<b>3</b>	<b>5</b>	<b>4</b>	<b>5</b>	<b>4</b>	<b>5</b>
- Deficiencies in the availability of external technical services	○	○						
- Lack of opportunities for cooperation with other firms and technological institutes							○	○
<b>First-Mover Impediment</b>	<b>6</b>	<b>6</b>	<b>6</b>	<b>6</b>	<b>6</b>	<b>6</b>	<b>6</b>	<b>6</b>
No need to innovate due to earlier innovations	○	○		○	○	○	○	○
<b>Lack of Technological Opportunities</b>	<b>4</b>	<b>4</b>	<b>5</b>	<b>4</b>	<b>5</b>	<b>4</b>	<b>5</b>	<b>3</b>
Lack of technological opportunities	○		○		○		○	

Note: The ranking of the objectives is based on the mean value of the respective cluster of objectives. 1 represents the highest ranking. The black circles “●” indicate the three most important single objectives and the white circles “○” the three least important ones.

“Innovation cost too 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 barriers to innovation in the chemical industry. High cost might be attributed to an entire range of items involving various degrees of innovation cost, but this factor particularly effects R&D efforts when it comes to more radical innovations. If this is matched by a lack of financial capital, then both factors, regardless of the prospective profitability of the innovation, might prove insurmountable. This result clearly demands some policy considerations.

## **6.3 Innovative Performance**

### ***6.3.1 Measuring Innovative Activity***

The CIS further identifies some of the input and output factors concerning the innovative activities of firms. The following measurements<sup>16</sup> are of interest to this study:

- Whether the 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. The outputs of incrementally- to radically-changed products and the amount of sales 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, such as technological competence, market opportunities, and the opportunity to appropriate returns. These factors cannot be isolated by simply comparing the share of innovators to non-innovators in our sample. As seen from Table 6.13, which shows the percentage of product innovators per country, there are significant differences. These are probably due to the specificities of the country samples and to a measurement bias resulting from the short reporting period (1990-1992). Since Table 6.13 also illustrates the share of firms with process innovations--which is highly correlated with the product innovations--we expect that there is also a country bias.

---

<sup>16</sup> The other pertinent information regarding R&D strategies and technological co-operation was already analyzed in Chapter 5.

**Table 6.13 Descriptive Statistics for Innovation, R&D, and Investment by Country, Sub-Sector, and Firm Size  
(Unweighted mean values of intensities and shares of firms in percent)**

	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 for the Next 3 Years	Product Innovators (Definition see note below.)	Process Innovators
<b>Country</b>										
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	-	-	-
Ireland	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	43.1	49.4
<b>Industrial Sector</b>										
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
<b>Firm Size (Employees)</b>										
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 industrial sector: 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 the case of R&D, there are 931 innovating firms and 1007 non-innovators ("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.

**DEFINITIONS:** Product Innovator = Its percentage of total sales from incrementally and significantly changed products is 30 percent (or more).

Process Innovator = Its percentage of total R&D expenditures allocated to process innovation is 25 percent or more.

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

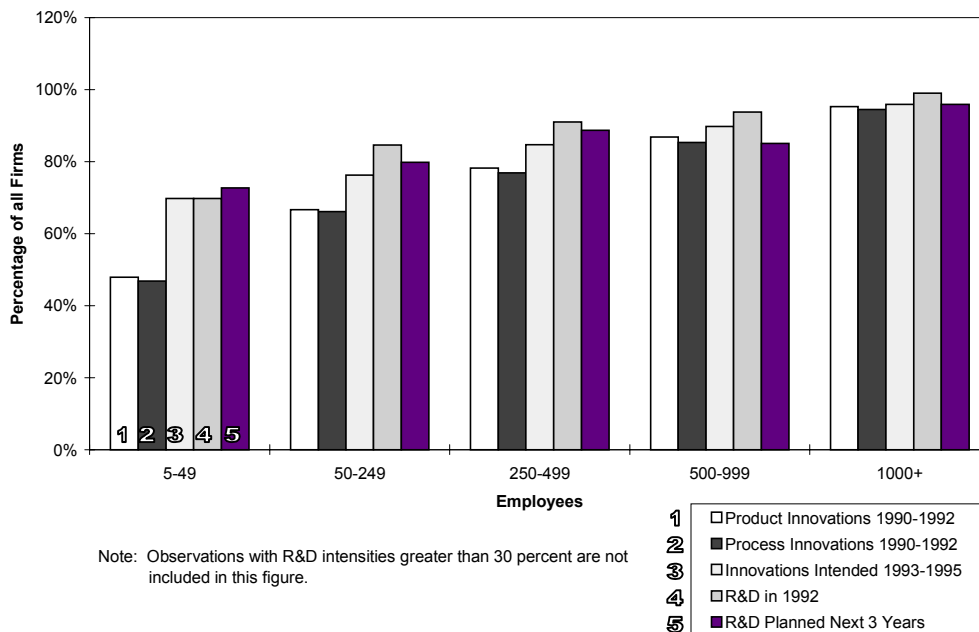
	Share of Total Sales				
Country	(Stages of the Product Life Cycle)				No. of Observations
	Introduction	Growth	Maturity	Decline	
Belgium	8	11	26	55	64
Denmark	10	17	30	43	35
France	-	-	-	-	-
Germany	13	15	25	47	120
Greece	5	17	27	51	21
Ireland	10	11	29	49	80
Italy	8	10	23	59	380
Luxembourg	3	14	36	48	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)					
<b>Segment</b>					
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
<b>Firm Size (Employees)</b>					
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.

We could not include the Greek and Portuguese firms because the only firms which were included in the survey of these countries were the innovative firms. Due to the small sample size, observations from Luxembourg and the U.K. are also excluded. The table shows Italy with the lowest share of innovating firms (47.7 percent). This is probably due to Italy's large sample size (791 firms, which is 40.8 percent of the entire sample) and the dominance of the 347 small firms with 5 to 49 employees.<sup>17</sup> The country with the next lowest share of product innovators was France (62.6 percent). The largest share of innovators were found for Denmark (89.7 percent) and Germany (89.9 percent).

Figure 6.1 shows the observed average share for innovators. The left bar represents the share of firms which introduced product innovations in the period 1990-1992. Only half of the small firms (with 5 to 49 employees) reported having developed an innovation. The share of innovators increases significantly (to 68 percent) with firms having 50 to 499 employees. The share converges to about 95 percent of the firms being innovators in the size group of 1,000 employees or more and the largest firms are all innovators.

**Figure 6.1 Firms Involved in R&D and Innovation (as a Percentage of all Chemical Firms in 13 European Countries, 1992)**



<sup>17</sup> 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).

A different picture emerges when analyzing the distribution of innovating firms by industrial sector. The variation among the sectors is quite small. The size effect is somehow equalized when applying a distribution according to the various sectors of the industry. The highest shares are agrochemicals and other chemical products.

Whether innovative activities are planned for the next three years is shown as the third bar (Innovation Intended 1993-1995) in the figure. The share shown in this table is actually lower for some countries and higher for others than the realized values (shown in Table 6.13), as these were estimated innovations. Significantly more innovations are to be 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 the totals spent on the various stages involved in the process of product innovation. The CIS includes the following activities in this process: R&D; acquisition of patents and licenses; product design; trial production, training and tooling-up; market analysis (excluding launch costs), and other activities. This definition is taken from the OSLO-Manual (OECD 1992). Previous research used a more restrictive definition, which focused on applied research and development expenditures. The CIS data allows one to single out and identify the importance of the expenditures allocated to each stage of the innovation process.

The analysis of R&D effort plays a crucial role in economic analysis.<sup>18</sup> The most common hypothesis in these studies is: that more important innovations require (on average) a larger share of innovation costs allocated for R&D than less important innovations. A second hypothesis states that: larger firms devote a greater percentage of their total innovation costs to R&D than smaller firms. And a third assumption is: that the more experienced firms become with R&D, the greater the likelihood that they will learn and, thus, become more efficient. From this assumption, one would expect experienced firms to use a smaller share of their innovation expenditures for R&D.

