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Innovation Activities in Pulp, Paper and Paper Products in Europe

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Summary

This report uses data from the Eurostat/DG-XIII *Community Innovation Survey* (CIS) to analyse innovation activity and innovation performance in the Pulp, Paper and Paper Products Industry in Europe. We distinguish between two important sub-groups within the industry, namely manufacture of pulp, paper and board (NACE 21.1) and manufacture of articles of pulp, paper and board (NACE 21.2).

Analyses of innovation, and policy discussions of innovation, are often focused on high-R&D performing sectors such as IT, biotechnology, pharmaceuticals and so on. Sectors such as Pulp and Paper are usually regarded as low-technology activities, since they perform relatively little internal R&D. However it is important to note that high-R&D sectors tend to be small in terms of output and employment. The bulk of European output and employment is found in low and medium-R&D performing industries such as Pulp and Paper. Though somewhat neglected in policy terms, such industries are vital to European competitiveness, growth and employment. This sector in particular is also very important in environmental terms.

The report is in three parts. The first presents an overview of the industry in Europe - its structure, products, innovation methods, investment patterns, export specialisation and general development trends. The second part explores innovation activity in the industry, looking at tangible and intangible investments, R&D co-operation, innovation-related expenditures (and their distribution across categories), and innovation outputs (in terms of shares of turnover generated by new products). Part Three analyses innovation performance, where we distinguish between high, medium and low-performing innovators, and analyse the characteristics of high-innovating firms in the industry. Three appendices present data on the innovation objectives of firms in the industry, factors hampering innovation, and on important sources of information for innovation in this industry. Where permitted by the data, these analyses are comparative: across firm size categories, and across countries.

A key message of this report is that low-R&D industries are not necessarily low-innovation industries. The Pulp and Paper sector is by any standards technology intensive, but the technological inputs to the industry originate mainly from outside the industry. This industry innovates via complex interactive relationships. These include interactions between users and producers of technology (particularly with specialised suppliers of capital equipment, especially process machinery), and with materials suppliers, with consulting firms, with technical institutes, with universities and so on. The ‘innovation system’ of the industry is distributed across many types of institutions and is a complex one. Through these interactive relationships, firms in the industry exploit very advanced research, and very advanced technologies.

The innovation activities of the industry do include R&D, especially in large firms, but non-R&D activities are particularly important. These include product design (especially in the sector that converts paper and board into final products). Activities connected with the installation and operation of new equipment are also of great importance: trial production, tooling up and training are central activities in innovation in this sector. Although Pulp and Paper generates a smaller proportion of

its sales from new products than the all-industry average, it nevertheless does introduce new products with new technical and performance characteristics. Depending on firm-size category and specific activity, the ratio between sales of new products (introduced to the market in the past three years) and unchanged products varies between approximately 20 and 45% in this industry. Competitiveness in this industry, as in other industries, depends on innovation.

In the third part of the study we seek to identify which firms innovate, and to map the characteristics of highly innovative firms. Some of the core results from this investigation are as follows:

- both small and larger enterprises in the pulp and paper industry can be very innovative according to the definition used in this study, although smaller enterprises are less likely to pursue innovation projects with high technological complexity.

- large enterprises are more frequently innovative than smaller ones.

- on the firm level there is no evidence that high innovation performance is linked with high growth rates over the two years period of the survey. However we can expect that innovation performance and growth are positively related in the longer run.

- innovation performance and export activity are unrelated on the enterprise level. Export activity rather depends on the country, firm size and firm ownership status.

- high performing enterprises in four out of seven samples tended to rank the following sources of information as particularly important: internal sources within the group of enterprises, suppliers of equipment, and competitive intelligence. Fairs and exhibitions, on the other hand, were ranked lower by high performing enterprises in four out of seven samples.

- in four of the seven samples high performing enterprises exhibit higher median values for the creation of new national markets, as an innovation objective, than average performers. In terms of innovation objectives, the improvement of production flexibility is considered more important among high performing enterprises from The Netherlands, Ireland, and Germany; Italian enterprises and German converters consider this objective unanimously as very important.

- high performing enterprises mentioned more frequently that they used externally contracted R&D and consultants to acquire technology. High performing enterprises in the conversion sector mentioned more frequently that they acquired technology through the purchase of equipment.

- about half of the enterprises achieved high innovation performance according to the definition of this study without internal R&D activity. Other studies on technology strategy in the sector suggest that such firms are unlikely to be industry leaders and unlikely to operate in market segments characterised by sophisticated technology.

- those enterprises that perform R&D exhibit higher R&D expenditures if they are highly innovative. Correlation analysis shows that R&D expenditures are linked with the level of expenditures related to innovation.

Although it is difficult to draw clear policy conclusions from data of this type, it should be recognised that Pulp and Paper, and Pulp and Paper Products, make up a large and growing global market. This is a sector of advanced technology creation and use, but this occurs through intense interactive relationships between the actors in the industry and a wider technology and knowledge-creating environment. Our view is that there is a strong case for policy-makers to consider actions aimed at supporting the infrastructural institutions that support this industry, and to strengthen the network links that are vital to its performance. The case for increased policy attention to Pulp and Paper is strengthened by the need to create and diffuse environmentally sustainable technologies for this industry in years ahead.

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1. Introduction

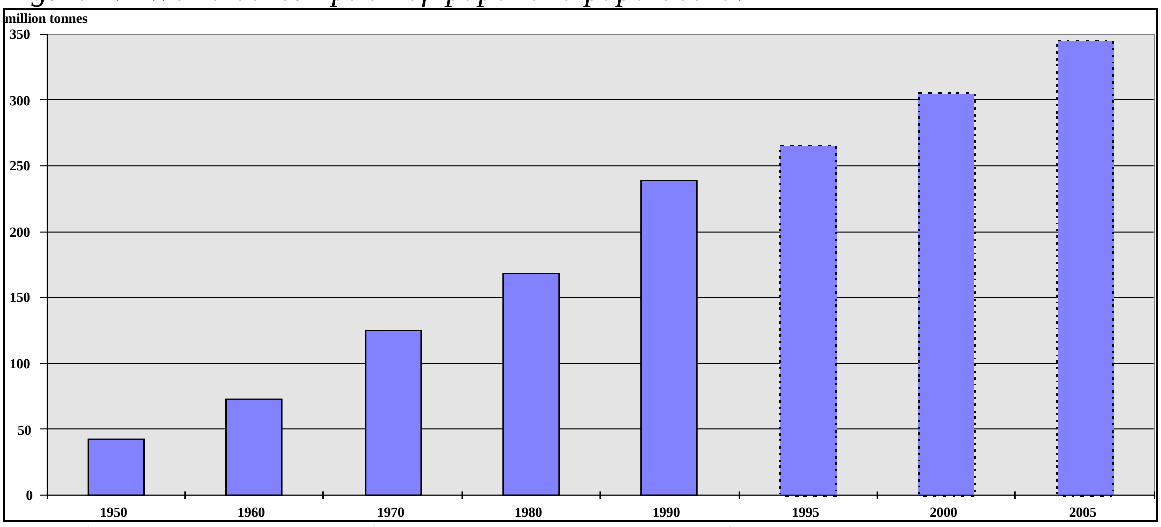
Innovation in Europe, as elsewhere, is frequently discussed in terms of high technology (or more accurately high-R&D) sectors, such as electronics and biotechnology. However the bulk of production and employment in Europe is found in mature, so-called low-tech sectors. Pulp and paper is one such sector. Such sectors are often characterised by a low level of technology creation, in the sense of performing relatively little direct R&D, but in many cases they are innovating sectors (in the sense of developing and marketing new products), and they are quite heavy users of new technology originating in other sectors. Since it is well known that the value of new technology is only realised when it is taken into use, such user sectors can be of great importance in transforming new technological opportunities into actual economic change. From this perspective, an industry such as pulp and paper is important as a site of innovation, growth and employment. In this study, we seek to understand how innovations come about in this particular industry, how important they are, and in particular what characterises successful innovating companies.

The structure of the report is as follows. The introductory chapter presents an overview the pulp and paper industry based on available studies and statistics, and introduces the Community Innovation Survey (CIS) data as a source for studying innovation activity in this industry. The second chapter gives an overview of innovation activity in the industry - based on CIS data - comparing companies of different size, nationality and industry subgroup. In the third chapter, companies are divided into high and low performers in terms of innovation, focussing on characteristics of success. A summary of main findings and conclusions are presented in Chapter four. Three appendices present data on innovation-related objectives and problems.

1.1 An overview of the Pulp, Paper and Paper Products Industry

Over the last fifty years the pulp and paper industry has enjoyed a steady growth in demand, particularly in the industrialised countries.

Figure 1.1 World consumption of paper and paperboard.



The data from 1995 are built on prognosis from a leading pulp and paper consulting firm, Jaakko Pöyry Oy (Inc)

World consumption of paper products is forecast to continue to increase, both in developed and developing countries. Production of pulp, paper, and board reached a new high in 1994, the twelfth consecutive increase for paper and board producers. World-wide, pulp and board production increased by 17 million tons in 1994, an increase of 6,7 % over 1993 output.[1] Pulp alone increased by 4,9 %, from 163 million tons in 1993 to 171 million tons in 1994. Several analyses predict that the demand for paper and pulp will continue to grow steadily in the future.[2]

1.1.1 Products

The pulp and paper industry manufactures a broad range of products. Pulp is the basic material for the production of paper and board and all the products thereof. The variety of products can be classified in various ways, for example according to the process used to separate the fibres (mechanical, thermo-mechanical, chemical etc.), the degree of bleaching (bleached, semi-bleached, and unbleached) and according to the wood used (conifers, leaf wood). The following list shows the commonly used classification into four categories, based on final use:

- graphics papers (newsprint, all printing and writing papers)
- industrial papers and cartons (packaging paper, paper for liquid containers and for construction)
- household and sanitary paper (including fluff tissues)
- special papers

A large share of the products of the paper manufacturing sector is then converted into other paper products. These products can be grouped into four main segments:

- packaging products (containers, bags, wrappings)
- household and hygienic paper goods (cellulose, cotton tissue and crepe paper for use in nursing, baby care and feminine hygiene, kitchen towels, and toilet paper)
- stationary and office supplies (envelopes, labels, printing and copying paper, and products for special applications such as fax paper)
- miscellaneous (e.g. tubes, wallpaper, metallised paper).

All these segments, whether commodities or speciality products, have grown significantly in recent years. In terms of volume, packaging represents the largest segment with some 60% share of the production in the paper and board conversion sector. In spite of some legislative measures aimed at reducing packaging waste, this segment has also experienced high growth. The second largest segment is household and hygienic paper products that have grown exceptionally during the past two decades. However, it seems that the EU market for household and sanitary papers has reached a certain level of saturation.[3] The stationary and office supply segment has also grown but it has undergone a shift from mail based stationary towards electronic transmission-oriented stationary at the same time: typical products such as envelopes

[1] Pulp and paper international, Annual Review, July 1995

[2] Jaakko Pöyry prognosis 1992

[3] Eurostat (1994), *Panorama of European Industry* Luxembourg: Office for Official Publications of the European Communities, pp.. 16-10 - 16-16

have receded compared to new products as, for instance, fax paper or computer printing paper.[4]

1.1.2 Companies

The largest companies in the pulp and paper sector are North American, with *International Paper* being the largest pulp and paper producing company. In 1992 International Paper produced close to 7 million tons of paper and board. The strong recovery in the US economy has further increased the scale of production of North American companies. During the last few years, however, some European companies have also become important players in the world market, as a result of acquisitions and mergers. In particular, Finnish and Swedish pulp and paper companies have actively sought to consolidate their position through mergers and acquisitions, motivated predominantly by the need to consolidate market position, as much by the need to upgrade the technological base.

Table 1.1 The top 30 pulp, paper, and board producers in the World in 1994[5]

Paper and board production (million tons)			**Pulp production (million tons)**		
Country	1994	Change 93-94	Country	1994	Change 93-94
1 USA	80,7	4,7 %	1 USA	58,7	2,9 %
2 Japan	28,5	2,8 %	2 Canada	24,5	7,2 %
3 China	21,4	14,3 %	3 China	17,1	11,5 %
4 Canada	18,3	4,5 %	4 Sweden	10,9	9,2 %
5 Germany	14,5	10,9 %	5 Japan	10,6	-0,1 %
6 Finland	10,9	9,2 %	6 Finland	10,0	6,7 %
7 Sweden	9,4	6,5 %	7 Brazil	6,1	10,8 %
8 France	8,7	8,9 %	8 CIS	3,3	-24,1 %
9 Italy	6,7	8,4 %	9 France	2,8	9,7 %
10 Rep. of Korea	6,3	9,3 %	10 Norway	2,3	8,1 %
11 Brazil	5,7	5,9 %	11 S Africa	2,2	3,1 %
12 UK	5,5	7,5 %	12 Australia	1,9	96,8 %
13 CIS	4,8	0 %	13 Chile	1,9	29,1 %
14 Taiwan	4,2	7,5 %	14 Germany	1,9	-2,5 %
15 Austria	3,6	9,1 %	15 Austria	1,6	9,7 %
16 Spain	3,5	4,6 %	16 Portugal	1,5	1,3 %
17 Indonesia	3,1	17,5%	17 Spain	1,4	7,1 %
18 Netherlands	3,0	5,4 %	18 Indonesia	1,4	7,7 %
19 Mexico	2,9	3,5 %	19 India	1,4	0 %
20 India	2,3	1,3 %	20 New Zealand	1,4	-0,7 %
21 Australia	2,2	5 %	21 Poland	0,9	16,4 %
22 Norway	2,1	9,1 %	22 Argentina	0,8	20,4 %
23 South Africa	1,7	12,3 %	23 UK	0,6	13 %
24 Thailand	1,7	27,3 %	24 Italy	0,5	14,1 %
25 Switzerland	1,5	8,9 %	25 Rep. of Korea	0,5	18,8 %
26 Poland	1,3	13,2 %	26 Czech Rep	0,5	22,6 %
27 Belgium	1,2	17,4 %	27 Turkey	0,4	23,7 %
28 Turkey	1,1	11,5 %	28 Belgium	0,4	15,2 %
29 Argentina	1,0	5,1 %	29 Taiwan	0,3	3,5 %
30 Portugal	0,9	8,3 %	30 Colombia	0,3	7,3 %

In 1994, the US companies produced more than 30 % of the total of world paper output, and more than 33 % of the world total of pulp output. Other strong countries in the pulp and paper are Japan, China, Canada, Germany, Finland, Sweden, and

[4] ibid.

[5] Pulp and paper international, *Annual Review*, July 1995

France (table 1.1). In terms of export specialisation (table 1.2), the Nordic countries (Finland, Sweden, and Norway), alongside with Canada, rank highest, as measured by the revealed comparative advantage (RCA). This holds especially for Finland, the RCA index of which is higher than 10.