The overall picture is illustrated in Figure 6.2. This figure allows one to compare intensities of innovation, R&D and investment (expenditures as a percentage of total sales). The innovation intensity is the highest for firms with 500 to 999 employees. For every other size category, including firms with 1,000 or more employees, the innovation intensity is lower. With R&D intensities, the pattern is different. The R&D intensity of the largest firms is the highest. Structural differences, with respect to industrial sectors, become clear in Figure 6.3. The similarity in the pattern of “innovation-R&D-investment intensity” for the agrochemical and the pharmaceutical sectors are obvious

---

<sup>18</sup> For an overview of empirical research on R&D, see Cohen and Levin (1989). For detailed analysis of the distributions of R&D expenditures in various US industries, see Cohen and Klepper (1992).

but the magnitude is different. In comparison, the R&D intensity is twice as large for the pharmaceutical sector. As was expected, the investment intensity for man-made fibers proved to be the highest in the industry, 50 percent higher than that of the pharmaceutical sector.

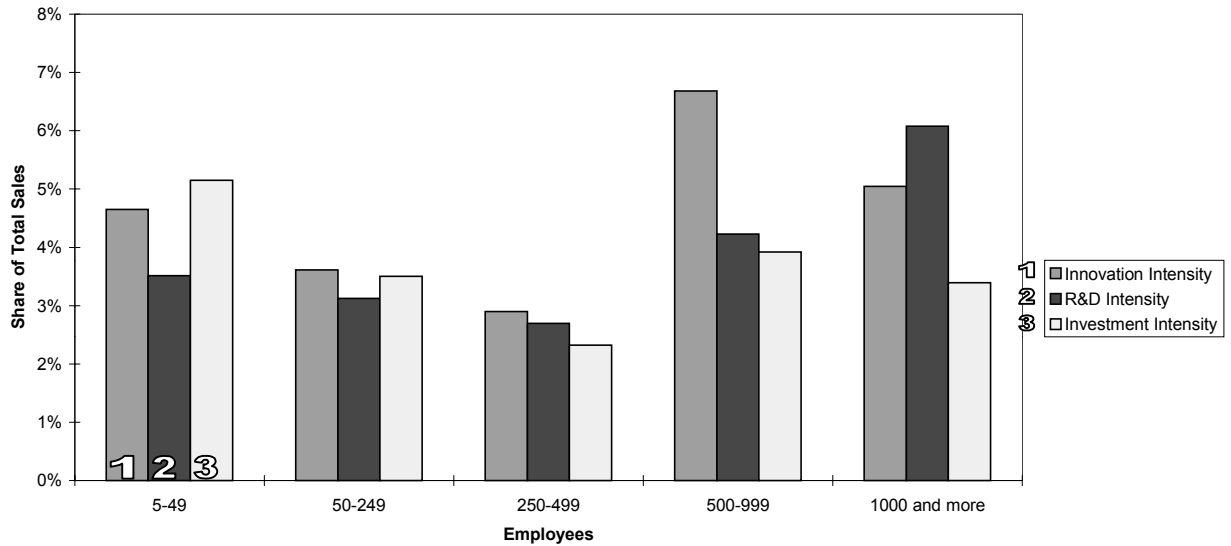
How the particular components of innovation expenditures vary according to firm size is shown in Figure 6.4. Again, we see that the R&D share of innovation expenditures increases with firm size. It is nearly twice as large for the largest firms as for the smallest firms. But, for the small firms the category “other innovation expenditures” is about 18 percent of total expenditures--which is much higher than in larger firms.

Figure 6.5 provides a comparison of the structure of innovation expenditures related to industrial sectors. The highest R&D percentages are in agrochemicals and paints and varnishes. There are considerable sector differences noticeable in the resources devoted to product design, trial production, training and tooling-up.

### ***6.3.3 Comparison of Innovative Performance***

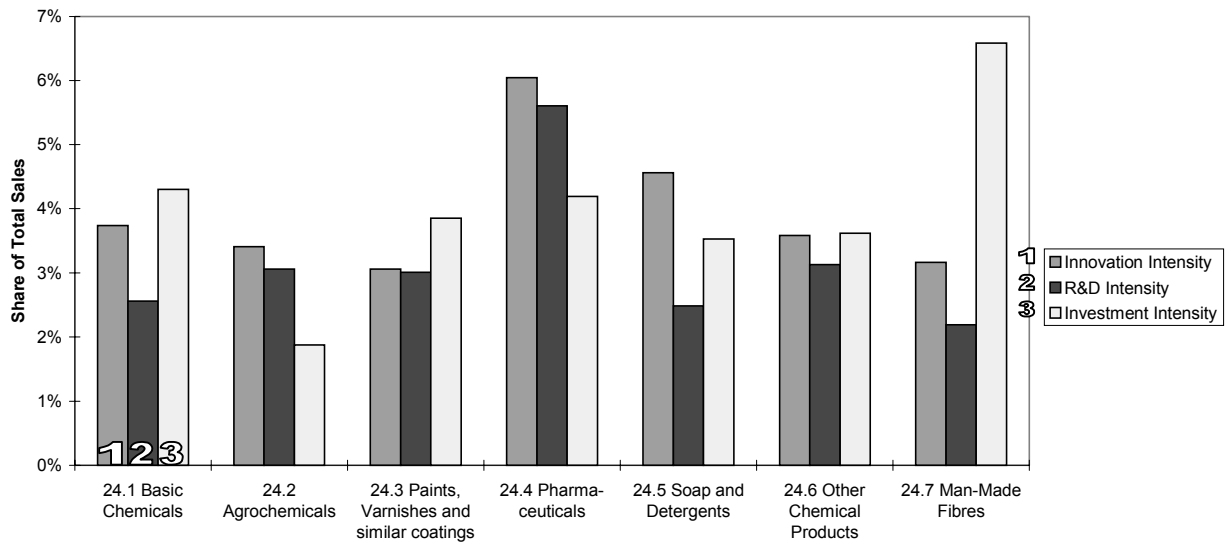
The CIS does not include any particular measure of innovative through-put (such as the number of patents applied for or the stock of patents). It also does not include information concerning the number of new products introduced into the market. Finally, it lacks information concerning profitability. As a result, this study focuses on innovative outputs involving incrementally and radically changed products, and the sales produced by these products. For this, we use the 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 are categorized, 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.

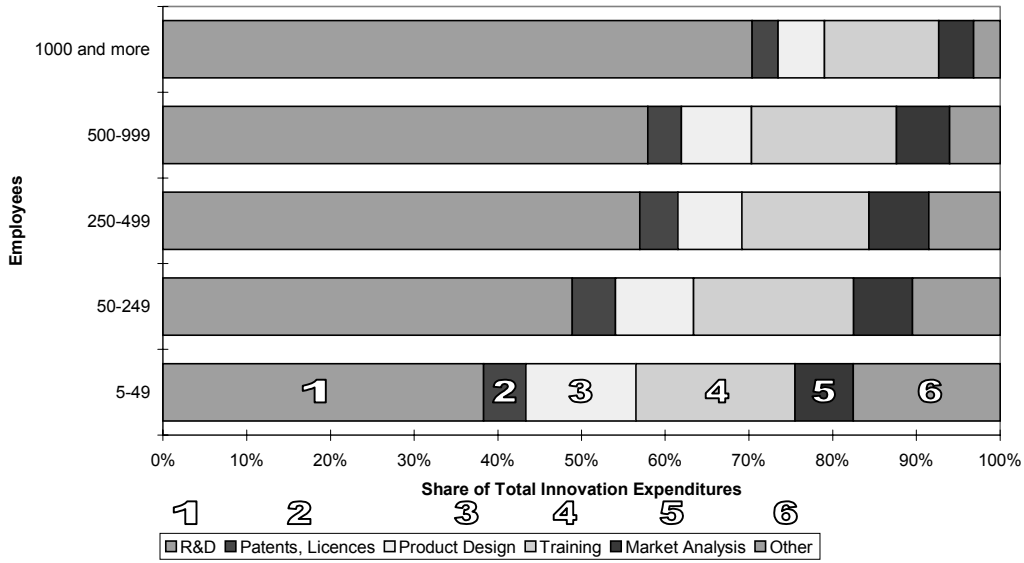
**Figure 6.3 Innovation Intensity, R&D Intensity and Investment Intensity by Segments of the European Chemical Industry for 8 Countries**



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.

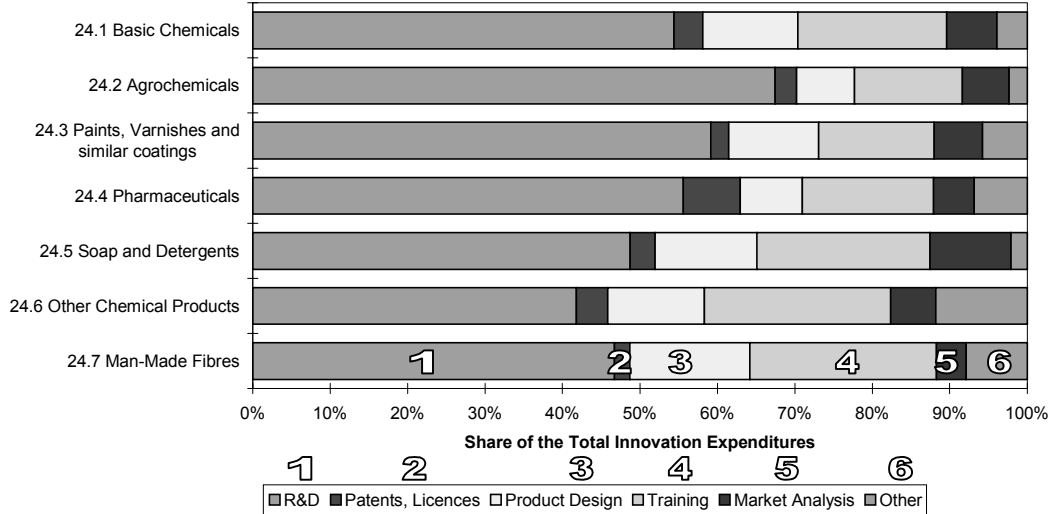


**Figure 6.4 Components of Innovation Expenditures by Firm Size for Chemical Firms in 13 European Countries**



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

**Figure 6.5: Components of Innovation Expenditures by Sub-Sectors 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 the 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 the 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 (when compared to innovative output). This became clear in the work by Acs and Audretsch (1987; 1988; and 1990), who found that in certain industries small firms can be as innovative as their larger counterparts. Although their analyses were undertaken at the aggregate industry level, the results cast some doubts on the central, but virtually untested, proposition that scale economies exist for R&D related to innovation.

**R&D and Innovation** The purpose of this section of the study is to analyze the CIS measurements concerning innovative sales output at the firm level to determine whether scale economies exist for the R&D input-output relationship 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, by using two measurements of innovative output,<sup>19</sup> and a large and homogeneous sampling of firms, these measurement issues should resolve themselves.

The first step in answering the question of whether scale economies exist for R&D in regards to innovative output, is to utilize a simple production function relationship of the type used by Bound et al. (1984):

$$NPS = aRD^{\beta_1}$$

where NPS is the sales due to significantly changed products introduced in 1990-1992 (“new product sales”) and RD is the firm’s expenditure on R&D. For the linear regression, the logarithmic values<sup>20</sup> are used, that is:

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

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

(25.78) (27.25)

---

<sup>19</sup> These measures are: (1) the sales share of significantly changed products, and (2) the sales share of incrementally and significantly changed products.

<sup>20</sup> We use the natural logarithm (ln) whereas Bound et al. (1984) apply the logarithm at basis 10 (lg). They are equivalent,  $\ln N = 2.30259 \lg N$ . 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 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 somewhat different from the elasticities for R&D and patents estimated by Bound et al. (1984. Based on 2582 firms and ranging from 0.32 to 0.38 ).

The range of elasticities for the various sectors of the industry is smaller (see Table 6.15). The values range from 0.49 for man-made fibers to 0.73 for paints and varnishes (i. e. 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 from 0.23 to 0.32 for the whole industry. The size effect has an impact on the estimations. The broader the size range, the steeper the slope of the estimated relationship and the higher the estimated elasticity. This is because the sums of R&D spent by larger firms are much higher than those spent by smaller firms. A second consideration is based on spillover effects. One could argue--in cases where spillover effects are observed in the entire industry--that the most reasonable estimation of elasticities is for the whole industry. This estimation would then capture all of the possible spillover effects. On the other hand, the estimations for more homogeneous groups lack consideration of spillover effects and, thus, their elasticities are significantly lower.

**Firm Size and Innovation** As Baldwin and Scott (1987) confirm in their review of the literature, a plethora of studies examining the relationship between firm size and R&D effort exists.<sup>21</sup> Work by Bound et al. (1984) indicates that expenditures on R&D increase proportionately with firm sales. Soete (1979) found that R&D increases more than proportionately with firm sales. No one has found that this relationship is anything less than proportional. However, as in the case of studies examining the relationship between innovative outputs and inputs, the lack of meaningful data has hindered researchers in estimating the relationship between firm size and innovative output. Thus, it remains to be empirically answered: To what extent does innovative activity increase or decrease with firm size?

---

<sup>21</sup> 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 Industry (Including Pharmaceuticals)**

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 Chemical Industry Sub-Sectors

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 Industry (Including Pharmaceuticals)**

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.

Again, we follow the example of Bound et al. (1984)<sup>22</sup> in providing an initial approximation of the relationship between firm size (as measured by ECU thousands of sales--SAL) and the innovative output (measured as new product sales). The estimated function for the entire sample of firms from the chemical industry is:

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

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

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

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

Table 6.17 shows the estimated elasticities of innovative output with respect to firm size by country and by industrial sector. The values for Portugal are much lower than unity 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 is reasonable to assume that innovative activity does increase proportionately with firm size.

With respect to industrial sectors, a less than proportionate increase with size is observed for the manufacture of basic chemicals. This is plausible due to the limited opportunities in this sector. On the other hand, we find a more than proportionate increase with size measured by employees for the agrochemical sector. This is also reasonable because this sector is confronted with an increasing number of opportunities to innovate when firm size increases.

---

<sup>22</sup> See also Schwartzman (1976) for an estimation of elasticities for the pharmaceutical industry. His equation includes also the term  $(\ln \text{size})^2$  which allows one 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 Chemical Industry Sub-Sector**

Country <sup>1)</sup>	Size Elasticity		$\bar{R}^2$ emp	$\bar{R}^2$ sal	N
	Employees	Sales			
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
Netherlands	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) <sup>2)</sup>					
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: <sup>1)</sup> All coefficients are significant at  $p < 0.0001$ , except the U. K. with  $p = 0.002$ .

<sup>2)</sup> All coefficients are significant at  $p < 0.0001$ .



### 6.3.3.2 Estimation of Returns to R&D

Further insights with respect to the returns of R&D might be achieved through the estimation of a linear and quadratic relationship. Some authors use an additional cubic term. For statistical reasons and because of problems 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 to problems of autocorrelation. The interpretation of the cubic term would require checking each individual function for turning point. For these two reasons we have estimated the following model:

$$\text{NPS} = a + b \text{RD} + c \text{RD}^2 .$$

For the dependent variable we used only one measure of innovative output--the one for significant product innovations. Using the sum of sales due to incremental and significant product innovations would have led to less discrimination between innovators and non-innovators. Table 6.18 shows the estimated coefficients for the countries and the chemical industry as a whole, including pharmaceutical firms. Based on the returns to scale of R&D, 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 the 134 firms in the German sample, there is evidence of increasing returns to scale in R&D. No conclusive evidence was found for Belgium, Denmark, and Portugal.