Table 1.2 Revealed comparative advantage (RCA) for the OECD countries, 1985 - 1991.
National totals. Group 1 countries have a RCA higher than 1. Group 2 countries have a RCA lower than 1[6]

Group 1	**Country**	**1985**	**1987**	**1989**	**1991**
	Finland	10,4	9,1	9,6	10,2
	Sweden	4,8	4,4	4,5	4,7
	Canada	3,9	4,0	4,2	4,1
	Norway	2,9	2,6	2,7	2,5
Group 2	**Country**	**1985**	**1987**	**1989**	**1991**
	US	0,8	0,8	0,9	0,8
	Netherlands	0,7	0,7	0,7	0,8
	France	0,7	0,6	0,7	0,7
	France	0,7	0,6	0,7	0,7
	Denmark	0,5	0,4	0,4	0,5
	UK	0,4	0,4	0,4	0,5
	Italy	0,4	0,4	0,4	0,5
	Australia	0,2	0,2	0,2	0,3
	Japan	0,2	0,2	0,2	0,2

Source: OECD, DSTI(STAN/Industrial Database), 1994

The recent membership of Finland and Sweden in the European Union has also considerably increased the relative importance of EU within the pulp and paper industry sectors. In terms of output of paper and board, EU is close to the Asia (table 1.3). Asia is expected to become an increasingly important producer of pulp and paper in the future. In 1994, Asia recorded a 8,4 % increase in the production of pulp and paper, not much more than Europe’s 8,2 % increase. But while Europe’s performance was mainly based on higher utilisation of existing capacity, Asia is steadily expanding production capacity. And while Europe will be hard pushed to maintain its growth rate in the pulp and paper sector above 5 % in the coming years, the growth in Asia will undoubtedly be faster.[7] Eastern European countries such as Poland, Slovenia, The Czech Republic, and Slovakia, may also increase their importance as pulp and paper producers in years to come. Pulp and paper firms in the EU countries can be expected to meet considerable competitive pressure from these nations in the future, especially if operating within the same product regimes.

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[6] The RCA index indicates the export specialization of a country. The RCA within pulp and paper for a specific country is constructed as the value of the pulp and paper export from a country (relative to all exports from the country) as a share of the value of the export of pulp and paper from all OECD countries (relative to all exports from all OECD countries). Formally the revealed comparative advantage within a sector *i* for a country *j* is constructed as:

$$RCA_{i,j} = \frac{E_{i,j} / \sum_k E_{k,j}}{\sum_l E_{i,l} / \sum_{m,n} E_{m,n}}$$

where $E_{i,j}$ is the value of the export from the sector *i* from a country *j*.

[7] Pulp and paper international, *Annual Review*, July 1995

Table 1.3 Pulp, paper, and board producers 1993 and 1994, by region[8]

Paper and board production (million tons)			**Pulp production (million tons)**		
Region	1993	1994	Region	1993	1994
European Union[9]	41,1	44,8	European Union	8,9	9,4
Nordic	20,7	22,4	Nordic	21,5	23,2
Other West Europe	4,6	5,1	Other West Europe	1,7	1,9
Total West Europe	66,4	72,3	Total West Europe	32,1	34,4
East Europe	8,3	8,7	East Europe	6,3	5,5
Total Europe	74,8	80,9	Total Europe	38,4	39,9
North America	94,6	99,0	North America	80,0	83,3
Latin America	11,2	11,8	Latin America	8,5	9,6
Asia	65,8	71,3	Asia	30,6	32,8
Australasia	3,0	3,1	Australasia	2,4	3,3
Africa	2,4	2,5	Africa	2,6	2,7
Total	251,7	268,6	Total	162,5	171,5

Against this background, policies focusing on innovation and on environmentally sustainable renewal of products and processes might offer one route to maintaining a dynamic and competitive European pulp and paper industry.

1.2 The Key Issues within Pulp, Paper and Paper Products

1.2.1 Technology

Paper has been produced in various forms since the dawn of civilisation. For a long time old paper, rags and cotton liner were the basic inputs for paper, which was essentially hand -made. During the last half of the nineteenth century and the first half of the twentieth century, however, a series of process innovations occurred that revolutionised the pulp and paper industry: groundwood mechanical pulping (1844), soda pulping (1851), sulphite pulping (1866), semichemical pulp (1880), Kraft pulp (1884) and thermomechanical pulp (1939)[10]. These technologies still provide the foundation of modern paper making. As in other mature, scale-intensive sectors such as steel or concrete, the emergence of information technology has contributed significantly to improving process technology in the pulp and paper industry: Of all the changes made over the past fifty years in the industry, control system designs have shown the most revolutionary changes.[11] For instance, they are the enabling factors for process management aimed at optimising the complete sales-to-delivery-cycle with respect to costs, flexibility (including the just-in-time delivery of small lot sizes), quality, and process documentation[12]. Another example is the introduction of information technologies such as CAD/ CAM and CIM into the design and

[8] Pulp and paper international, Annual Review, July 1995

[9] Finland and Sweden are in this figure included in the numbers for ‘Nordic’ (and hence not included in the EU figures)

[10] Kundrot, R., Tillman D. (1987) ‘Pulp and paper’ in *Encyclopedia of Physical Science and Technology*, vol. 11, pp. 386-402

[11] Nelson, P. (1995), ‘Tappi engineering and the paper industry- reminiscing and memories from 40 to 50 years ago’ in *Proceedings of 1995 Tappi Engineering Conference,* Atlanta: Tappi Press, pp. 1-5

[12] Leffler, N. (1993), ‘Process Control: Today and Tomorrow’ in *Proceedings of XXV. Eucepa Conference Oct. 4th-8th, 1993 in Vienna*, vol.2, Vienna: Eucepa, pp. 275-280. For a general overview, see James R. Beniger, *The Control Revolution. Technological and Economic Origins of the Information Society*, (Harvard: HUP), 1986.

manufacturing of paper products, which has significantly improved productivity in this sector and enabled the construction of new paper products with advanced features[13].

Next to chemistry and information technology as the major constituents of paper technology, life sciences and medicine have become more relevant for the pulp and paper industry during the past decades. In face of potential dangers emanating from processes with hazardous chemicals, medicine, biology, bio-technology and environmental technology are nowadays indispensable in assessing and reducing the impact of production processes and products on the human health and the environment. Moreover life sciences are employed to tackle the raw material issue in the pulp and paper industry; for example, life sciences studies are being carried out on sustainable wood fibre producing crops. Bio-technology research is developing natural fibre with reduced lignin content for efficient pulping.[14] The relevant fields of knowledge suggest a complex and deep knowledge base behind the pulp and paper sector; technology is based on a comparatively large number of sciences which are harnessed in order to solve the industry's problems. This view is also supported by inter-sectoral studies on the relevance of sciences for industries. A recent Yale study revealed that pulp and paper manufacturing ranks number three after semiconductors and measuring and controlling devices with respect to the number of technologies in use.[15] It can therefore be argued that the pulp and paper industry is neither a high-tech industry nor a low-tech industry - it may instead be considered as a 'broad-technology' industry.[16]

Another technological hallmark of the pulp and paper industry is the difficulty it faces in creating and diffusing generally applicable or even codified knowledge,[17] a feature that distinguishes this sector from those such as iron, steel, electronics or pharmaceuticals. The difficulty is rooted in the natural heterogeneity of the industry's primary raw material, wood, which is an organic fibre exhibiting a high degree of variability with respect to its physical characteristics.[18] Such heterogeneity leads to a subtle interaction among many variables which make technological problems often too elusive and multivariate for scientific methodology to offer generalised results. For example, knowledge of the mechanical properties of paper is still far from propounding comprehensive models: There are few, if any, systems where it has been possible to integrate knowledge of the behaviour of fragments of a

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[13] Bourque, J. (1987), 'CIM and flexible package conversion equipment', in *Proceedings of 1987 Tappi conference on Polymers, Laminations and Coatings*, Atlanta: Tappi Press, pp. 93-95

[14] CEPI (1995), *The European Paper Industry: Competitive and Sustainable*, Brussels: Confederation of European Paper Industries (CEPI)

[15] Klevorick, A., Levin, R., Nelson, R. Winter,S. (1995), 'On the sources of significance of inter industry differences in technological opportunities', *Research Policy* vol. 24, p. 185-204

[16] Lindström, T. (1996) 'Strategy and tactics for the pulp and paper industry's R&D' *Proceedings of 6th International Conference on New Available Technologies and Current trends,* Stockholm: SPCI, pp. 37-39

[17] Clewley et al (1995), 'Recycled fiber - the research needs', *Paper Technology*, October 1995, pp. 51-55

[18] Rosenberg, N., Ince, P., Skog, K. Platinga, A. (1990), 'Understanding the adoption of new technology in the forest products industry' in Rosenberg, N., *Exploring the black box*, New York: Cambridge University Press, pp. 233-249

system to explain the behaviour of the system as a whole.[19] The multitude of inter-related variables also become apparent in the fact that the factors affecting the performance of paper multiply with each downstream step from pulping to papermaking and conversion to its final application, for instance in a laser printer. Hence improvements with respect to better performance in the final application of paper frequently require holistic approaches that integrate the whole product chain in innovation processes: suppliers, papermakers, converters, and end-users.[20] Innovation in this sector thus tends to involve strong user-producer interactions.

Finally - and closely related to the previous points - the high complexity and heterogeneity also account for a considerable time to market for innovations: For major technology advancements, the research and development phase generally requires about ten years, and even incremental changes need some time because intensive testing in pilot scale in often indispensable in order to reduce the risk of huge capital investments into new technology. [21]

1.2.2 The Environment.

Due to legislative concerns and market awareness of ecological issues, the importance of 'ecological competitiveness'[22] will grow in the future. One the one hand, the minimisation of ecological risks arising from the production of pulp and paper has gained relevance in the face of stringent legislative measures and potentially large claims for damages. On the other hand, much of the future of paper depends on re-using waste paper, so that virgin forests are preserved and landfills reduced. And last but not least, a favourable ecological company image has become a successful marketing tool.[23]

The use of recycled fibre as an input in paper making is a major environmental issue, and the use of waste paper in relation to virgin fibres is continuously increasing. The potential of recycling is highly dependent on geographical location, which makes it a strategic location issue as well. Recycled fibres have traditionally been used in production of bulk grades such as newsprint, packaging products, and tissue. It is commonly expected that in the future the use of recycled fibre will also extend to higher value-added grades, such as coated magazine paper. One reason for this is the green image of recycled material based products. Recycling is an important source of innovation as well, since new technologies are required to enable efficient, less energy-consuming production.

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[19] Steenberg, B. (1983) ' The role of fundamental research on knowledge of the mechanical properties of paper' in *The Role of Fundamental Research in Papermaking,* London: The British Paper and Board Industry Federation, Vol 1. pp 103-114

[20] Meixner, M., Ramaswamy, S. (1994), 'A conversion and end-use approach to alkaline fine paper size development' *Proceedings of Tappi 1994 Papermakers Conference,* Atlanta: Tappi Press, pp. 559-563

[21] Trice, W. (1992), ' Keynote address [to the workshop]' Proceedings of the Workshop *Paper Industry Research Needs*, May 26th-28th, 1992, sponsored by Tappi. Atlanta: Tappi Press

[22] M. Diesen, CEO of Enzo Gutzeit OY in the lecture 'Enterprise Forum' held at Helsinki University of Technology Jan. 30th, 1995

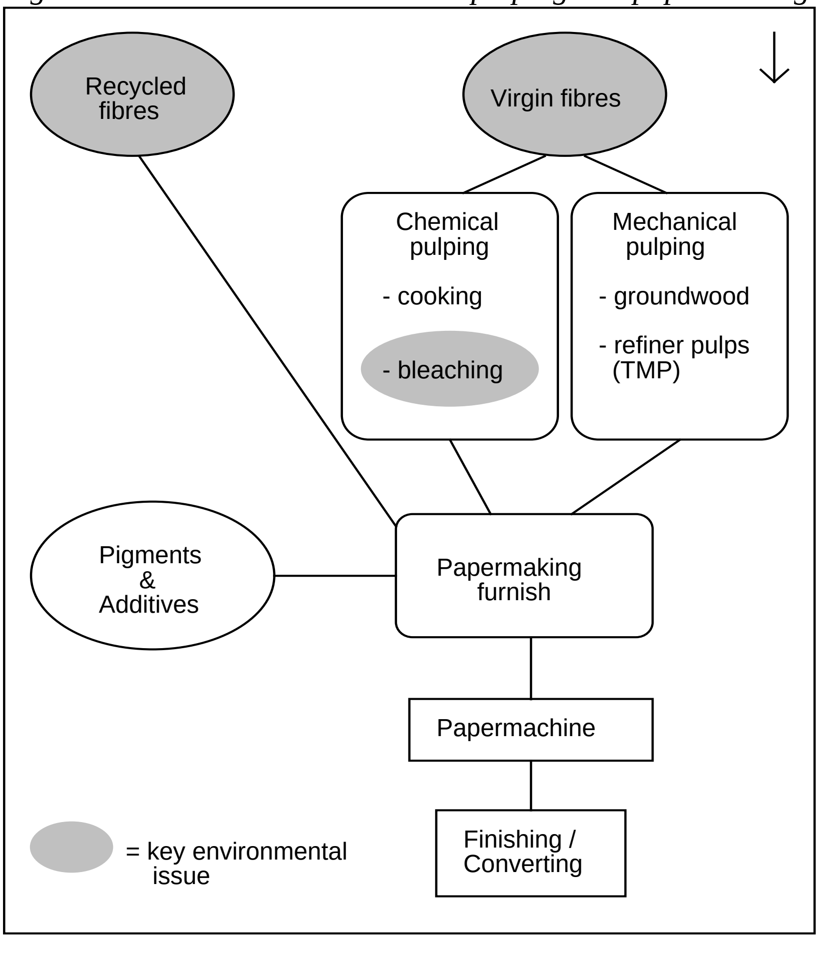
[23] FAZ (1996): 'Schwedischer Zellstoffhersteller mit geschlossenem Wasserkreislauf' in *Frankfurter Allgemeine Zeitung*, June 3rd,1996, p.20

The reduction of waste is likely to shrink the total volume of packaging in future but, on the other hand, paper as natural polymer is an advanced material with a considerable intrinsic potential,[24] one that offers several ecological advantages over other materials[25]:

> "Paper and board packaging not only have favourable strength and weight characteristics while in use but they are also flexible and simple to transport after disposal. In addition they are based on the same raw materials which facilitates sorting. Finally, the fibre can be reprocessed several times relatively cheaply. For these reasons, paper and board will continue to replace other packaging materials such as plastics or wood"[26].

Hence the future of paper as a packaging material appears to be positive, whereas its use as a means for the transport and storage of information may decline in future.

Figure 1.2: Environmental issues in pulping and paper making



'The totally closed process circuit' for recycling and pollution control represents another important scenario and spur to innovation in the pulp, paper and paper products industry. During the last decades the strain on lakes, rivers, and seas from

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[24] CEPI (1995), *The European Paper Industry: Competitive and Sustainable*, Brussels: Confederation of European Paper Industries (CEPI)

[25] Ehrhart, K. (1993), 'Wie sieht die Verpackung der Zukunft aus' *Das Papier* vol. 10, pp. V93-V95

[26] Martin-Löf, J. (1995) 'An industry under continuous change' *Papermaker* vol. 22 June 1995, pp.

pulp and paper mills has decreased dramatically in Europe, even as production capacities have expanded. The major loads of water effluents originated from bleaching of chemical pulp, which was traditionally carried out by using chlorine. Recently however, new bleaching methods have been developed, chlorine has been replaced, and ECF (Elemental Chlorine Free) and TCF (Totally Chlorine Free) pulps and papers have emerged to the market. The aim of this ongoing change process is in fact to totally close the process loops in bleaching, after which a total closure of mills' waste water systems could become possible. Total closure still contains many problems, and it may take some years before all of them are solved. But progress in this field has been very rapid, and a mill without waste water may eventually become feasible in the near future. To sum up, innovation is a key issue linking cleaner processes, better environment, improved resource productivity as well as improved competitiveness in the pulp and paper industry.

1.2.3 Raw Materials

Access to raw materials, timber in particular, and the technical ability to exploit raw materials, continues to be a dominating factor for competitiveness in the pulp and paper industry. The importance of raw materials can be seen in terms of costs for wood, which make up between 45% and 65% of the final price for pulp and paper.[27] Depending on their location, enterprises in the pulp and paper manufacturing sector in Europe face different supply conditions. Traditionally Scandinavian and North American producers had a favourable supply situation in their home countries with abundant deposits of softwood which is well-suited for the manufacture of pulp and paper. The favourable endowment with raw material has certainly contributed to the fact that Scandinavian companies account for half of the current pulp production in Europe[28]. But advances in the processing of hardwood fibres have created also opportunities for countries in other regions of the world. In Europe Iberian producers could considerably expand their pulp production based on fast-growing and cost efficient eucalyptus being cultivated in plantations. Paper factories in other European countries still have to buy a large part of their pulp internationally and are thus more subject to considerable price fluctuations on the international market that is dominated by Scandinavian, North American and South American producers. In recent years, supply pressures have meant that both producers and users of pulp based on virgin fibres have faced criticism concerning clear-cutting, leading to decrease in the variety of species, and the destruction of rain forests in other parts of the world.[29] These ecological issues and long-standing pressures to reduce costs have spurred efforts to intensify the use of other raw materials in paper making processes. It is in this that the importance of recovered fibres lies. Since recycling is demanded by consumers and politicians and moreover because re-use is important for the economics of the sector, fibres recovered from waste paper continue to replace virgin fibres in paper: Nowadays packaging and cartons consist of almost 100% recycled fibres, and the re-utilisation rate in other paper product categories is expected to grow further in the future. However, logistic difficulties in the collection and supply

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[27] Maspons, R., Escorsa, P., Colom, J. (1993), *La gestión de la tecnología en el sector de las pastas y papel*, Terrassa (Spain): Universitat Politècnica de Catalunya, p. 2

[28] Sundquist, J. (1995), 'Wirtschaftliche Aspekte der Zellstofferzeugung im europäischen Maßstab', *Wochenblatt für Papierfabrikation*, pp.. 137-140

[29] reported for the UK in Cockram, R. (1994) 'UK - still well ahead of Europe' *Papermaker* vol. 14, pp. 14-15

with appropriate waste-paper grades and technological limitations will create certain bounds for the share of secondary fibres in paper.[30] Technological limitations arise from the gradual degradation of fibres during the recovery process, which adversely affects the quality of the resulting end product, and from the impracticability of replacing virgin fibres in wood-free paper grades. Hence virgin fibres may be diminished in their overall importance but they continue to be an significant part of the feedstock for paper.

1.2.4 Economies of Scale and Business Cycles

A main factor driving competition in the whole pulp and paper industry is economies of scale in conjunction with high capital investments and sunk costs; there are thus both entry and exit barriers in the paper manufacturing sector. After mining, crude oil and building materials, the forest products industry ranks third with an average capital intensity of 1.3 in 1992, measured by the total assets to sales ration.[31] The technological optimum is about 1,000 tons of paper per day for full chemical mills and 200-400 tons of paper for semi-chemical or mechanical mills.[32] The investment for a state of the art plant of that size totals between 0.5 and 1 Billion US $, a figure that is roughly equivalent to the plant's likely sales over three years.[33] On the other hand, the installation of such additional production capacity can cause imbalances between supply and demand.[34] Particularly during periods of recession, the pulp and paper industry suffers then from considerable over-capacity, leading to major price fluctuations.[35] The severe economic recession of the early 1990s illustrated well the significance of this over-capacity problem: due to very optimistic forecasts of market development, and relatively easy financing conditions in the early 1980s, Scandinavian and North American firms built new, larger, and more efficient pulp and paper mills whose additional capacity exceeded what the still-growing market of the 1980s could absorb. In 1992, the average over-capacity rate in Europe reached 87,9%, with even higher values in the newsprint segment.[36] As a result, price erosion for pulp and paper, particularly for the commodity grades, assumed dramatic proportions. Such sharp upswings and downswings characterise cyclical patterns in the pulp and paper industry. An econometric model of the past 30 years shows that there are 18 +-2 years between severe recessions and 4,5 +-1 years between rapid expansions.[37] In the wake of falling prices profitability collapsed, and severe losses were reported by many major players, causing crisis for many companies whose investment had largely been debt financed. It has been suggested that the

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30 Göttsching L. (1993), 'Steigerung des Altpapiereinsatzes unter dem Einfluß von gestetzlichen Maßnahmen in Deutschland', *Wochenblatt für Papierfabrikation* vol. 5, pp. 149-156

31 *Fortune 500*, 1992

32 Kundrot, R., Tillman, D. (1987), 'Pulp and Paper' in *Encyclopedia of Physical Science and Technology*, vol. 11

33 Trice, W. (1992), ' Keynote address [to the workshop]' Proceedings of the Workshop *Paper Industry Research Needs*, May 26th-28th, 1992, sponsored by Tappi. Atlanta: Tappi Press

34 CEPI (1995), *The European Paper Industry: Competitive and Sustainable*, Brussels: Confederation of European Paper Industries (CEPI)

35 Clark, D (1994), 'Zukünftige Marktbedingungen für gestrichenes *Papier' Wochenblatt für Papier-fabrikation* vol. 6, pp..201-204

36 Eurostat (1994), *Panorama of European Industry1994*, Luxembourg: Office for Official Publications of the European Communities, pp. 16-1 - 16-10

37 Croon, I. (1995), 'The pulp and Paper Industry - a dynamic but cyclic affair', *Papermaker* Jan. 1995, pp. 24-27

Governments of Finland and Sweden even felt obliged to devalue their currencies in order to step up export for their severely hit paper industry[38]. In contrast to what might be expected from lower prices for paper during the recession, the conversion sector could not achieve higher profit margins since labour, transport and energy costs simultaneously increased dramatically.[39]At the same time, the conversion industry's principal customers - distributors, retailers and food processors - have become more powerful negotiating partners following the advent of the single European market, and were able to enforce lower prices for paper products upon suppliers in the paper conversion industry.[40]

Besides cyclical fluctuations, the continuing internationalisation of markets on the European and global level has further increased the pressure for change in this historically conservative industry. The situation has induced consolidation in the industry manifested in two developments. Firstly, investment in new technology and improved efficiency, a process mainly spurred by the inroad of Scandinavian companies into the EU market. In the face of higher labour costs and lower general productivity, many EU manufacturers adapted the strategies of these new entrants and introduced new production techniques and process innovations. This upgrade was accompanied by numerous shut-downs of old, inefficient mills throughout Europe and increases in the average operating size of remaining plants, which often required the replacement of old machinery: The result is a rather modern production base: a third of the total current production capacity was installed in the past decade.[41]

Intertwined with upgrading of the production base is increased concentration in the pulp and paper sector. Swedish and Finnish groups have been particularly active, acquiring both paper mills and paper conversion production units throughout the EU.[42] In 1994 some 20 companies held nearly 55% of the European industry capacity in the manufacturing sector, which represents a major change since 1980. Similarly the cross-border ownership of paper companies in the EC increased from 22 per cent in 1976 to 45 per cent in 1994.[43]

The above factors have induced a general strategic move from production-oriented cost- and quality strategies into market-oriented differentiation strategies with a focus on value-added products for key customers in a rapidly changing market.[44] This strategic shift also entails more emphasis on corporate specialisation and

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[38] Henning, H. (1994), 'Marktbedingungen der Zukunft für gestrichenes graphisches Papier - Am Beispiel holzfrei gestrichener Papiere' *Wochenblatt für Papierfabrikation* vol. 6, pp..205-212

[39] Eurostat (1994), *Panorama of European Industry* Luxembourg: Office for Official Publications of the European Communities, pp. 16-10 16-16

[40] Eurostat (1994), *Panorama of European Industry* Luxembourg: Office for Official Publications of the European Communities, pp. 16-10 16-16

[41] CEPI (1995), *The European Paper Industry: Competitive and Sustainable*, Brussels: Confederation of European Paper Industries (CEPI)

[42] Cockram, R. (1993), 'Mergers and acquisitions in Europe' *Papermaker* Oct. 1993, pp. 24-25

[43] CEPI (1995), *The European Paper Industry: Competitive and Sustainable*, Brussels: Confederation of European Paper Industries (CEPI)

[44] Croon, I. (1995) 'The Pulp and Paper Industry - a dynamic but cyclic affair' *Papermaker* January 1995, pp. 24-27

concentration on core businesses. In order to exploit the advantages arising from high added value products and high technological content papers, companies are expanding export towards a global market.[45] At the same time rationalisation and efficiency increases continue to be a key strategic element in the pulp and paper industry in order to sustain competitiveness.[46] Concentration in the pulp and paper industry is likely to continue: industry experts such as Magnus Diesen of the Finnish Enzo Gutzeit group believe that on the long run only two types of companies will be successful.[47] In his view, large companies with annual sales revenue over ca. 4 billion US$ will prosper through economies of scale and small producers with sales less than ca. 500 million US$ through specialisation and flexibility. Medium-sized companies manufacturing bulk products, on the other hand, will find themselves under increasing pressure.

1.2.5 Substitutes

Due to the variety of applications, most of the pulp and paper grades and the products made from them are imperfect substitutes. However, there are substitutes from outside the sector which are likely to have a discernible impact on the consumption of paper: A serious threat is constituted by information technologies that have revolutionised communications. So far the "paperless office" is not yet realised and printed media still dominate the communications market, accounting for around 60% of its current value.[48] But the digitisation of information potentially allows electronic information to gradually win more and more ground, and the market for graphics papers may therefore become more difficult in the future.[49]

1.3 Product Strategies

The strategic options of companies in the pulp and paper industry depend very much on the segments in which they operate. Traditional bulk products such as standard newsprint, standard market pulp, liner board or ordinary sack paper are in the mature or even declining phase of their product-life-cycle; they are traded as commodities with well-specified properties on the international market (which thus continues to be highly speculative and cyclical). The nature of these products permits no other strategy than maintaining a competitive cost structure. Cost minimisation has taken several forms. Firstly firms have increased the size of plants in order to achieve cost advantages through economies of scale. The second strategy aims at integrating the production of pulp and paper and hence achieving advantages through economies of scale and scope, and more predictable costs for pulp.[50] A third focus is on minimising the cost of raw materials. Scandinavian producers have concentrated on sustained yield management of their forests whereas the focus in continental Europe is on

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[45] Soulas, A. (1994), 'The paper industry - global strategies in the post recessionary era' *Paper Technology,* Nov. 1994, pp. 37-41

[46] Maspons, R., Escorsa, P., Colom, J. (1993), *La gestión de la tecnología en el sector de las pastas y papel*, Terrassa (Spain): Universitat Politècnica de Catalunya, chapter

[47] M. Diesen, CEO of Enzo Gutzeit OY in the lecture 'Enterprise Forum' held at Helsinki University of Technology Jan. 30th, 1995

[48] Navin B.(1995), 'Beyond 2000: Is there a future?', *World paper*, vol 220, pp. 73-75

[49] Camels, P., Harris, R. (1994) 'Paper's future is held up on the superhighway' *Pulp and Paper International* Dec. 1994, pp. 47-51

[50] Maspons, R., Escorsa, P., Colom, J. (1993), *La gestión de la tecnología en el sector de las pastas y papel*, Terrassa (Spain): Universitat Politècnica de Catalunya, chapter 4

utilising the waste paper, which is amply available at low costs in urban regions.[51] Since distribution costs can also be reduced with mills close to their markets, the industry is increasingly interested in so called mini-mills. These mills are low tonnage facilities which use a single fibre line and which can be built at much lower costs than large scale mills for virgin-fibres.[52] In the face of the dramatic expansion of pulp capacity in low cost regions such as Latin America, firms in this segment will be forced to consolidate their position in a market segment whose business fundamentals are strong balance sheets and flexibility in order to survive periods of low prices. Mergers and acquisitions continue to be a major strategic tool to achieve this objective. In addition increasing numbers of firms attempt entry into value-added products.[53]

Printing and packaging paper can be characterised as semi-commodity segments, which offer some possibilities for differentiation. For instance, differentiation in the publications paper segment has mainly been achieved through offering a better service level to end-users, the printing companies, in form of a wider range of quality grades.[54] However, the development of new paper grades in this segment is costly, so that smaller firms are at a disadvantage in servicing key accounts. Therefore, this segment is also characterised by mergers and acquisitions and a certain degree of exit.

Due to the highly fragmented market without large single customers, the strategic direction in the office paper segment is more on product development and diversification into new markets, for example in paper for colour laser printers. In general, there is a tendency to offer products with high quality and unique value for a distinct end-use. Success in this segment is dependent on a number of factors. Initially, the basic building blocks must derive from excellence in the manufacturing of fine paper, i.e., advanced coating technology, watermarking, and security systems, which can only be sustained through an emphasis on technological enhancement and R&D. Besides the ability to continuously upgrade the production process, the creation of brand names, and the management of efficient distribution systems with an international scope are important success factors.[55] It is obvious that smaller firms will increasingly face problems in raising the necessary resources, while producers from developing countries are more and more able to attack the European market in less value-added segments. In this context mergers and acquisitions are likely also to remain an important strategic tool in the fine paper business.