Table 6.19 shows the returns to scale in R&D for the various sectors of the chemical industry. We find no conclusive evidence for the manufacture of man-made fibers and for agrochemicals. The returns for all other sectors 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 for this one exception, there is no evidence of increasing returns for R&D expenditures related to producing innovative output. Rather, our empirical results for the European chemical industry suggest, with the one exception, that diminishing returns to R&D are the rule. Thus, while larger firms undertake a greater effort towards R&D, each additional ECU of R&D is found to yield less in terms of innovative output. Therefore, it is reasonable to determine whether we can find differences distinguishing innovators from 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.  
Firms with R&D Intensities greater than 30 percent are excluded.)

Country	RD	RD2	Constant	R2	F	n
<u>Decreasing Returns</u>						
Italy	2.516 (7.472) [0.0000]	-2.577*10 <sup>-5</sup> (-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 <sup>-6</sup> (-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 <sup>-4</sup> (-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 <sup>-4</sup> (-2.925) [0.0049]	2455.4 (1.405) [0.1654]	0.228	9.744 [0.0002]	60
Norway	4.680 (4.473) [0.0006]	-9.084*10 <sup>-5</sup> (-4.538) [0.0006]	2330.2 (0.656) [0.5235]	0.554	10.313 [0.0021]	16
<u>Increasing Returns</u>						
Germany	1.036 (3.457) [0.0007]	1.936*10 <sup>-6</sup> (6.007) [0.0000]	17151.9 (2.211) [0.0287]	0.896	577.022 [0.0000]	134
<u>No Conclusive Evidence</u>						
Belgium	-4.831 (-1.285) [0.2048]	9.861*10 <sup>-5</sup> (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 <sup>-6</sup> (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.  
Firms with R&D Intensities greater than 30 percent are excluded.)

Industry	RD	RD2	Constant	R2	F	n
<u>Decreasing Returns</u>						
24 Chemical Industry (without Pharmaceuticals)	3.945 (13.666) [0.0000]	-1.069*10 <sup>-6</sup> (-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 <sup>-5</sup> (-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 <sup>-4</sup> (-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 <sup>-6</sup> (-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 <sup>-4</sup> (-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 <sup>-6</sup> (-7.168) [0.0000]	769.2 (0.235) [0.8142]	0.966	2541.039 [0.0000]	177
<u>No conclusive Evidence</u>						
24.2 Agrochemicals	0.492 (0.180) [n.s.]	-3.956*10 <sup>-4</sup> (-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 <sup>-5</sup> (0.064) [0.9494]	6505.4 (1.495) [0.1498]	0.228	4.411 [0.0251]	24

Note: The following countries are included 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 truly remarkable. It is important to determine whether such development will continue and to assess which factors might influenced future innovative behavior. One question of particular significance is: How can a firm in a scientific and technology-based industry build and maintain its capabilities? Despite the fact that the CIS data provides no information concerning individual innovations and recognizing the limitations of the CIS survey data, we, nevertheless, examine the relationship between the important characteristics of firms in the chemical industry and their innovative behavior.

Although this is not the place for a critical examination of the literature concerning 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).<sup>23</sup> The separate studies were undertaken by Mueller (1962) and by Hollander (1965). Mueller analyzed 25 of Du Pont's most important product and process innovations made between 1920 and 1950. These innovations accounted for about 45 percent of the company's sales. Mueller found that only five of the 18 new products could be credited to Du Pont (Du Pont was a co-inventor for one other). 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 for Du Pont, but also (with some qualifications) for the nine large European firms we have analyzed 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” (Mueller 1962, p. 346, as quoted according to Hounshell 1995, p. 176).

---

<sup>23</sup> These studies are: W.F. Mueller (1962), *The Origins of the Basic Inventions Underlying Du Pont's Major Product and Process Innovations, 1920-1950*; and S. Hollander (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).

Mueller also raised the issue of 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 reasonably 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" (Mueller 1962, p. 346, quoting Nelson 1959; quoted according to Hounshell 1995, p. 176).

Another provoking finding was put forward by Hollander (1965). While looking for the sources of increased production efficiency in Du Pont's manufacture 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 Du Pont's industrial R&D did not contribute as much to technological change 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 as they argued for the massive funding of basic research. They are interesting, nevertheless, because they shed some light on the uncertainties involved with R&D. 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) studied individual and co-operative R&D decisions as examples of feedback processes concerning market structures and firm behavior. This is important because firms today are increasingly deciding to coordinate their R&D activities with their potential rivals. Furthermore, in Europe and in the USA, anti-trust authorities tend to treat these co-operative agreements favorably. Whether to extend this favorable treatment to R&D agreements which provide joint exploitation of the results is also being discussed. There is still little empirical evidence or theoretical knowledge, however, concerning these relationships within the chemical industry.

Our study is also interested in the theoretical work by Rosenkranz (1995, 1996) concerning the simultaneous choice of process and product innovation. She shows how the optimal division between these two kinds of R&D activities changes with market size. The higher is the 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 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 Rosenkranz is that welfare is increased if firms coordinate their research activities and share R&D costs. When firms co-operate but do

not share their R&D costs, welfare is only enhanced if product innovations are not too expensive.

This discussion suggests that is important for firms in the European chemical industry to explore the possibilities of coordinating their research efforts and, if possible, share R&D costs. Furthermore, a firm's strategic formulation determines how the firm will allocate its R&D budget between product and process innovation activities. This is not the place to provide further details on these issues, but attention should be paid to studies which discuss the relative importance of firm characteristics and technological innovations (see e.g. Albach 1994). Questions concerning what kinds of firms, under what conditions, produce what product and process innovations still need to be answered. What are the characteristics which affect strategic formulation and thereby determine a firm's innovative behavior? In order to explore these questions, we will use a simple logit regression model to estimate the likelihood of a firm being either a product innovator or a process innovator.

**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, with the variable being 1, when the share of total sales from incrementally and significantly changed products is 30 percent (or more). The variable is equal to 0 when the share is less than 30 percent.

The firm is defined as being a process innovator, with the dependent variable being 1, when the percentage of total R&D expenditures allocated to process innovation is 25 percent or more. If the percentage 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. The first variable is the perceived importance of the objective of innovation--i. e. the importance attributed to product improvement through innovation. The second variable measures commitment to competition. If a firm regards lead time advantage over competitors as important, 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 this purpose, a measurement of the barriers to innovation is used, namely, the role of excessive perceived risk related to a product innovation.

We assumed that a very strong orientation towards competition would characterize best the process innovators. We expected findings concerning price-volume competition, since this can only be achieved via process innovations. The most appropriate CIS variable to proxy this is the inclination to create new markets in Japan. We would expect this to be an important characteristic of a process innovator, since this is a domain of the Japanese and other Asian rivals in global competition. Furthermore, we

expected an economical use of resources as an important determinant for being a process innovator. We thought the reduction of energy consumption must be an important objective for the chemical industry. This seems to be a rational strategy when the pay-off period of an innovation is expected to be too long to approach a situation via the use of a process innovation. A relationship is assumed to exist between the attitude of regarding a pay-off period as too long and the use of process innovation to compensate for this. The risk involved in the imitation of product innovations would reduce the likelihood of the use of process innovations, i. e. in cases where an innovation is easy to copy, it is regarded as crucial for the firm (to a lesser extent) to be a process innovator.

To test the impact of the resources committed to product and process innovation, we include innovative intensity. This is reasonable because it measures the overall commitment of the firm towards both product and process innovation. A similar argument can be made concerning the export intensity of a firm. The higher the export intensity of a firm is, the more committed it is to innovation and to competition. Export intensity is measured as the percentage of exports divided by sales.

The results from our models appear in Table 6.20. The product innovator model provided strong support for the view that a commitment to product innovation and an awareness of the risks involved increases the likelihood of being a successful product innovator. A commitment to improving product quality particularly increases the probability of being a successful product innovator. Innovation intensity was not found to be significant, nor was export intensity as measured by the export share.

The process innovator model supports the view that emphasis on competition and competing 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. When product innovations are easy to copy, the probability for process innovation decreases. While the innovation intensity is not significant, the export intensity is. The more a firm pursues an export strategy, the higher the likelihood of being a process innovator.

The two models are different in character. This is because of differences in the properties of each particular type of innovation. The patterns found here imply that models of innovation strategy have to make a clear distinction between product and process innovation, to stress the importance of uncertainty related to innovation, and to consider the role of competition. However, the CIS data are too crude to be definitive on these points. Further theoretical and empirical work on innovation processes in the chemical industry is certainly needed.

**Table 6.20 Logit Regression Estimates for Product and Process Innovators in the European Chemical Industry (Including Pharmaceuticals)**

Variable	Type of Innovator	
	PRODUCT INNOVATOR	PROCESS INNOVATOR
Improving product quality ( <i>objective of innovation, v5_17</i> )	0.466 (0.000)	
Effectiveness of having lead time over competitors ( <i>effectiveness of methods, v9a_5</i> )	0.159 (0.052)	
Excessive perceived risk ( <i>innovation barrier, v12_1</i> )	0.140 (0.091)	
Creating new markets: in Japan ( <i>objective of innovation, v5_8</i> )		0.247 (0.005)
Reducing energy consumption ( <i>objective of innovation, v5_13</i> )		0.309 (0.000)
Pay-off period of innovation too long ( <i>innovation barrier, v12_4</i> )		0.120 (0.091)
Innovation too easy to copy ( <i>innovation barrier, v12_15</i> )		-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 from incrementally and significantly changed products is 30 percent or more and equal to 0 when the share is 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 or higher (CIS question 10c\_2) and equal 0 when the share is less than 25 percent.



## 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 utilized was gathered from the annual reports of nine major European chemical companies. Additional data from the Community Innovation Survey (CIS) were used to describe and explain the differences in innovative performance across firms within the European chemical industry. This novel methodological approach of combining two different databases for the study of innovative behavior in the chemical industry seems to be very promising.

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

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

The overall plausibility of the results of the quantitative investigation proves that annual reports are suitable as a base for such an investigation. The study was also able to confirm certain statements regarding various life cycle models. Life cycle models are one of the few practically-orientated approaches available to innovation research.

The qualitative investigation found numerous similarities prevailing in the contemporary corporate and innovative strategies utilized by Europe's chemical companies. Especially noticeable, is the attempt to increase the sales share of highly refined products. The strategies described in Chapter 5 are of special importance. They are decisive for future innovative trends and, thus, for the future of the chemical industry in Europe. The CIS database provided further evidence for the following trends:

1. Increasing efforts to apply strategies of cost leadership. This is particularly evident for mass products, such as basic chemicals. Cost leadership strategies are becoming more feasible as restructuring within the basic chemical sector has concentrated on cost cuts. Since 1991, employment in this sector has been reduced by 255,000--a reduction of 14 percent.
2. Increasing tendencies towards specialization in certain product areas, which relates to Trend 1. For large firms, we see attempts to acquire large market shares in relatively

few products. The CIS data concerning the allocation of R&D expenditures for product and process innovation highlights the close interrelationship between these two corporate strategies: cost leadership and specialization.

3. Almost every annual report in this study assigned a central role to increased concentration on key areas and/or key competencies. The goal is the achievement of a strong market position and the ability to focus on areas with a high synergistic effect.
4. Increasing strategic co-operation in the areas of production and R&D. Co-operation allows firms to enter new markets, to shorten innovative periods, and to recognize technological potential at an earlier stage. The findings of the analysis of the annual reports are supported by the CIS data (although, we were not able to evaluate the quality of the co-operative arrangements and had to rely on quantitative data).
5. A continuing trend towards globalization. The analysis of the annual reports suggests a significant level of globalization. The reports give detailed accounts of regional developments (such as in Europe, North America, Latin America and Asia). The large chemical firms studied are able to compensate for a lack of opportunities within Europe by simply operating on an international level. The CIS data supported this observation, at least for the European market. One interesting result of this is that a U-shaped relationship holds for the creation of new markets within Europe--it is important for 60 percent of the smaller firms and all of the largest firms, but not so important for the medium-sized firms.

Our detailed analysis of the CIS database has shown a number of similarities, as well as significant differences, in the patterns of innovative behavior. We have analyzed these patterns in terms of the countries involved, chemical industry sectors, and size classes of the firms. Finally, we provided two models of innovative behavior in the European chemical industry.

The product innovator model strongly supports the view that a commitment to product innovation and an awareness of the related risks increases the likelihood of being a successful product innovator. The commitment to improved product quality particularly increases the probability of being a successful product innovator. Innovation intensity is not significant, nor is export intensity as measured by export share.

The process innovator model supports competition and competing with rivals in their own arena, as well as a commitment to the economical use of resources. When product innovations are easy to copy, the probability for process innovation decreases. While the innovation intensity is not significant, the export intensity is. The more a firm pursues an export strategy, the higher the likelihood of being a process innovator.

**Recommendations** There seems to be widespread agreement that the Green Paper on Innovation, published by the European Commission in December 1995, is a useful base

for beginning the discussion regarding policy implications. Therefore, we will relate the major problem regarding the chemical industry and cite a few additional problems, which future Green Papers should address.

The major problem is due to the unfavorable legal and regulatory environment blocking innovation in the European chemical industry. If the concern of policy-makers is keeping employment and competitiveness in the European chemical industry at high levels, they should address this concern. Obviously, this problem needs solving at both the national and the European levels. The Green Paper on Innovation seems not to recognize this obstacle, as it makes little use of the “Molitor-Report” and the evidence it cites. It would be of use to the Commission to examine a paper by the Association of the German Chemical Industry on the removal of obstacles to innovation (Verband der Chemischen Industrie 1994, VCI-Paper). This corresponds to the argument that Giulio Grata raised in Berlin--the discussion needs to come to earth and “we must now explore all these paths, and many more, and identify priorities” (Grata 1996). In keeping with this sentiment, we provide a brief summary of the VCI-Paper on the removal of obstacles to innovation in Appendix 9.2.

## 8 References

- Achilladelis, Basil, and Albert Schwarzkopf (1990), "The Dynamics of Technological Innovation: The Case of the Chemical Industry," *Research-Policy*, vol. 19, pp. 1-32.
- Acs, Zoltan J., and David B. Audretsch (1987), "Innovation, Market Structure and Firm Size," *Review of Economics and Statistics*, vol. 69, November, pp. 567-575.
- Acs, Zoltan J., and David B. Audretsch (1988), "Innovation in Large and Small Firms: An Empirical Analysis," *American Economic Review*, vol. 78, September, pp. 678-690.
- Acs, Zoltan J., and David B. Audretsch (1990), *Innovation and Small Firms*, Cambridge, Mass.: MIT Press.
- Acs, Zoltan J., and David B. Audretsch (1991), "R&D, Firm Size and Innovative Activity," in: Zoltan J. Acs and David B. Audretsch (eds.): *Innovation and Technological Change: An International Comparison*, Ann Arbor: University of Michigan Press, pp. 39-59.
- Akzo (1984-1993), *Annual Reports*.
- Albach, Horst (1994), "Culture and Technical Innovation - A Cross-Cultural Analysis and Policy Recommendations," in: Akademie der Wissenschaften zu 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, pp.1-597.
- Albach, Horst, David B. Audretsch, Manfred Fleischer, Robert Greb, Evelyn Höfs, Lars-Hendrik Röller, and Ines Schulz (1996), "Data Appendix to EU-Project 'Innovation in the European Chemical Industry': A Summary of Descriptive Statistics for the Community Innovation Survey of 1992/1993," Discussion Paper FS IV 96-26a, Berlin: Wissenschaftszentrum Berlin.
- Albach, Horst, and Diana de Pay (1991), "Quellen, Zeiten u. Kosten von Innovationen," *Zeitschrift für Betriebswirtschaft*, vol. 61, no. 3, pp. 309-324.
- Amecke, Hans-Bernd (1987), *Chemiewirtschaft im Überblick*, New York: Weinheim.
- Ansoff, Igor H., and John M. Stewart (1967), "Strategies for a Technology-Based Business," *Harvard Business Review*, November/December, pp. 71-83.
- Archibugi, Daniele, Patrick Cohendet, Arne Kristensen, and Karl-August Schäfer (1995), "Evaluation of the Community Innovation Survey (CIS) - Phase I," EIMS

Publication No. 11, European Innovation Monitoring System, European Commission, DG XIII, Luxembourg.