Other high-value added segments such as speciality papers and containerboard are highly fragmented and in the latter case also of fairly local nature because the high volume to weight ratio poses logistical problems. The predominant strategy in this segment is focused on product differentiation in the form of identifying and serving the needs of local customers. However major pan-European multinational users, such

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[51] Thunberg, J. (1993), ‘Entering the age of the tree’ *Papermaker* March 1993, p. 43

[52] Kinstrey, R. (1993) ‘Mini mills: the beginning of a new trend’ *Proceedings of 1993 Tappi Engineering Conference*, Atlanta: Tappi Press, pp.. 895-899

[53] Martin-Löf, J. (1995) ‘An industry under continuous change’ *Papermaker*, June 1995, pp. 22-26

[54] Martin-Löf, J. (1995) ‘An industry under continuous change’ *Papermaker*, June 1995, pp. 22-26

[55] Soulas, A. (1994), ‘The paper industry - global strategies in the post recessionary era’ *Paper Technology*, Nov. 1994, pp. 37-41

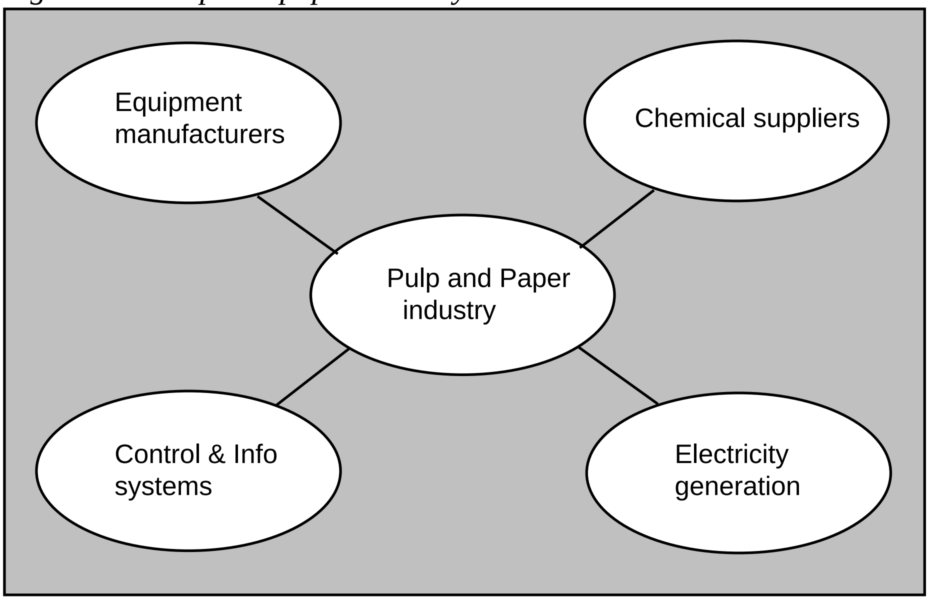
as Procter & Gamble, Philip Morris, or Nestlé currently prefer to purchase all their packaging for the European market from one or two suppliers, so these segments also show a trend towards concentration of large players with strong development capacities. Other high value-added such as hygienic paper already exhibit a high level of concentration with a strong presence of global players such as Procter & Gamble and Scott Paper in the European market. The strategic direction in this segment is towards product development for specific markets:[56]

> "Looking at a significant area of growth in our industry over the past two decades - cut size business papers, form bond, computer grades, Fax paper - we need to realise that these markets did not develop as a result of anything that we did. Let's not forget that this volume growth was driven by technology developments outside our industry"[57]

1.4 The Pulp, Paper and Paper Products Industry Cluster

We have argued that in spite of its relatively low-tech and smokestack image, the pulp and paper industry is highly technology intensive, and often characterised by strong links between related industries. Together, these constitute an industry cluster, in which inter-sectoral complementarities and related knowledge flows constitute an important driving element of technological change. The industries belonging to the pulp and paper industry cluster are illustrated in figure 1.3.

Figure 1.3: Pulp and paper industry cluster



As for the pulp and paper producing companies themselves, they can be structured in many different ways. Pulp and paper mills can be either integrated (pulp- and paper mills in close proximity of each other, with pulp going directly to the paper mill) or non-integrated (pulp mill sells to, and paper mill buys from the world market). The importance of related and supporting industries may differ to some degree,

56 Martin-Löf, J. (1995) 'An industry under continuous change' *Papermaker*, June 1995, pp. 22-26

57 Trice, W. (1992), ' Keynote address [to the workshop]' Proceedings of the Workshop *Paper Industry Research Needs*, May 26th-28th, 1992, sponsored by Tappi. Atlanta: Tappi Press

depending on how the company is structured. From certain raw material based points of view, the mechanical forest industry (saw milling etc) can be a very important related industry as well, although not presented in figure 1.3, mainly because sawmill waste (wood chips) constitutes an excellent raw material for pulping. There are also important differences between countries. In Scandinavia, for example, the relationships between pulp and paper producers and their suppliers have traditionally been very close[58].

The distinction between the paper and board manufacturing and paper and board conversion industry is not easy to make. Increasingly, the major European paper producing manufacturers integrate forward into the production chain. As such, they become active both in paper production and in paper conversion. Still, the paper and board conversion can be classified as a kind of 'sub-cluster' of the pulp and paper industry cluster. Conversion operations start when paper or board has left the manufacturer, and conversion ends when the final consumer product is ready. According to this generally accepted definition, pigment coating of printing paper is a papermaking operation. Calendering, winding, and packaging of paper are regarded as finishing operations of papermaking. Sheeting, on the other hand, is a conversion operation. In the past, printing was considered to be a conversion operation, but today it is most often considered as an industry of its own (and is thus classified in NACE). Still, almost all production lines of paper conversion include some kind of printing stages, so it may sometimes be difficult to draw the line precisely between different industries.

The conversion industry differs from actual pulp and paper making in many respects. Conversion plants do not usually require large capital investments, and the whole industry is much less capital intensive than is pulp and paper manufacturing. In technological terms, the conversion sector is also usually less complicated and less sophisticated than paper and board production. Modern paper machines, for example, incorporate a wide variety of advanced technologies, whereas conversion plants often use well-established conventional methods. Typical conversion companies in many countries are rather small in size, and they may not perform substantial R&D activities.

The largest group of paper and board conversion companies is constituted by packaging companies. Operations of packaging manufacture include, e.g., creasing and die cutting of board, lamination and extrusion coating processes, corrugation of board, gluing and sealing as well as final case or box making. Several conversion phases are usually needed, because packages are required to have certain resistance properties against light, different chemicals, gases, and liquids. Converters are naturally rather dependent on the suppliers of paper and board, chemicals, and equipment. The suppliers of chemicals and equipment are usually quite specialised, and are not the same for converters and paper producers.

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58 Ojainmaa K. (1994), International competitive advantage of the Finnish chemical forest industry, Helsinki, ETLA C 66, p. 63

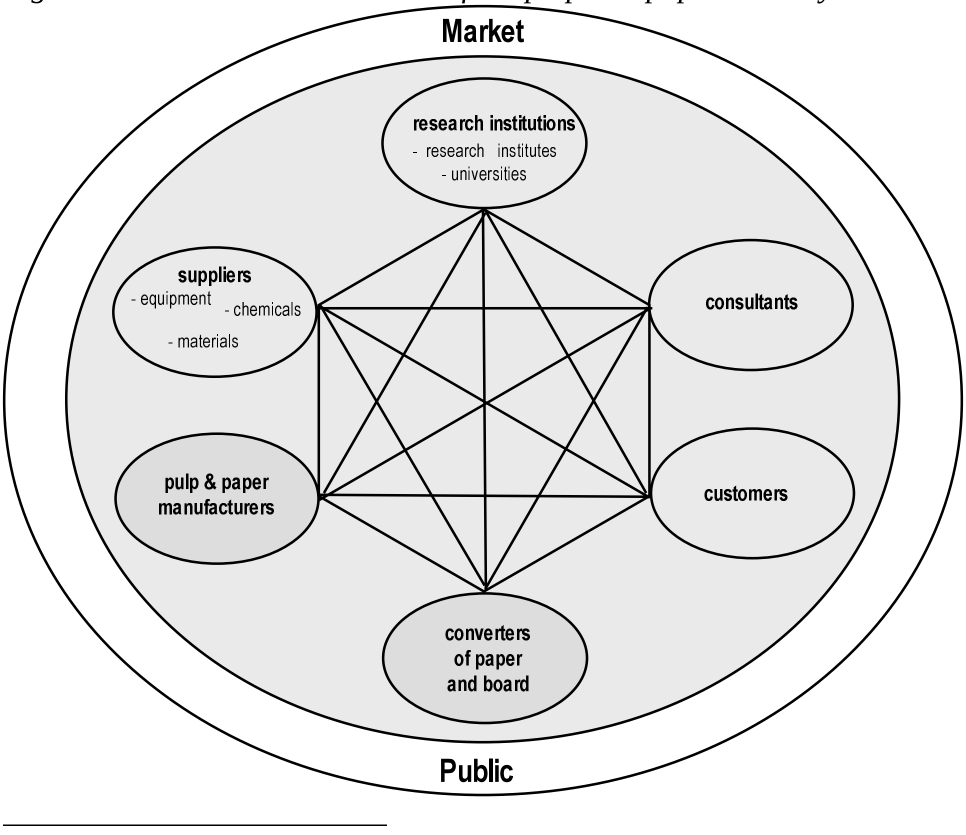
1.5 Structure of the Innovation System

Perhaps more than in most other industries, innovation in the pulp and paper industry is truly a systemic phenomenon. The way innovations develop and proceed in the pulp and paper industry cluster is usually not simple. The basic structure of the industry cluster and related innovation links are illustrated in figure 1.4. The main actors participating in the network and their general relations, are discussed below.

1.5.1 Actors

The necessity of mastering a broad palette of technologies in the pulp and paper industry requires a symbiotic relationship with customers, research institutes, and industries belonging to the pulp and paper industry cluster because the different technologies cannot be developed by the industry alone.[59] The technology needed in the pulp and paper sector can be classified into three categories. Firstly, there are straightforward transplantations of technology developed outside the pulp and paper industry cluster such as power generation or electrical drive technology. Secondly, adapted technology which is used in the pulp and paper industry with some changes. Examples are control systems with modified sensors, or screening and cleaning technologies. Thirdly genuinely pulp and paper specific technology such as the development of head boxes, systems analysis, and devices for control and optimisation of the manufacturing process.[60] Technologies of category two and three are predominantly developed within the pulp and paper industry cluster. The main constituents of this industry cluster are depicted graphically in Figure 1.4.

Figure 1.4: The main constituents of the pulp and paper industry cluster



[59] Lindström, T. (1996) 'Strategy and tactics for the pulp and paper industry's R&D' *Proceedings of 6th International Conference on New Available Technologies and Current trends*, Stockholm: SPCI, pp. 37-39

[60] Wahren, D. (1983), 'The Role of Fundamental Research in the Manufacture of Paper' *The Role of Fundamental Research in Papermaking*, London: The British Paper and Board Industry Federation, Vol 1. pp. 77-103

The lines drawn between all members in the cluster aim at characterising the institutional structure of innovation, which is extremely variegated and involves a complex network of backward, forward, horizontal and lateral relationships and linkages among firms and organisations such as universities or research institutes. Information exchange relies very much personal and contractual relationships among individuals and organisations within the technological system. Various trade shows, conferences and more than 110 professional journals world-wide mediate communication and information exchange in the pulp and paper business. [61]

1.5.2 The Pulp, Paper and Paper Products Industry

Although the majority of hardware embodied technology is furnished from supplier industries, enterprises in the pulp and paper sector assume a central role for innovations in the industry: they manufacture innovative products and use innovative process technology in their plants. Here we identify five major roles of the pulp and paper industry in the industry's systemic innovation system:

Firstly, due to their proximity to the actual production process, operators and other front-end actors represent a primary source of user knowledge about pulp and paper technology. Often tacit and person embodied, this experience provides a valuable source of information for improvements.

Secondly, many pulp and paper companies create knowledge on pulp and paper technology through research and development on an occasional or continuous basis. As a reflection of the systemic nature of paper technology, R&D intensities tend to be low, though. In their 1980 cross-sectoral R&D statistics, the OECD places the pulp and paper industry at the lower end of the lower category, with R&D expenditures of 0.3 percent of output.[62] Mawson distinguishes four types of R&D in the pulp and paper industry: a) continuing support for the enterprise's activity, b) provision of fundamental research behind existing business, c) development of major new products and processes for existing businesses, and d) provision of support for new business diversification.[63] R&D of type a) is basically oriented to solving specific and well-perceived business problems with a short term focus whereas types c) and d) are of longer term character and represent higher risk. Due to higher cost efficiency, the bulk of R&D in the pulp and paper industry has an applied character and is directed towards attaining concrete goals that support the company's business objectives. This implies a relatively small possibility for public support or a public role. Commercial success ordinarily goes beyond what can reasonably be attained by a public agency: fine tuning the product design and characteristics to satisfy the specific needs of specialised categories of users, as well as improving process and machinery are activities in which publicly-supported research agencies have only a modest capability.[64] The research activities of Smurfit provide a picture of typical research activities: a systems engineering project, which included trying out vendor's equipment in pilot plants and recommendations for a system to be installed, the evaluation of technologies dealing with the strength and graphic properties of

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[61] see Birkner, *1996 European and International Paper World - Directory of the Paper industry*, Hamburg: Birkner Verlag

[62] OECD quoted in OECD (1994): *Technology and Economy - The Key Relationships* Paris:OECD

[63] Mawson, A. (1983), 'Organization requirements for innovation and economic growth' in *The Role of Fundamental Research in Papermaking*, London: The British Paper and Board Industry Federation, vol 2. pp. 1079-1087

[64] Rosenberg, N., Ince, P., Skog, K. Platinga, A. (1990), 'Understanding the adoption of new technology in the forest products industry' in Rosenberg, N., *Exploring the black box*, New York: Cambridge University Press, pp. 233-249

recycled paper, research on the performance of cartons and containers in which they are transported to the end-user, the development of an optimal gluing pattern for carton in collaboration with a customer, the joint development with an adhesives producer to develop a glue that does not hinder recycling, or the analysis of taste and odour problems with food products.[65]

A third major role of the pulp and paper industry is the organisation of innovation projects that usually involve a number of players. For instance, typical activities in capital projects of the pulp and paper industry comprise market studies, feasibility studies, risk assessment, the development of specifications, and the selection of suppliers. These projects typically involve both management and engineering activities, often in collaboration with suppliers and consultants.[66]

A fourth role of the pulp and paper industry is the provision of pulp and paper machinery for the trial production and testing of innovations originating from supplier industries or research institutions, provided that a pulp and paper company has a stake in such projects. The reason for this kind of producer-user interaction rests with the high capital costs for pulp and paper equipment and the variety of processes and products. This prevents many, particularly smaller, suppliers from carrying out these activities in-house. Hence the nature of this relationships fits well to Rosenberg's notion of 'technological convergence' or 'vertical disintegration'.[67]

The fifth role of the pulp and paper industry consists of funding for the research institutions operated by the industry. These institutes with a focus on pre-competitive research usually receive large part of their budget from the pulp and paper industry. In turn the industry delegates representatives in the supervisory boards of those institutions and hence influences objectives and fields of research.