Ayres, Robert U. (1988), "Barriers and Breakthroughs: An 'Expanding Frontiers' Model of Technology-Industry Life Cycle," *Technovation*, vol. 7, pp. 87-115.

Baldwin, William, and John T. Scott (1987), *Market Structure and Technological Change*, London: Harwood Academic Publishers.

BASF (1984-1993), *Annual Reports*.

Bayer (1984-1993), *Annual Reports*.

Bound, John, Clint Cummings, Zvi Griliches, Bronwyn Hall, and Adam Jaffe (1984), "Who Does R&D and Who Patents," in: Zvi Griliches (ed.), *R&D, Patents and Productivity*, Cambridge, Mass., pp. 21-54.

Chemical Industries Association (1995), *Chemical Industry Research Priorities*, London.

*Chemische Industrie*, Issues, 8/89, 1/92, 10/92, 3/94, 4/94.

Chenier, Philip J. (1992), *Survey of Industrial Chemistry*, New York: Weinheim.

Ciba-Geigy (1984-1993), *Annual Reports*.

Cohen, Wesley M., and Steven Klepper (1992), "The Anatomy of Industry R&D Intensity Distributions," *American Economic Review*, vol. 82, no.4, pp. 773-799.

Cohen, Wesley M., and Richard C. Levin (1989), "Empirical Studies of Innovation and Market Structure," in: Richard Schmalensee and Robert D. Willig (eds.), *Handbook of Industrial Organization*, vol. II, chap. 18, Amsterdam, pp. 1060-1107.

Colombo, Umberto (1980), "A Viewpoint on Innovation and the Chemical Industry," *Research Policy*, vol. 9, pp. 205-231.

Cooper, Robert G. (1984), "New Product Strategies: What Distinguishes the Top Performers," *Journal of Product Innovation Management*, pp. 151-164.

Deutscher Industrie- und Handelstag (DIHT) (1996), "Stellungnahme zur Mitteilung der Europäischen Kommission vom 20. Dezember 1995, 'Grünbuch zur Innovation,'" Bonn, February.

Dosi, Giovanni (1988), "Procedures and Microeconomic Effects of Innovation," *Journal of Economic Literature*, vol. 26, pp. 1120-1171.

Economist (1995), "Betting on Alchemy," *The Economist*, 09/September, pp. 9-10.

- Europäische Kommission (1995), Molitor-Report, *Bericht der Gruppe unabhängiger Experten für die Vereinfachung der Rechts- und Verwaltungsvorschriften*, KOM(95) 288 endg./2, Brüssel.
- Europäische Kommission (1996), *Grünbuch zur Innovation*, Bulletin der Europäischen Union, Beilage 5/95, Luxemburg.
- European Commission (1994a), *Panorama of EU Industry - 1994*, Luxembourg: Office for Official Publications of the European Communities.
- European Commission (1994b), *Innovation: The Community Innovation Survey - Status and Perspectives*, Luxembourg: Office for Official Publications of the European Communities.
- European Commission (1995), *Panorama of EU Industry 95-96*, Luxembourg: Office for Official Publications of the European Communities.
- European Commission (1996), *Green Paper on Innovation*, Special Issue, Innovation and Technology Transfer, Luxembourg, February.
- Eurostat (1996), Statistik kurzgefaßt, No. 2.
- FAST - Forschungsgemeinschaft für Außenwirtschaft, Struktur- und Technologiepolitik e. V. (1991), "Die Internationalisierung von Forschung und Entwicklung," *FAST-Studien* Nr. 15, Berlin.
- Felder, Johannes, Dietmar Harhoff, Georg Licht, and Eric Nerlinger (1994), "Das Innovationsverhalten der deutschen Wirtschaft," ZEW-Dokumentation 1994-01, Mannheim.
- Felder, Johannes, Georg Licht, Eric Nerlinger, and Harald Stahl (1995), "Appropriability, Opportunity, Firm Size and Innovative Activities - Empirical Results Using East and West German Firm Level Data," ZEW-Discussion Paper No. 95-21, Mannheim.
- Fond der Chemischen Industrie (1993), "Fortschritt durch Innovation," *Chemische Industrie*, November, pp. 13-15.
- Foster, Richard N. (1986), *Innovation*, Wiesbaden.
- Franck, Heinz-Gerhard (1983), "Die volkswirtschaftliche Bedeutung der Innovation," *Chemische Industrie*, November, pp. 666-671.
- Frankfurter Allgemeine Zeitung* (1995), 28 March, 12 July, 06 October.
- Freeman, Christopher (1982), *The Economics of Industrial Innovation*, London: Francis Pinter, 2nd. edition (1st edition: Penguin Economics, 1974).

- Freeman, C., R. C. Curnow, J. K. Fuller, A. B. Robertson, and P. J. Whittacker (1968), "Chemical Process Plant: Innovation and the World Market," *National Institute Economic Review*, no. 45 (August), pp.29-51.
- Froböse, Rolf (1994), "Raus aus der Sackgasse," *Chemische Industrie*, 1/94, pp. 8-12.
- Gabler Wirtschafts-Lexikon* (1988), Wiesbaden, 10th Ed.
- Gehrke, Birgit, and Hariolf Grupp (1994), *Innovationspotential und Hochtechnologie*, 2nd Ed., Heidelberg.
- Grata, Guilio C. (1996), "Speech on the Green Paper on Innovation," presented at the Conference on Innovation, Berlin, 9-10 May.
- Graumann, Mathias (1993), *Die Analyse der Innovationstätigkeit deutscher Automobilhersteller auf dem Markt für Personenkraftwagen, 1975 - 1990*, Frankfurt/M.
- Henkel (1984-1993), *Annual Reports*.
- Hill, Christopher T., and James M. Utterback (1979), *Technological Innovation for a Dynamic Economy*, New York.
- von Hippel, Eric (1988), *The Sources of Innovation*, New York-Oxford.
- Hoechst (1984-1993), *Annual Reports*.
- Hoechst (1993), *Neue Wege finden*, Frankfurt/M.
- Hollander, Samuel (1965), *The Sources of Increased Efficiency: A Study of Du Ponts Rayon Plants*, Cambridge, Mass.
- Hounshell, David A. (1995), "Strategies of Growth and Innovation in the Decentralized Du Pont Company, 1921-1950," in: Francois Caron, Paul Erkner, and Wolfram Fischer (eds.), *Innovations in the European Economy between the Wars*, Berlin/New York: de Gruyter, pp. 175-196.
- ICI (1984-1993), *Annual Reports*.
- Jewkes, John, David Sawers, and Richard Stillerman (1969), *The Sources of Invention*, 2nd Edition, New York: Norton.
- Kleindorfer, Paul R. (1985), *The Management of Productivity and Technology in Manufacturing*, New York.
- Kleinknecht, Alfred (1984), *Innovation Patterns in Crisis and Prosperity: Schumpeter's Long Cycle Reconsidered*, Ph. D. Thesis, Free University of Amsterdam.
- Kuhn, Wolfgang (1992), *Forschung und Entwicklung im Lagebericht*, Hamburg.