1.5.3 Research Institutes

A considerable share of research on pulp and paper technology is carried out in research institutes. Due to their collective character, research institutes are mainly concerned with pre-competitive research that may range from fundamental investigation to applied research and development on behalf of the pulp and paper industry and their supplier and customer industries as well as government organisations. Nevertheless some of them also offer contract research and consulting services, so that they are at times involved in competitive research for particular companies. The rationale for collective research in the pulp and paper technological system has several aspects. Firstly, the industrial problems are to a great extent the same for different pulp and paper companies, or groups of companies. For example there is a need throughout the industry to reduce water and air pollution, to improve energy efficiency, or to make a better use of wood supplies and waste paper. Consequently there is good reason to carry out necessary research work, whether

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[65] Marley, M. (1995), 'Smurfit R&D shifts the emphasis to pro-active development' *Paper Technology* Jan./Feb. 1995, pp. 29-33

[66] Johnson, J. (1995), 'Phases of a project concept' in *1995 Tappi Engineering Conference*, Atlanta: Tappi Press, pp.. 629-630. Townsend, D. (1995), 'Translation of business objectives into engineering requirements and design criteria' *in 1995 Tappi Engineering Conference*, Atlanta: Tappi Press, pp.. 631-644

[67] Rosenberg, N. (1976)

fundamental or applied, in cooperation at collective research institutes. A second aspect favouring collective research is the manpower intensity of research. Generally speaking, basic investigation requires high inputs whereas its results are characterised by a high degree of uncertainty (and perhaps inappropriability) with respect to pay-offs. Therefore enterprises tend to focus their research activities on those fields of applied character where R&D investments promise tangible returns in the short and medium term. Thirdly the number of relevant technologies and the increasing complexity and cost of research instruments, e.g. pilot machinery, are factors which mitigate against companies undertaking R&D entirely in-house.[68]

In recent years, contract research projects have gained importance throughout the pulp and paper industry, in spite of potential difficulties in appropriating the results of such investigation. According to Ehretsmann, there are three major motivations for enterprises contracting with research organisations.[69] Firstly, firms with low or no enterprise R&D utilise the research organisation for undertaking necessary research. Secondly, companies use research institutes for solutions to a particular problem. Thirdly enterprises may be attracted by innovations proposed by the research institute.

Almost all European countries have research institutes concerned with research and development for the pulp and paper industry. These institutes are either independent establishments, such as PIRA in Great Britain or the Centre Technique du Papier (CTP) in France, or they are part of larger institutions such as the paper department of TNO in Holland or the IFP at Darmstadt University of Technology in Germany. The funding of these laboratories is based on government support, or is mixed, with joint industry and government contributions. The contributions of the industry are made up of research contracts and subscriptions by member firms, the latter often being linked to annual production or sales volume.[70] National public support has increasingly been supplemented by EC/EU sponsored programs since the late 1970s.

The fields of research and the resource endowment of research institutes across Europe are frequently country specific. The varying importance of the pulp and paper sector, and the product specialisation patterns within the national economies are major determinants of this. Finland and Sweden dispose of the most developed research infrastructure, with KCL in Finland and STFI in Sweden being the two biggest research institutes in Europe. These institutes cover almost the full range of research areas in pulp and paper technology. Finland also possesses the largest number of university faculties concerned with pulp and paper technology. Research institutes in other countries are more limited with respect to the breadth of R&D activity. For example, PIRA in Great Britain and SIVA in Italy concentrate on the

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[68] Martin-Löf, R. (1983), 'The role of fundamental research in paper-making' *The Role of Fundamental Research in Papermaking,* London: The British Paper and Board Industry Federation, vol 2. pp. 973-983

[69] Ehretsmann, J. (1983), 'The Role of contract research laboratories in fundamental paper making research' *The Role of Fundamental Research in Papermaking,* London: The British Paper and Board Industry Federation, vol 2. pp. 1063-1069

[70] Göttsching, L. (1983) 'Research and development activities for the pulp and paper industry in the EEC countries' in *The Role of Fundamental Research in Papermaking,* London: The British Paper and Board Industry Federation, vol 2. pp. 973-983

paper, board, conversion and packaging sectors.[71] This focus can be explained by the fact that there is virtually no pulp production in these countries. Research activities in Germany, on the other hand, are much more dispersed over several universities and institutes, reflecting the Federal structure of the country.

Another noteworthy aspect is the distribution of responsibility between university institutes and other research establishments. Due to their academic nature the aspect of commercial applicability is less dominant for universities, with researchers enjoying more freedom to select research activities according to personal interests; such research relates at most to pre-competitive phases. A basic role of universities and other institutes of higher education is education and training of future scientists and engineers, and direct collaboration with the industry tends to be subordinate to this function. Finally, most university institutes lack the capacity to develop larger scale processes or equipment with the given resources of capital, personnel, space etc. Industry practitioners emphasise another interesting aspect: It is more difficult to organise collaboration in a big project between several university institutions than with collective institutes that have generally much more effective two-way communications with the industry, through advisory industrial committees and organised information systems.[72]

Notwithstanding their limitations, universities are an indispensable part of the innovation system. Firstly, through their formation of future scientists and engineers, universities assume a central role for the creation of human capital and secondly academic freedom provides the appropriate atmosphere for creative ideas with the potential for revolutionary change. Thirdly, compared to other possibilities, university research is available at relatively low cost.[73]

1.5.4 Suppliers of Equipment, Chemicals and Raw Materials.

The importance of supplier industries for innovations in the pulp and paper industry can be seen by the fact that the costs for equipment and materials constitute between 60% and 70% of the total costs of capital projects[74]. The pulp and paper industry usually does not manufacture its equipment or chemicals because costs for in-house manufacturing tend to be higher with respect to capacity requirements, competence, and quality. Van Hippel provides a complementary explanation that also applies to pulp and paper technology: ”When manufacturers of a given category can reasonably expect to sell many more of a given process machinery innovation than any single

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[71] Göttsching, L. (1983) ‘Research and development activities for the pulp and paper industry in the EEC countries’ in *The Role of Fundamental Research in Papermaking,* London: The British Paper and Board Industry Federation, vol 2. pp. 973-983

[72] Martin-Löf, R. (1983) ‘The Role of Fundamental Research in Paper-Making’ *The Role of Fundamental Research in Papermaking,* London: The British Paper and Board Industry Federation, Vol 1. pp 973-985

[73] Maspons, R., Escorsa, P., Colom, J. (1993), *La gestión de la tecnología en el sector de las pastas y papel*, Terrassa (Spain): Universitat Politècnica de Catalunya, chapter 6

[74] Knight, R. (1995) ‘Focus on business objectives in project planning’ 1995 Tappi Engineering Conference, Atlanta: Tappi Press, pp.. 621-624

large user can utilise then process machinery manufacturers will be found to be the source of innovation in that category of process machines"[75].

Equipment manufacturers have traditionally played an important role in the pulp and paper industry cluster. This remains the case today although their role in capital projects has undergone a certain shift. For the first two or three decades of the post-war expansion, most capital projects were engineered and designed (and sometimes constructed) either by independent design firms or by the in-house engineering staff of the pulp and paper company involved. Usually vendors were limited to providing equipment and contractors to equipment erection and to construction. The procedure has gradually changed to the point where many, if not most capital projects are performed on a lump sum, turnkey basis, either by equipment vendors or independent contractors.[76] This historic perspective points to the general tendency in the strategies of larger equipment manufacturers to offer value-added products to the customer and to establish long lasting relationships with clients. Maspons et al note in their study on technology management in the pulp and paper industry that companies tend to buy the main components of technology from one major supplier which has gained good reputation and which has proved in the past able to offer a broad range of products with high quality and service, and to develop and transfer new technologies.[77] In practice, after-sales service has become as important as the supply of machinery, and the role of equipment manufacturers can more and more be viewed as that of a problem-solver with respect to the specific needs of a plant.

The world's leading equipment manufacturers are Valmet and Tampella (both in Finland), Beloit in the U.S., and the Swiss-German Voith Sulzer group. Compared to their customers in the pulp and paper industry, these enterprises are research intensive. The typical R&D investments range up to 4-6% of sales, with fixed amounts being dedicated to development projects with high risk, and to fundamental research.[78] The organisation of R&D in these firms reflect the orientation towards high value-added products and services in close relationships with the customer. The Finnish Valmet corporation, for instance, has strengthened its position by heavy investment in research and development. New paper and board production methods and machine configurations are developed in cooperation with customers at three technology centres containing six pilot machines and many separate pilot units.[79]

Similar developments can also be observed for suppliers of chemicals. A leading vendor, the German BASF Chemicals, with a product range from basic chemicals such as sodium hydroxide to polymer dispersions for the manufacture of coated paper, has extended its product program with value-adding services around the needs of the pulp and paper industry. This supplier consults its customers in the paper

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[75] Hippel, E. von (1982), 'Appropriability of innovation benefit as a predictor of the source of innovation' *Research Policy* vol. 11 pp. 95-115

[76] Nelson, P. (1995) 'Tappi engineering and the paper industry- reminiscing and memories from 40 to 50 years ago' *Proceedings of 1995 Tappi Engineering Conference*, Atlanta: Tappi Press, pp.. 1-5

[77] Maspons, R., Escorsa, P., Colom, J. (1993), *La gestión de la tecnología en el sector de las pastas y papel*, Terrassa (Spain): Universitat Politècnica de Catalunya, pp. 186

[78] Maspons, R., Escorsa, P., Colom, J. (1993), *La gestión de la tecnología en el sector de las pastas y papel*, Terrassa (Spain): Universitat Politècnica de Catalunya, pp. 186

[79] Valmet's www server on the Internet

industry in wet-end chemistry and runs a technology centre which also provides a good example of cooperation among suppliers industries aimed at creating innovative products and solutions for the pulp and paper industry. BASF's technology centre accommodates a coating line and a new film press which is used by customers of BASF, the machine supplier, and other interested parties for trial production and the training of users. Joint operation of the pilot line helps to convert operating experiences more rapidly into product improvements.[80] The development of the MILOX pulping and bleaching process shows that chemicals suppliers are very important for advances in core pulp and paper technology. In general the role of chemical suppliers is traditionally an important one. After all, pulp and paper production is based on chemical reactions in wood. It is widely recognised that one of the most significant contributions to paper product development in the future probably will come from the chemical side of paper making, a trend which should maintain the relative importance of the chemical industry within the pulp and paper industry cluster.

Energy producers also have extensive links into the pulp and paper industry since the industry is an important consumer of energy. The largest energy consumers in this industry are traditionally mechanical pulping plants. Recently, de-inking plants for recycled paper have also become significant energy consumers. As the pulp and paper industry is scale and cost driven, the price and availability of energy have an impact on pulp and paper investment decisions. Some companies have even invested in their own energy generation plants in order to ensure that energy supply will not become a major problem, no matter what kind of regulatory changes are imposed on them by government authorities.

Suppliers of control and information systems play an essential role in modern pulp and paper production. Digital process automation systems and mill-wide information systems are often used as strategic tools when upgrading the technological sophistication of production from bulk to more specialised grades of pulp, paper, and board.[81] The range of different paper grades has expanded tremendously during recent years, and because production capacity has kept increasing, this has resulted in an increase in operational grade changes performed at pulp and paper mills. Another IT driven change is the general decrease in order sizes because of storage optimisation and logistical enhancement projects of many customers. As product variation increases, also the number of customers tends to increase. All these changes together increase the relative importance of the IT sector as a catalyst of technological and structural change in the pulp and paper sector, particularly in enhancing flexibility.

1.5.5 Consultants

Consulting activities in the pulp and paper industry comprise a spectrum from business analysis at one end to engineering services to offering R&D solutions for innovation and production problems; in the latter case difference between

[80] N.N. (1996), 'Neue Filmpresse im Technischen Zentrum der BASF eingeweiht' *Wochenblatt für Papierfabrikation* vol. 14/15, pp. 652-655

[81] Ranta et al, 1992, Information technology and structural change in the pulp and paper industry, Computers in industry, Vol. 20, pp 255-269

consultancy and contract research become blurred. In the past decades consulting has gained significant importance in the pulp and paper industry. Several factors have motivated companies in the paper business towards an increasing reliance on such services. On the one hand, sustained pressure to cut costs has not exempted R&D labs and engineering departments in mills, whose problem-solving contributions are increasingly assessed in terms of cost efficiency. On the other hand, the number of relevant technologies, legislative measures affecting the industry and the dynamics of markets have increased drastically so that consultants are indispensable to supplement and complement the core skills in pulp and paper companies.[82] It has already been suggested earlier that research institutions and suppliers also endeavour to offer value-added products with services that tend to include consulting activities. The following discussion, however, will focus on the role of those firms without manufacturing or origins in collective research that offer consulting services. Pertinent business directories suggest that the majority of these consulting firms provide engineering related services, while only a few are explicitly business consultants offering advice in strategy development, general management, or market analysis.[83] Typical examples of activity are the development of software for the optimisation of logistics, production scheduling or the cutting of paper, the engineering of custom-made conversion machinery, or the design of packaging. Encouraged by potential legal problems, and by safety and environmental concerns, consultants are increasingly hired to assist paper companies in the management of identification and evaluation of risk, especially from the technical side.[84] Larger consulting firms such as the Finnish Jaako Pöyri Group have developed their services towards the delivery of turn-key systems to the pulp and paper industry where they compete with large vendors of equipment. In recent years consulting firms have therefore strengthened their competence into fields outside the domain of machinery suppliers. Typical areas are energy generation, environmental technology, or as in Jaako Pöyri's case, forestry.[85] These technologies became particularly important in non-discretionary projects throughout the pulp and paper industry which are not business driven but necessitated by government regulations. In conclusion of this section can be said that consultants have assumed an interface role for the pulp and paper industry. They dispose of the necessary competencies and resources in various fields of technology, are familiar with legislative and market issues, and can integrate various technologies from all kinds of suppliers in such a way that projects can be completed within the planned turnaround time, costs, and performance.[86]

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[82] Hanock, M. (1995) 'Pira International: the innovation catalyst' in Harrington, M. (ed) *Profit Through Innovation - 65 years of partnership with industry* London: Atalink Ltd., pp. 10-16. Knight, R. (1995) 'Doing the right thing' *1995 Tappi Engineering Conference*, Atlanta: Tappi Press, pp.. 621-624

[83] see Birkner, *1996 European and International Paper World - Directory of the Paper industry*, Hamburg: Birkner Verlag

[84] Hoke, J. (1995) 'As engineering services customers' 1995 Tappi Engineering Conference, Atlanta: Tappi Press, pp.. 15-18

[85] Henry Ehrnroth, President of Jaako Pöyri, in the lecture Enterprise Forum held at Feb. 2nd,1995 at Helsinki University of Technology

[86] Interview with Nicolas Simonin of Rodamin OY, Vantaa, Finland, May 1st, 1996 in Helsinki.

1.5.6 Customers

The market has a strong influence on the pulp and paper industry because innovations in other industries have created demand for new paper products: The significant areas of growth in the industry over the past two decades, cut size business papers, forms bond, computer grades, fax paper, diapers or liquids packaging must be viewed primarily as a result of technical innovations outside the paper industry.[87] Nevertheless, the customers of the pulp and paper industry, mainly printers and industries using paper packaging materials, do not usually develop new products or processes which are then introduced in the pulp and paper industry. Hence the development of carbonless paper by NCR must be rather be viewed as an exception than a regular pattern of innovation in the pulp and paper industry. [88]

The role of customers in innovation processes of the pulp and paper industry must rather be viewed as that of a feedback mechanism and information provider. As users of the paper industry's products, they know about the strengths and weaknesses of products and are thus a valuable source of ideas for continuous improvement. Moreover, the needs and strategies of customers have created pressure for change in the pulp and paper industry. Xerox, for example, a pioneer in total quality management strategy, only places contracts for copy paper with those manufacturers who have a comprehensive approved quality system.[89] Similarly, large printers and distributors have more flexible delivery, smaller lot sizes, new paper grades, lighter packaging, and so on.

Closer links with customers are driven by a general aim of escaping the risks involved in extremely price sensitive, cyclical commodity segments; thus more and more paper companies realign their strategies towards high value-added products for specific customers. In many cases, this has fostered the development of close user-producer relationships which involve longer lasting collaboration between paper companies and user industries. A typical example is the development of paper based packaging for food processors, in which the paper converter collaborates with its customer to find solutions that preserve food reliably without affecting taste. Increasing technological complexity and tougher competition has further intensified the level of cooperation with customers: the change from acid to alkaline papermaking, for instance, affects the whole product chain - suppliers, paper makers, converters and end users. Because the factors that affect paper performance multiply with each downstream step, establishing a system to manage and measure the impact of change is critical for success. This can only be achieved by integrating the converter and end user into the development process, and for this reason new technology is of more value to the paper maker and more rapidly accepted. [90]

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[87] Wahren, W. (1992) 'Keynote address' *in Tappi Workshop: Paper industry research needs*, May 26th-May 28th,1992. Atlanta: Tappi Press, pp.viii-xi

[88] Maspons, R., Escorsa, P., Colom, J. (1993), *La gestión de la tecnología en el sector de las pastas y papel*, Terrassa (Spain): Universitat Politècnica de Catalunya, chapter 6

[89] Hendry, I. (1983), 'The Role of Fundamental Research in the Paper-making quality control' *The Role of Fundamental Research in Papermaking*, London: The British Paper and Board Industry Federation, Vol 1. pp. 117-149

[90] Meixner, M., Ramaswamy, S. (1994), *'A conversion and end-use approach to alkaline fine paper size development'*, 1994 Tappi Papermakers Conference, Atlanta: Tappi Press, pp.. 559-563

1.6 Overview of the CIS data

The remaining chapters of this report provide a quantitative analysis of innovation activities and outputs in the pulp and paper industry using data from the Community Innovation survey 1992 (CIS). This sections overviews the CIS data.

Until recently R&D expenditure (supplemented by data on patents, trade data and technological balance of payments) has been the main data source available for innovation analysis. This type of data, although extremely valuable, has the defect that it measures only one input to innovation, an input which is of varying importance across industries. IN addition it tells us nothing about the outcomes of innovation activity. Triggered by new innovation theories, emphasising the roles of non-R&D inputs to innovation, a major new data set has now been established by a joint contribution from several countries within Europe. This data set, the Community Innovation Survey, was initiated by DGXIII/SPRINT/EIMS and EUROSTAT in 1991 and it is based on the recommendations from the OECD's *Innovation Manual*. The survey looks into an extended range of factors which influence innovation. In addition to R&D and R&D co-operation, the data includes information on sources of innovation, objectives of innovation, obstacles to innovation, technology diffusion, investments and so on so forth. In our view, this survey represents a rich data source, including completely new indicators on innovation. The survey covered more than 40,000 firms across all European countries, and therefore enables comparative analysis across industries and countries in Europe.

Unfortunately, this comparative opportunity is limited by highly varying sampling procedures in the different countries which participated in CIS (one country may draw its sample from innovative firms only, others draw them from the whole population etc). Due to this, comparisons across countries and pooling of observations across countries is difficult. The reader should be aware of this when interpreting the results which are presented below.[91] Other problems with the data limit the analysis, and should be noted. As a result of item non-responses, there are many missing values in the data set. Eurostat has estimated values in many of these cases. This is not unproblematic, since many of the techniques used impose assumptions on the data which may or may not be accurate. For example, missing values have been estimated on the basis of the answers obtained from other firms with more or less the same characteristics. This implies the idea of similar relationships between variables in similar firms, which may be questionable.[92]

Due to the limited number of observations for the pulp and paper industry, in particular when breaking down on different subgroups, these estimated values are used in the analysis which follows.

Another problem confronted by researchers, is the strict confidentiality imposed on the use of data. In order to give access at all for researchers outside Eurostat, the data

[91] For more information on the comparability of the data, see Daniele Archibugi et.al, 1995, Evaluation of the community innovation survey, CIS - Phase I, EIMS Publication No 11, Luxembourg 1995

[92] For an overview of modifications and methods used by Eurostat see 'The modifications of the CIS data by Eurostat', Annex 3.

has been micro-aggregated, meaning that observations have been pooled three and three, and the original value replaced by the mean of each group. This is done in such a way that the main characteristics of the underlying data set are preserved. All analyses in this report are run on this micro aggregated data set.

1.6.1 CIS and the concept of Innovativness

There are many definitions for the concepts of innovation and innovativeness. Firms can be considered innovative, for example, if they have more new and improved products than competitors, carry out more R&D, continuously upgrade their production facilities, implement new business systems, and improve market share. Often, economic success is built into the concept of innovativeness, since innovative firms are often assumed to be more profitable and to grow more rapidly than less innovative firms. When doing research on industrial innovation, it is always useful to indicate what aspects of the concept of innovation are being emphasised.

Schumpeter defined innovation as: [93]

> "Technological change in the production of commodities already in use, the opening up of new markets or of new sources of supply, Taylorization of work, improved handling of material, the setting up of new business organisations such as department stores – in short, any 'doing things differently' in the realm of economic life – all these are instances of what we shall refer to by the term Innovation"

The focus of the Community Innovation Survey (CIS) exercise is, by necessity, a more narrow one. In the CIS survey, the focus is predominantly on technological innovation that affects the outputs and the value creating processes of the firm. Organisational innovations and, for example, innovations concerning the business system, are beyond the scope of the CIS study. The CIS study essentially views the firm as an input-output unit of innovation, which uses [technological] information and [technological] knowledge inputs as one key ingredient in this process. This is one point to which we will return when discussing the further development of the CIS approach.

In order to make empirical research possible, the concept of innovativeness needs to be operationalised. This means that the concept must be defined in terms of identifiable metrics that can be measured in a more or less valid and reliable manner. For the sake of practicality, the validity requirement can sometimes be relaxed, as long as measurable relationships can be established between the proxies used for innovation and the proxies used for business success.

In operationalising the concept of innovation in the present study, we make a distinction between three categories of innovation indicators. These we denote as input indicators, process indicators, and output indicators. The bulk of empirical studies on innovation focuses on input and output indicators for the simple reason

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[93] Schumpeter, J A, Business cycles: A theoretical, historical, and statistical analysis of the capitalist process, Porcupine Press, Philadelphia, 1982 (First edition by McGraw-Hill, New York, 1939), p 84. This definition is actually an abbreviated version of Schumpeter's earlier definition, which can be found in: Schumpeter, J A, The theory of economic development, Harvard University Economic Studies Series, vol XLVI, Cambridge, Massachusetts, 1934, p 66

that these are simple to measure in quantitative terms. Process indicators are more difficult to assess, especially in large scale empirical surveys, such as the CIS. Perhaps the best way of producing valid process data is to carry out business process benchmarking studies, since these consistently focus on business process performance. The data derived from such exercises is highly firm and industry specific, however, and is hardly of use for large scale surveys. The best proxy of process indicators in large scale surveys is to measure organisational arrangements set up for carrying out innovative activities. Such an approach has been used by Hagedoorn, who created the MERIT database of strategic alliances between large industrial firms. Examples of input and output indicators are presented in table 1.[94]

The CIS study has chosen to view innovation as an input-output process, in which technology and information flow into the firm, where these are transformed to new products and processes. This approach emphasises the inputs and outputs of the innovation process, and the process itself is given only small consideration. Another distinctive characteristic of the CIS approach is that the firm is essentially viewed as a producer of products and related services. Even though not explicitly so stated, the underlying conception of the CIS study is very much one viewing the firm as an unit that loads value into its products and services during the production process, using innovation as a means of either increasing the value created or decreasing the cost of producing it. In this sense, the CIS study is rooted in the industrial organisation perspective. Indicators rooted in the resource-based perspective (e g, Wernerfelt, 1984) are largely missing from the CIS questionnaire. In here, resource-based indicators inlay to indicators relating to the process of leveraging firm-specific innovation resources with external ones in order to generate economic rents.

The pulp and paper industry consists of two important subgroups, the manufacture of pulp, paper, and board (NACE 21.1) and the manufacture of articles of pulp, paper, and board (NACE 21.2). Although both industries have much in common, there are still some differences. The following points illustrate these differences:

- the conversion of pulp and paper products is much less capital intensive than the manufacturing of pulp and paper
- NACE 21.2 firms are predominantly SME’s, often entrepreneurial companies whereas NACE 21.1 firms are often large, internationally operating industrial corporations
- NACE 21.2 firms are more locally focused with customised products whereas NACE 21.1 firms produce various pulp and paper grades which are often traded as commodities in international markets
- related to the previous point, NACE 21.2 seems less sensitive to business cycles, as the producer price indices for NACE 21.1 and NACE 21.2 show.

The consequence of the above is that NACE 21.1 and NACE 21.2 firms are likely to exhibit significant differences in their answers to the CIS survey questionnaire. Thus it seems more reasonable to analyse those industries separately whenever possible.

[94] Table from Autio, E, Laamanen, T, Measurement and evaluation of technology transfer: Measurement and evaluation of technology transfer: Review of technology transfer mechanisms and indicators, *International Journal of Technology Management*, vol 10 (1995), nos 7/8, pp 643 - 664

Unfortunately, a NACE 3-digit classification is not available for all 13 countries in the CIS survey: Denmark, Spain, Greece, Portugal, and UK are only available in NACE 2-digit classification. Because it does not make sense to combine the sectors NACE 21.1 and NACE 21.2 especially when exploring differences between high and low innovation performers, these countries are therefore left out from the present analysis.

2 Innovation in the European pulp, paper and paper products industry

2.1 Innovation Activities

The pulp and paper industry has been relatively neglected within European innovation policies. One underlying reason is surely the impact of the linear model in innovation policies. From the perspective of the linear model of innovation, in which innovation is held to originate with R&D-based processes of discovery, the low R&D content of pulp, paper and paper products has led to the industry being seen as a mature one with few technological opportunities.[95] Insofar as policies have been adopted to strengthen competitiveness in the pulp and paper sector, they have focused on macro-level phenomena such exchange rates, wages, tax conditions and so on.

A report by the Office of Technology Assessment exemplifies the above view:

> 1) The industry is mature in the sense that wood products are well developed and have been used in essentially the same form for a long time, 2) wood products are not high technology and, therefore are not likely to be subject to revolutionary technological breakthroughs in their manufacturing and use...[96]

The view here seems to be that because the industry is both long-standing and low-tech, it is unlikely to be innovative. This seems to be based on a confusion *technology creation* and *technology use* across sectors: a sector may have low technology creation as measured by R&D intensity, but may be an intensive user of technology (and hence may play an important role in shaping trajectories of technological change). Looking into the history of economics and technical change it appears that the world has many old and mature industries and products that have been completely revitalised by ‘revolutionary technological breakthroughs’: examples might be the introduction of lasers into textiles, biotechnology into agriculture and so on.[97] The potential for such innovation is certainly present also in pulp & paper, but this does not necessarily mean that increased R&D is the main trigger of innovation in this specific industry. Rather, new innovation theories suggest that a wide range of factors influence innovation and innovation capabilities, such as the national institutional set-up, customer/supplier relationships, alliances,

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[95] Pulp, paper and paper products are most commonly put in the category ‘low tech’ industries. The OECD definition of high tech, medium tech and low tech is the following: Sectors that spend more than 4,5% of their sales on R&D are classified as high tech, sectors that spend between 1,0% and 4,5% of their sales on R&D are classified as medium tech, and sectors that spend less than 1,0% of their sales on R&D are classified as low tech.

[96] Office of Technology Assessment, Wood use: The US Competitiveness and Technology, Washington D.C. , 1984, Volume 2

[97] Nathan Rosenberg: An outsiders view of technological change in the forest products industry, Fremtek notat 22/93, Oslo 1993

acquisitions of other companies and so on. These interactive relationships are particularly important when key technologies are developed and supplied from outside the industry. In this case, an industry may be innovative in terms of organisational change or the development of new products, without exhibiting significant internal R&D performance. One such case, where a number of different innovation sources are utilised, is illustrated in a recent study of the Finnish pulp and paper industry:

> In essence, the basis for the high technological competence and the relatively great self sufficiency of Finnish chemical forestry industry is thus formed by the close links to the nation's engineering branch. In fact, the pulp and paper industry itself is not a very research intensive sector ... , but the industry benefits directly from most of the research done in the domestic supporting and related industries.
>
> Contrary to the reputation of lethargy in the pulp and paper industry, a number of significant technological advances enhancing significantly Finnish competitive advantage has been realised over the past few decades, with major innovation concentrated in the area of fibrous raw material processing, product properties and in that of environmental technologies. It is primarily as a result of the efficient technology system and interactive links between the chemical forest industry and its supporting and related industries that the Finnish pulp and paper companies' performance in the area of technology nowadays reveals major competitive strengths. [98]

The CIS data set gives direct and rich quantitative information on these issues. Consistent with the Finnish study cited above, CIS has shown (see Section 2.1.1 below) that links to suppliers and customers are very important in pulp, paper and paper products, and that this source of innovation was more important than for other industries. The CIS also suggests relatively high infrastructure dependence of this specific industry. More indirectly, OECD STAN data also confirms these finding: we see that the pulp and paper industry invests considerably more in tangible assets (as a proportion of sales) than other industries. Once again, this points to a relatively high focus on assets created *externally to the firm*.

In the following sections we look into the different types of innovation activities within NACE 21.1 and NACE 21.2, focusing on how patterns of innovation and investment differ from other industries.