- Mensch, Gerhard (1979), *Stalemate in Technology. Innovations Overcome Depression*, Cambridge, Mass., Ballinger.
- Moenaert, Rudy (1990), "Turnaround Strategies for Strategic Business Units with an Aging Technology," in: Roy Loveridge and Martyn Pitt (eds.), *Strategy of Management and Technology Innovation*, New York, pp. 29-61.
- Mueller, Willard F. (1962), "The Origins of the Basic Inventions Underlying Du Pont's Major Product and Process Innovations, 1920-1950," in: *The Rate and Direction of Inventive Activity. Economic and Social Factors*, Princeton, 1962.
- Nelson, Richard R. (1959), "The Simple Economics of Basic Scientific Research - A Theoretical Analysis", *Journal of Political Economy*, vol. 67, pp. 297-306.
- OECD (1992), OECD Proposed Guidelines for Collecting and Interpreting Technological Innovation Data -- *OSLO Manual* --, Paris.
- OECD (1993), Proposed Standard Practice for Surveys of Research and Experimental Development -- *Frascati Manual* --, Paris.
- Pavitt, Keith (1984), "Sectoral Patterns of Technical Change: Towards a Taxonomy and a Theory," *Research Policy*, vol. 13, pp. 343-373.
- Pavitt, Keith (1990), "What We Know about the Strategic Management of Technology," *California Management Review*, no. 1, pp. 17-26.
- Pavitt, Keith, Michael L. Robson, and Joe Townsend (1987), "The Size Distribution of Innovating Firms in the UK: 1945-1983," *The Journal of Industrial Economics*, 55 (1), March, pp. 297-316.
- Porter, Michael E. (1980), *Competitive Strategy--Techniques for Analyzing Industries and Competitors*, New York.
- Quadbeck-Seeger (1995), "Innovationen in der chemischen Industrie - der Weg in die Zukunft," (Reihe BASF im Dialog), Ludwigshafen.
- Research - Bayer Forschungsmagazin* (1993), no. 7, Leverkusen, November.
- Riemann, Achim (1993), "Neue Konzepte sind gefragt," *Chemische Industrie*, November, pp. 16-18.
- Riggert, Thomas (1992), "Umstrukturierung jetzt oder nie," *Chemische Industrie*, 7-8, pp. 9-10.
- Roberts, Edward B. (1988), "Managing Invention and Innovation," *Research-Technology Management*, January/February, pp. 11-29.



- Rohe, Dieter (1989), "Die Last wird zum Wettbewerbsvorteil," *Chemische Industrie*, 8, pp. 20-26.
- Rosenkranz, Stephanie (1995), "Simultaneous Choice of Process and Product Innovation," Discussion Paper FS IV 95-30, Berlin: Wissenschaftszentrum Berlin.
- Rosenkranz, Stephanie (1996), *Cooperation for Product Innovation*, Berlin: Edition Sigma.
- Sahal, Devendra (1981), *Pattern of Technological Innovation*, Reading.
- Sandoz (1984-1993), *Annual Reports*.
- Servatius, Gerd-Hans (1985), *Methodik des strategischen Technologie-Managements*, 2nd Ed., Berlin.
- Servatius, Gerd-Hans, and Wolfgang Falter (1994), "Innovationsprozesse beschleunigen," *Chemische Industrie*, no. 1, pp. 13-16.
- Schmidt, Rolf (1991), *Umweltgerechte Innovationen in der chemischen Industrie*, Ludwigsburg/Berlin.
- Schulze, Joachim, and Manfred Weiser (1982), *Die Innovationsintensität in der chemischen Industrie*, Berlin.
- Schwitalla, Beatrix (1993), *Messung und Erklärung industrieller Innovationsaktivitäten*, Heidelberg.
- Specht, Guenther, and René Perillieux (1988), "Erfolgsfaktoren technischer Führer- und Folgerpositionen auf Investitionsgütermärkten," *Zeitschrift für betriebswirtschaftliche Forschung*, pp. 204-225.
- Solvay (1984-1993), *Annual Reports*.
- SV - Gemeinnützige Gesellschaft für Wirtschaftsstatistik mbH (1994), *Forschung und Entwicklung in der Wirtschaft*, 1990 - 1991, Essen.
- Utterback, James M., and William J. Abernathy (1990), "A Dynamic Model of Process and Product Innovation," in: Christopher Freeman, *The Economics of Innovation*, Hants, pp. 424-441.
- Verband der Chemischen Industrie e. V. (Association of the German Chemical Industry) (1995), *Chemiewirtschaft in Zahlen - 1995 Edition*, Frankfurt/M.
- Verband der Chemischen Industrie e. V. (Association of the German Chemical Industry) (1994), "Beseitigung von Innovationshemmnissen," Documentation, Frankfurt/M.
- Walsh, Vivian (1984), "Invention and Innovation in the Chemical Industry: Demand-Pull or Discovery-Push?," *Research Policy*, pp. 211-234.

Wolfrum, Bernd (1992a), *Strategisches Technologiemanagement*, Wiesbaden.

Wolfrum, Bernd (1992b), "Technologiestrategien im strategischen Management,"  
*Marketing-ZFP*, no. 1, pp. 23-36.

## 9 Appendix

### 9.1 Characteristics of the Selected Nine Companies

Nine large companies in 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:<sup>24</sup>

**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 sales 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 fibers.

**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 when they were still with I.G. Farben, BASF was considered *the* supplier of raw materials within 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 sales, 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

---

<sup>24</sup> Based on Amecke, p. 45-55, and various annual reports.

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.

**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, analogous 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 sales. 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 divestment of their chemical line (16 percent of the 1993 sales, 8200 employees) by the end of 1995. Sandoz also plans to separate from its agricultural and building chemistries divisions.

**Akzo N. V.** Akzo resulted from the merger of Aku (synthetic fibers) and KZO (salt) in 1969. In the 1970s, the production of synthetic fibers still dominated Akzo, but its capacity overshoot soon pushed the company into a major crisis. Over the last few years, Akzo successfully reduced its dependence on fiber production. While fibers accounted for 52 percent of sales in 1969, it was down to less than 20 percent in 1993. Today, Akzo is considered very competitive due to its special strengths in paints/varnishes and its vast pharmaceutical production (20 percent of sales). 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, 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.

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 sales), 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).

## 9.2 Some Considerations Concerning 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 at minimal 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.

**Examples of the excessive regulation** The EU guideline 67/548/7 is considered to be one of the greatest obstacles. Therefore, the industry demands exemption of all substances serving only R&D from the compulsory registration and testing (because the 100 Kg/year limit is not sufficient).

Additionally, it criticizes the test of indication of quantity (Mengenschwellen-konzept) because it admits no exposition view. This means that new materials from substance classes with known low toxic values have to pass the same test program as those with high toxic substance classes.

The time limit of one year for introducing new material for use for production-oriented R&D is often inadequate for the competition of producing.

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

The industry proposes to minimize the licensing, technical and bureaucratic conditions considerably for gen-technical work, except where necessary 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 stimulation of innovation** This point especially applies to Germany. Germany is the only big industrial country which does not favor R&D through

government tax funding. Besides this, the 1988 decision to tax the income of inventors had a negative effect on innovation activities and resulted in only a modest fiscal profit (tax income of 87 Mio DM/year).

The prevalent opinion regarding the size of the patent fees is that they are too high for independent inventors, as well as for small and medium-sized businesses and welfare enterprises. In the USA, 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 the EU should make plans for producing innovative products within the public sector. In Japan and in the USA, this method of innovation stimulation is more successful.

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

**Bücher des Forschungsschwerpunkts Markt und politische Ökonomie**

**Books of the Research Area Markets and Political Economy**

(nur im Buchhandel erhältlich/available through bookstores)

Andreas Stephan

**Essays on the Contribution of Public Infrastructure to Private: Production and its Political Economy**

2002, dissertation.de

Hans Mewis

**Essays on Herd Behavior and Strategic Delegation**

2001, Shaker Verlag

Andreas Moerke

**Organisationslernen über Netzwerke – Die personellen Verflechtungen von Führungsgremien japanischer Aktiengesellschaften**

2001, Deutscher Universitäts-Verlag

Silke Neubauer

**Multimarket Contact and Organizational Design**

2001, Deutscher Universitäts-Verlag

Lars-Hendrik Röller, Christian Wey (Eds.)

**Die Soziale Marktwirtschaft in der neuen Weltwirtschaft, WZB Jahrbuch 2001**

2001, edition sigma

Michael Tröge

**Competition in Credit Markets: A Theoretic Analysis**

2001, Deutscher Universitäts-Verlag

Tobias Miarka

**Financial Intermediation and Deregulation: A Critical Analysis of Japanese Bank-Firm-Relationships**

2000, Physica-Verlag

Damien J. Neven, Lars-Hendrik Röller (Eds.)

**The Political Economy of Industrial Policy in Europe and the Member States**

2000, edition sigma

Jianping Yang

**Bankbeziehungen deutscher Unternehmen: Investitionsverhalten und Risikoanalyse**

2000, Deutscher Universitäts-Verlag

Horst Albach, Ulrike Görtzen, Rita Zobel (Eds.)

**Information Processing as a Competitive Advantage of Japanese Firms**

1999, edition sigma

Dieter Köster

**Wettbewerb in Netzproduktmärkten**

1999, Deutscher Universitäts-Verlag

Christian Wey

**Marktorganisation durch Standardisierung: Ein Beitrag zur Neuen Institutionenökonomik des Marktes**

1999, edition sigma

Horst Albach, Meinolf Dierkes, Ariane Berthoin Antal, Kristina Vaillant (Hg.)

**Organisationslernen – institutionelle und kulturelle Dimensionen**

WZB-Jahrbuch 1998

1998, edition sigma

Lars Bergman, Chris Doyle, Jordi Gual, Lars Hultkrantz, Damien Neven, Lars-Hendrik Röller, Leonard Waverman

**Europe's Network Industries: Conflicting Priorities - Telecommunications**

Monitoring European Deregulation 1

1998, Centre for Economic Policy Research

Manfred Fleischer

**The Inefficiency Trap**

Strategy Failure in the

German Machine Tool Industry

1997, edition sigma

Christian Göseke

**Information Gathering and Dissemination**

The Contribution of JETRO to

Japanese Competitiveness

1997, Deutscher Universitäts-Verlag

Andreas Schmidt

**Flugzeughersteller zwischen globalem Wettbewerb und internationaler Kooperation  
Der Einfluß von Organisationsstrukturen auf die Wettbewerbsfähigkeit von Hochtechnologie-Unternehmen**

1997, edition sigma

Horst Albach, Jim Y. Jin, Christoph Schenk (Eds.)

**Collusion through Information Sharing?**

**New Trends in Competition Policy**

1996, edition sigma

Stefan O. Georg

**Die Leistungsfähigkeit japanischer Banken  
Eine Strukturanalyse des Bankensystems in Japan**

1996, edition sigma

Stephanie Rosenkranz

**Cooperation for Product Innovation**

1996, edition sigma

## DISCUSSION PAPERS 2001

Fredrik Andersson Kai A. Konrad	<b>Globalization and Human Capital Formation</b>	FS IV 01 – 01
Andreas Stephan	<b>Regional Infrastructure Policy and its Impact on Productivity: A Comparison of Germany and France</b>	FS IV 01 – 02
Tomaso Duso	<b>Lobbying and Regulation in a Political Economy: Evidence from the US Cellular Industry</b>	FS IV 01 – 03
Steffen Huck Kai A. Konrad Wieland Müller	<b>Merger and Collusion in Contest</b>	FS IV 01 – 04
Steffen Huck Kai A. Konrad Wieland Müller	<b>Profitable Horizontal Mergers without Cost Advantages: The Role of Internal Organization, Information, and Market Structure</b>	FS IV 01 – 05
Jos Jansen	<b>Strategic Information Revelation and Revenue Sharing in an R&amp;D Race</b> <i>(A revision of FS IV 99-11)</i>	FS IV 01 – 06
Astrid Jung	<b>Are Product Innovation and Flexible Technology Complements?</b>	FS IV 01 – 07
Jonas Björnerstedt Johan Stennek	<b>Bilateral Oligopoly</b>	FS IV 01 – 08
Manfred Fleischer	<b>Regulierungswettbewerb und Innovation in der chemischen Industrie</b>	FS IV 01 – 09
Karl Wärneryd	<b>Rent, Risk, and Replication – Preference Adaptation in Winner-Take-All Markets</b>	FS IV 01 – 10
Karl Wärneryd	<b>Information in Conflicts</b>	FS IV 01 – 11
Steffen Huck Kai A. Konrad	<b>Merger Profitability and Trade Policy</b>	FS IV 01 – 12
Michal Grajek	<b>Gender Pay Gap in Poland</b>	FS IV 01 – 13
Achim Kemmerling Andreas Stephan	<b>The Contribution of Local Public Infra-structure to Private Productivity and its Political-Economy: Evidence from a Panel of Large German Cities</b>	FS IV 01 – 14
Suchan Chae Paul Heidhues	<b>Nash Bargaining Solution with Coalitions and the Joint Bargaining Paradox</b>	FS IV 01 – 15
Kai A. Konrad Harald Künemund Kjell Erik Lommerud Julio R. Robledo	<b>Geography of the Family</b>	FS IV 01 – 16
Tomaso Duso Lars-Hendrik Röller	<b>Towards a Political Economy of Industrial Organization: Empirical Regularities from Deregulation</b>	FS IV 01 – 17



Kai A. Konrad	<b>Investment in the Absence of Property Rights – The Role of Incumbency Advantages</b>	FS IV 01 – 18
Roman Inderst Christian Wey	<b>Bargaining, Mergers, and Technology Choice in Bilaterally Oligopolistic Industries</b>	FS IV 01 – 19
Kai A. Konrad Helmut Seitz	<b>Fiscal Federalism and Risk Sharing in Germany: The Role of Size Differences</b>	FS IV 01 – 20
Klaus Gugler Dennis C. Mueller B. Burcin Yurtoglu Christine Zulehner	<b>The Effects of Mergers: An International Comparison</b>	FS IV 01 – 21
Kjell Erik Lommerud Odd Rune Straume Lars Sørgaard	<b>Downstream Merger with Oligopolistic Input Suppliers</b>	FS IV 01 – 22
Andreas Blume Paul Heidhues	<b>Tacit Collusion in Repeated Auctions</b>	FS IV 01 – 23
Roman Inders Christian Wey	<b>The Incentives for Takeover in Oligopoly</b>	FS IV 01 – 24
Klaus Gugler Dennis C. Mueller B. Burcin Yurtoglu	<b>Corporate Governance, Capital Market Discipline and the Returns on Investment</b>	FS IV 01 – 25
Sven-Olof Fridolfsson Johan Stennek	<b>Why Mergers Reduce Profits and Raise Share Prices: A Theory of Preemptive Mergers</b>	FS IV 01 – 26

## DISCUSSION PAPERS 2002

Fredrik Andersson Kai A. Konrad	<b>Human Capital Investment and Globalization in Extortionary States</b>	FS IV 02 – 01
Lars-Hendrik Röller Christian Wey	<b>Merger Control in the New Economy</b>	FS IV 02 – 02
Talat Mahmood Klaus Schömann	<b>Die Determinanten der Migrationsentscheidung von IT-Hochschulabsolventen aus Pakistan – Empirische Befunde zur Ausgestaltung der deutschen „Green Card“</b>	FS IV 02 – 03
Jos Jansen	<b>The Effects of Disclosure Regulation on Innovative Firms: Common Values</b>	FS IV 02 – 04
Jos Jansen	<b>The Effects of Disclosure Regulation on Innovative Firms: Private Values</b>	FS IV 02 – 05
Günter Franke Harris Schlesinger Richard C. Stapleton	<b>Multiplicative Background Risk</b>	FS IV 02 – 06
Tomaso Duso	<b>On the Politics of the Regulatory Reform: Econometric Evidence from the OECD Countries</b>	FS IV 02 – 07