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[98] Ojainmaa K., 1994, *International competitive advantage of the Finnish chemical forest industry*, Helsinki, ETLA C 66

Figure 2.1: R&D intensity
(defined as R&D expenditures as a percentage of sales) in pulp, paper and paper products (labelled as OECD 34) compared to average manufacturing (labelled as OECD total), 1985, 1987, 1989, 1991. (For a breakdown by country see Tab.(2.1).) [99]

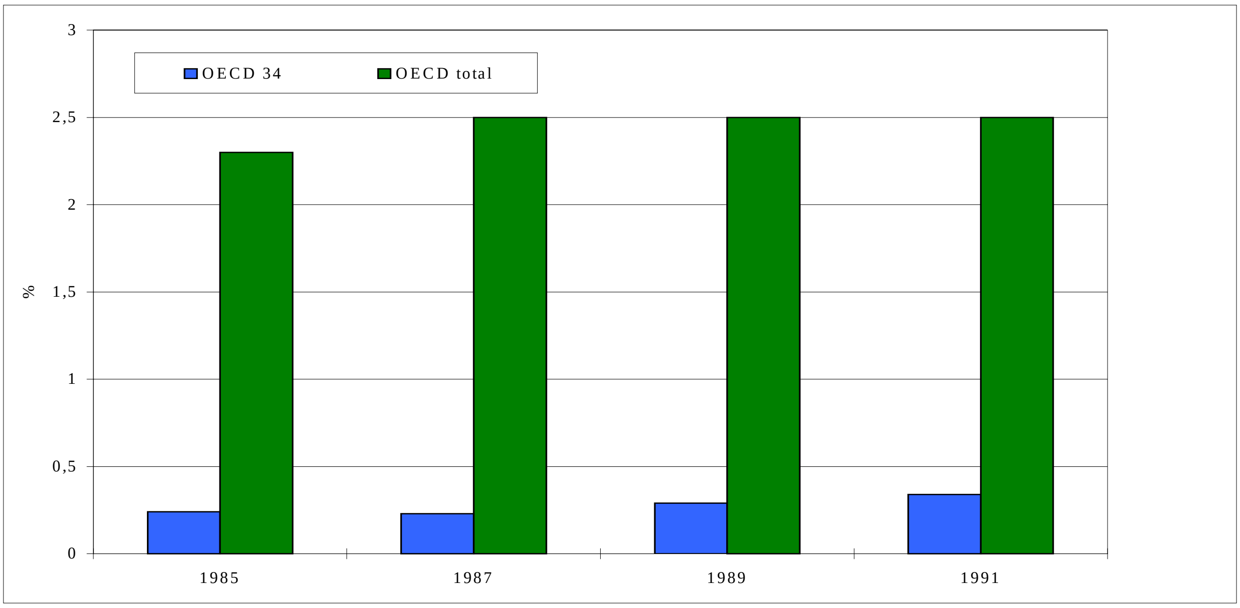
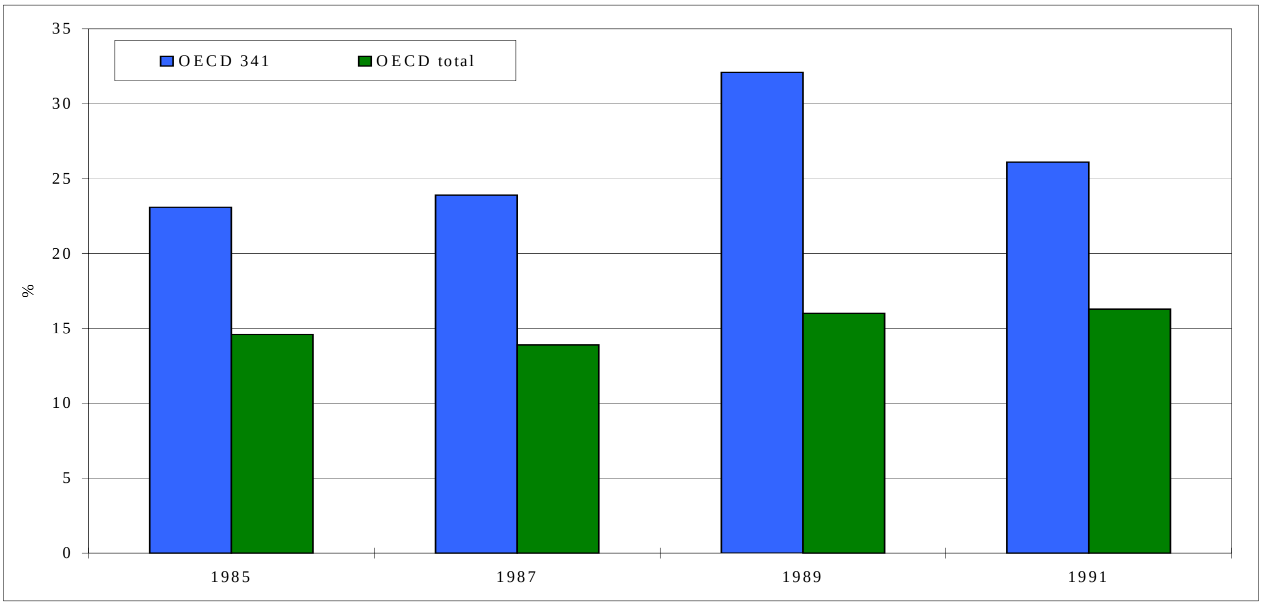


Figure 2.2: Investment intensity
(defined as gross fixed capital formation as percentage of value added) in pulp, paper and paper products (labelled as OECD 341) compared to average manufacturing (labelled as OECD total), 1985, 1987, 1989 and 1991. For a breakdown per country see Tab.(2.2)[100].



[99] These figures are based on data from ISIC 34. This includes printing, publishing and allied products besides pulp & paper and articles of pulp and paper. Source: OECD, DSTI(STAN/ANBERD Database)

[100] Source: OECD, DSTI(STAN/Industrial Database), 1994

Table 2.1 R&D intensity (R&D expenditures as a percentage of sales) in pulp, paper and paper products compared to average manufacturing, OECD, 1985, 1987, 1989, 1991.

Country	**1985**	**1987**	**1989**	**1991**	**1993**	**% points change 1985-1991**
Norwegian ISIC 34[101]	0,12	0,18	0,12	0,17		0,05
OECD ISIC 34[102]	0,24	0,23	0,29	0,34		0,1
OECD total	2,3	2,5	2,5	2,5		0,2
Australia ISIC 34	0,11	0,12	0,24	0,35		0,24
Canada ISIC 34	0,29	0,27	0,40	0,29		0
Denmark ISIC 34	0,02	0,02	0,08	0,10		0,08
Finland ISIC 34	0,39	0,44	0,56	0,84		0,45
France ISIC 34	0,11	0,12	0,11	0,11		0
Germany ISIC 34	0,19	0,15	0,14	0,13		-0,06
Italy ISIC 34	0,01	0,01	0,00	0,00		-0,01
Japan ISIC 34	0,30	0,31	0,39	0,41		0,11
Netherlands ISIC 34	0,07	0,07	0,07	0,09		0,02
Sweden ISIC 34	0,63	0,66	0,67	0,73		0,1
UK ISIC 34	0,12	0,15	0,13	0,12		0
US ISIC 34	0,27	0,25	0,33	0,44		0,17

Source: OECD, DSTI(STAN/ANBERD Database), 1994 & Norwegian R&D data

Table 2.2 Investment intensity
(gross fixed capital formation as percentage of value added) for pulp, paper and paper products in OECD countries compared to the average in manufacturing total 1985, 1987, 1989 and 1991

Country	***1985***	***1987***	***1989***	***1991***
Norway ISIC 341	18,8	36,7	12,9	26,4
Denmark ISIC 341	17,0	23,8	19,5	40,8
Sweden ISIC 341	38,2	32,1	33,0	22,5
Finland ISIC 341	36,3	40,3	48,6	55,9
Canada ISIC 341	10,4	9,4	9,7	n.a.
Netherlands ISIC 341	23,7	51,9	25,3	36,7
France ISIC 341	16,5	28,2	23,9	31,8
Japan ISIC 341	26,5	28,0	37,0	42,6
US ISIC 341	21,1	18,8	28,1	23,9
Belgium ISIC 341	17,6	30,7	31,1	40,0
Germany ISIC 341	15,3	17,3	25,4	21,7
UK ISIC 341	19,2	20,3	25,3	15,0
Italy ISIC 341	22,7	29,7	25,5	28,0
OECD ISIC 341	23,1	23,9	32,1	26,1
OECD total	14,6	13,9	16,0	16,3

Source: OECD, DSTI (STAN/Industrial Database), 1994

[101] Norwegian numbers are not available as ANBERD. They are computed on the basis of Norwegian statistics.

[102] OECD branch and total are estimates based on the given 13 countries.

2.1.1 Use of Internal and External Resources at firm Level

In the innovation process firms invest both in disembodied or *intangible* resources (for instance training for employees, design, R&D etc.) and in embodied or *tangible* resources (for instance new machines). These are complementary assets in the sense that investments in (tangible) new technology requires investments in (intangible) human resources in order to integrate, test and develop the new technology into a new system. Nevertheless, industries differ extensively in their technology use with regard to their focus on intangible/tangible and external/internal relations. While for instance a software firm devotes a large part of its innovation costs to R&D performed in-house, quite commonly with a R&D intensity of more than 50%, other industries rely extensively on R&D and technological systems developed external to the firm. In the following we utilise several indicators available in the CIS to elaborate on these issues. The following definitions are used:

Intangible investments: The sum of expenditures on R&D, Acquisition of patents and licences, Product design, Trial production, training and tooling up, Market analysis (in 1992).

Tangible investments: Total capital expenditure (linked to new product innovation) spent on investments in plant machinery and equipment (in 1992).

2.1.1.1 How does 'Pulp paper and paper products' differ from other industries

In the following analysis all countries are pooled together and we study the following groups of firms:

i) NACE 21.1 (Manufacture of pulp, paper and paperboard) vs. ALL NACE (Other industries)

ii) NACE 21.2 (Manufacture of articles of paper and paperboard) vs. ALL NACE (Other industries).

Were the data allows it, we have divided the firms into size categories according to the number of employees in the firm.

Fig.(2.3) shows the weighted average on intangible/tangible investments to innovation by firm size and NACE category.[103] We have also calculated the ratio of intangible/tangible investments for each firm in the CIS database and performed a

[103] The weighted average is calculated as the sum of intangible investments for a given NACE category and firm size divided by the sum of tangible investments for the same firms. This may be expressed as:

$$(WA = \frac{\sum_{i}^{N} (Intangible)_i}{\sum_{j}^{N} (Tangible)_j}).$$

Wilcoxon test in order to check whether or not the differences we observe are statistically significant.[104]

The industry invests considerably more in tangible assets relatively to intangible assets than other industries. As pointed out earlier this is consistent with the fact that pulp, paper and paper products utilise large machine inputs and complex technology partly generated external to the firm giving a relatively low ratio on intangible/tangible investments to innovation. Together with the STAN data and other indicators presented later in this section, this reveals a highly outward orientation in the innovation process of the industry.

Table A

Statistical methods

We seek to test statistically the difference between the *pulp, paper and paper products industry* and other industries. One problem emerges however: most of the distributions in the CIS are not normal and, moreover, there are very few observations when we split on firm size and three digit NACE. The way to overcome this problem is to use a non parametric test, where we do not have to assume that the data comes from some underlying distribution which is known. The main disadvantage of a non parametric test is that it is generally less powerful than the corresponding parametric test when the assumptions are satisfied. However, for many of the commonly used nonparametric methods the decrease in power is not large. This is for instance the case for the Wilcoxon test which we have utilised. For normal distributions with a shift in the mean, the asymptotic efficiency of the Wilcoxon test relative to the t-test is 0.955. Thus a small price is paid for using the nonparametric test, in return for greater applicability. If the underlying populations are not normally distributed , the power of the Wilcoxon test is much higher than the two sample t-test. In fact, the asymptotic relative efficiency can be as high as infinity. A further advantage with this kind of test is that it utilises rank scores, hence the scale is recalculated and the problems related to outlayers are minimised. We do not know whether these outlayers are actually a 'slip of the pen' or whether they reflect true heterogeneity within the industry. This statistical method hence allows us to compromise on this issue. The Wilcoxon test is a non parametric test of the null hypothesis that the distribution of an ordinally scaled response variable is the same in two independently sampled populations.

Performing a distribution free test (Wilcoxon) on intangible/tangible investments, it was found that the above differences are statistically significant at the 1% confidence level (see Table 2.3): with a significant lower ratio 'intangible/tangible investments to innovation' than other industries. This holds for both small and large firms.[105]

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[104] It is not possible to do a statistical test on the weighted average above. Instead we performed a test of a related measure by ranking each firm according to its 'intangible/tangible' investments.

[105] Furthermore we find that there is not a large difference between small and large firms in the category 'ALL NACE'. On the contrary we find that there are differences between small and large firms within pulp, paper and paper products. This points to a great deal of heterogeneity within the group, where small firms invest considerably more in human resources and in flexible production as opposed to the larger firms which invest in large machines with longer production lengths. This

Another important indicator revealing the focus of the firm and its use of internal/external resources, is *information sources*. Various types of information are required in the development and introduction of new products and processes. In the CIS questionnaire the firms were asked to evaluate 13 factors on a scale from 1(insignificant) to 5 (crucial). In the following we have transformed these numbers to a binary scale. Sources that were rated from 1 - 3 were given the value '0' (unimportant), and sources that were rated 4 or 5 were given the value '1' (important). Hence we were able to calculate the share of firms within a certain group that ranked a certain information source as important. Again we tested whether differences between groups are statistically significant using the Wilcoxon test. In Figures 2.5-2.8 differences that are statistically different at the 5% level are indicated by one star, and those significant at the 1% level by two stars.

We find consistently that *external commercial/network sources* (clients and customers, suppliers of equipment and materials and components, fairs, exhibitions, conferences) are by far are the most important information sources in the firms innovative behaviour in this industry. Furthermore, 'Suppliers of materials' and 'Suppliers of equipment' are consistently rated as more important in pulp, paper and paper products than in other industries. Figures on R&D co-operation also underline the importance of external agents such suppliers, consultants and customers; these account about 60% of the R&D co-operations.

To sum up, there is strong statistical evidence that pulp, paper and paper products have a high ability to utilise knowledge external to the firm. By implication, this is a sign of a relatively high dependence on the surrounding technological infrastructure as 'suppliers of material and equipment', 'customers' etc. This point is also revealed in Figures 2.5-2.8 where it is seen that pulp, paper and paper products rank these agents as one of their most important sources for innovation, for both for small and large firms. By implication, a large part of learning and competence building takes place in the interface between the firm and its external environment and especially with suppliers of new machines. Figures on R&D co-operation also underlines this point. More than 30% of the R&D co-operation in pulp, paper and paper products were undertaken together with suppliers (see Fig.2.11).

The data seems therefore to suggest that development of the pulp, paper and paper products industry requires a relevant technological infrastructure in parallel, and much depends on the networks and knowledge transfer between this infrastructure and firms in the industry. Similar findings are confirmed by a study of the Finnish pulp and paper industry. Using input output analysis the study identified core and related industries in the Finnish forestry cluster. There is considerable interdependence between a series of industries, as indicated by Fig.2.12. From a policy viewpoint, this suggests the importance of an integrated, co-ordinated innovation policy taking into account the interactions between different industries. However, this also reveals a weakness of the CIS data which does not include questions that makes it possible for researchers to identify clusters of co-operating industries. Because of the very significant differences between industries, we can also conclude that industrial sectors are characterised by quite specific innovation

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seems especially to be the case for large firms within NACE 21.1, which have a particularly low ratio on intangible/tangible investments. This issue is elaborated on in Sec.(2.1.1.5) structures. By implication, innovation policies should incorporate industry specific components focused on the key issues in each industry.

Figure 2.3: Intangible investments in innovation as a share of tangible investments in Innovation[106]*. The share is calculated as a weighted average*[107]*. NACE 21.1 (small and large firms) compared to other industries (small and large firms).*

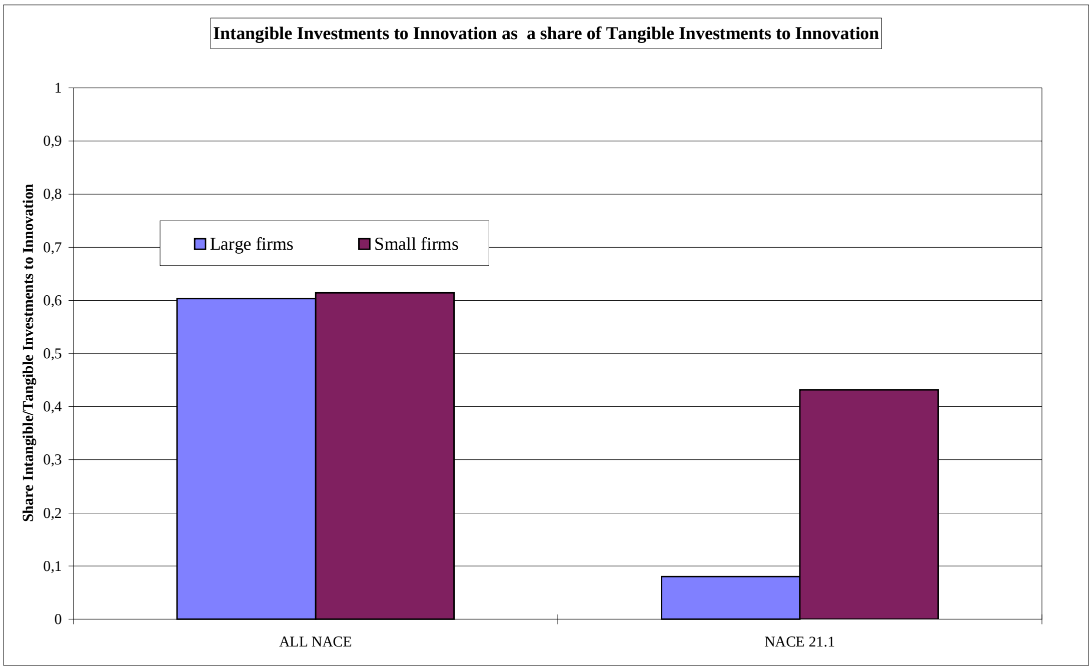
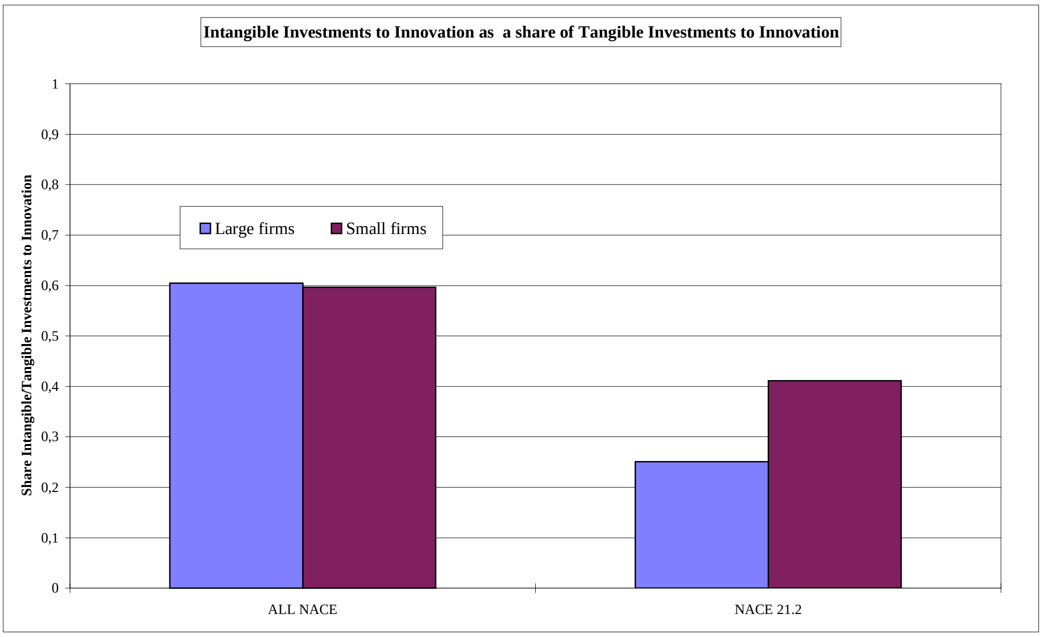


Figure 2.4: Intangible investments in Innovation as a share of tangible investments in Innovation. The share is calculated as a weighted average. NACE 21.2 small and large firms compared to other industries (small and large firms).[106+107]



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[106] *Intangible investments*: The sum of expenditures on R&D, Acquisition of patents and licenses, Product design, Trial production, training and tooling up and Market analysis.

Tangible investments: Total capital expenditure (linked to new product innovation) spent on investments in plant machinery and equipment .

[107] The weighted average is calculated as the sum of intangible investments for a given NACE category and firm size divided by the sum of tangible investments for the same firms.

Table 2.3: Significance testing of different categories on the ratio intangible/tangible investments to innovation: Wilcoxon test.

TEST	Highest ratio	Is the difference statistically different?
All NACE vs NACE 21.1 - large firms	All NACE	Yes (on a 1% level, 99% confidence)
All NACE vs NACE 21.1 - small firms	All NACE	Yes (on a 1% level, 99% confidence)
All NACE vs NACE 21.2 - large firms	All NACE	Yes (on a 1% level, 99% confidence)
All NACE vs NACE 21.2 - small firms	All NACE	Yes (on a 1% level, 99% confidence)

Figure 2.5: Sources of information for innovation by industrial category; Y-axis shows the share of firms that ranked a specific source as important.

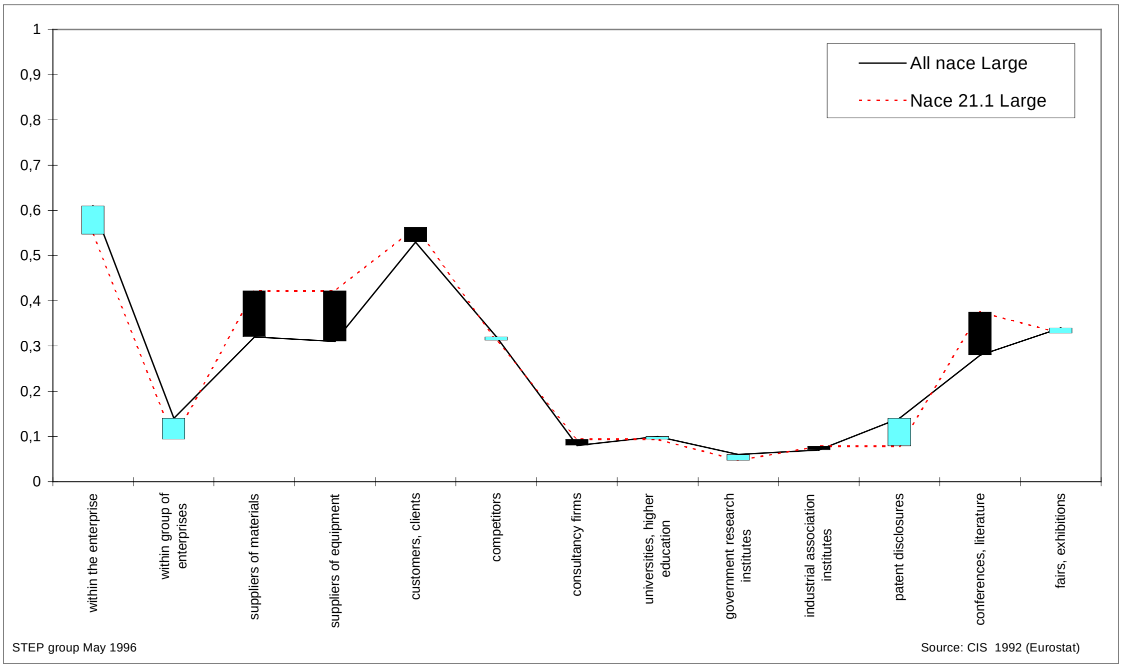


Figure 2.6: Sources of information for innovation by industrial category; Y-axis shows the share of firms that ranked a specific source as important.

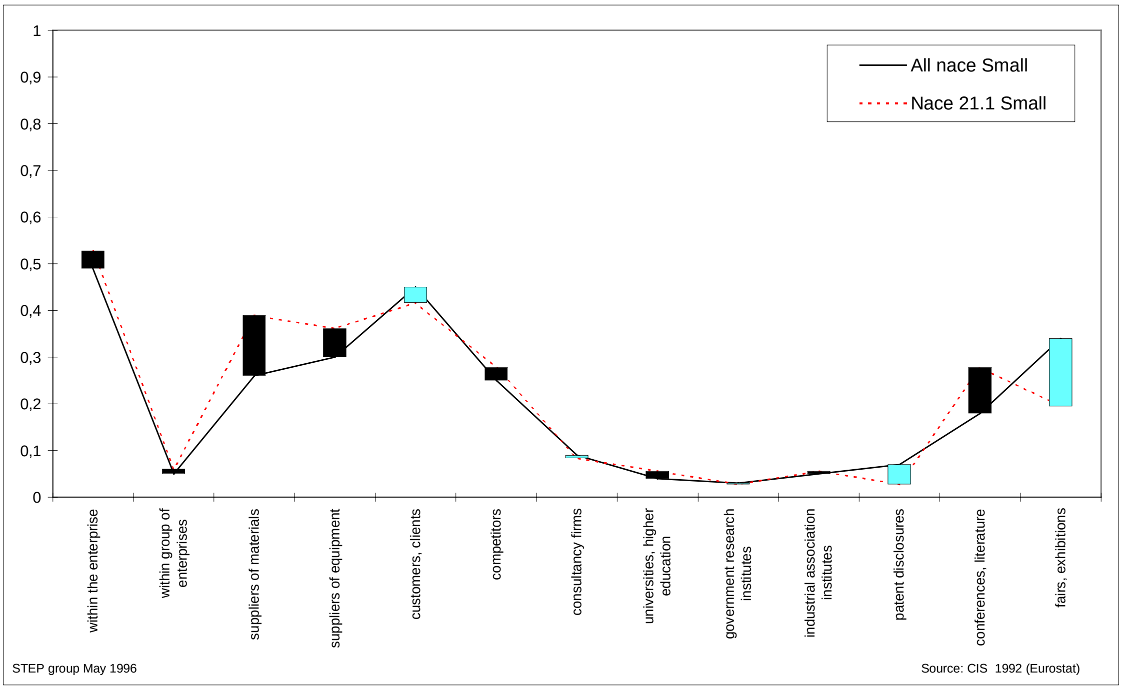


Figure 2.7: Sources of information for innovation by industrial category; Y-axis shows the share of firms that ranked a specific source as important.

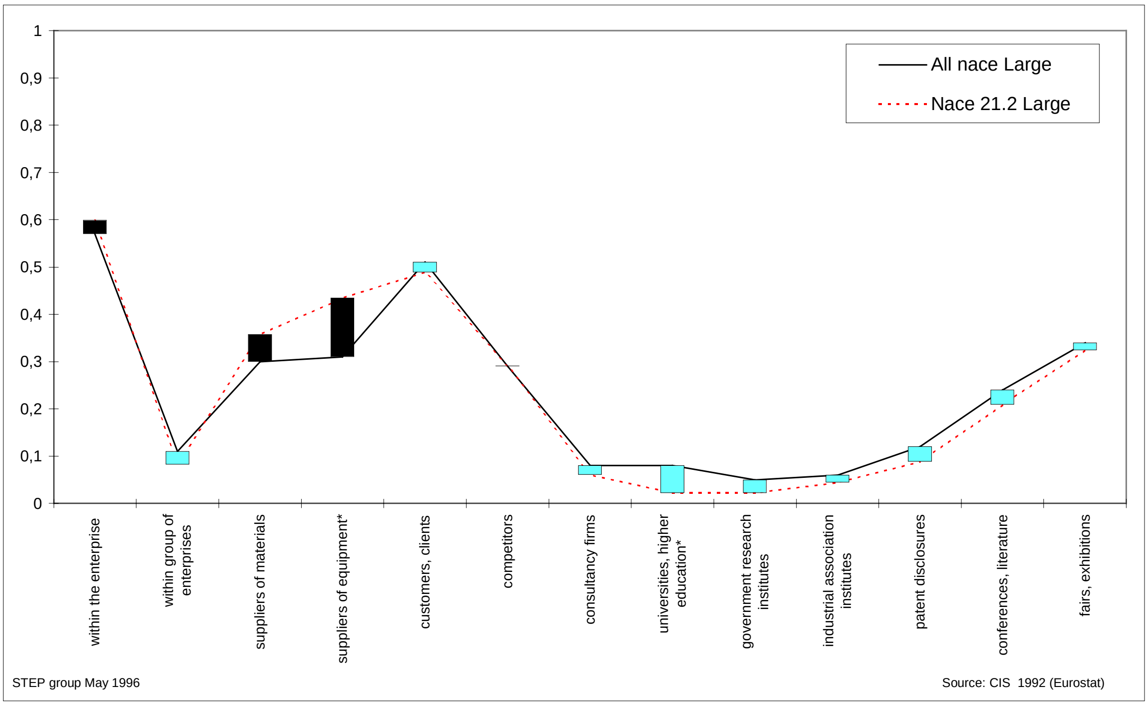


Figure 2.8: Sources of information for innovation by industrial category; Y-axis shows the share of firms that ranked a specific source as important.

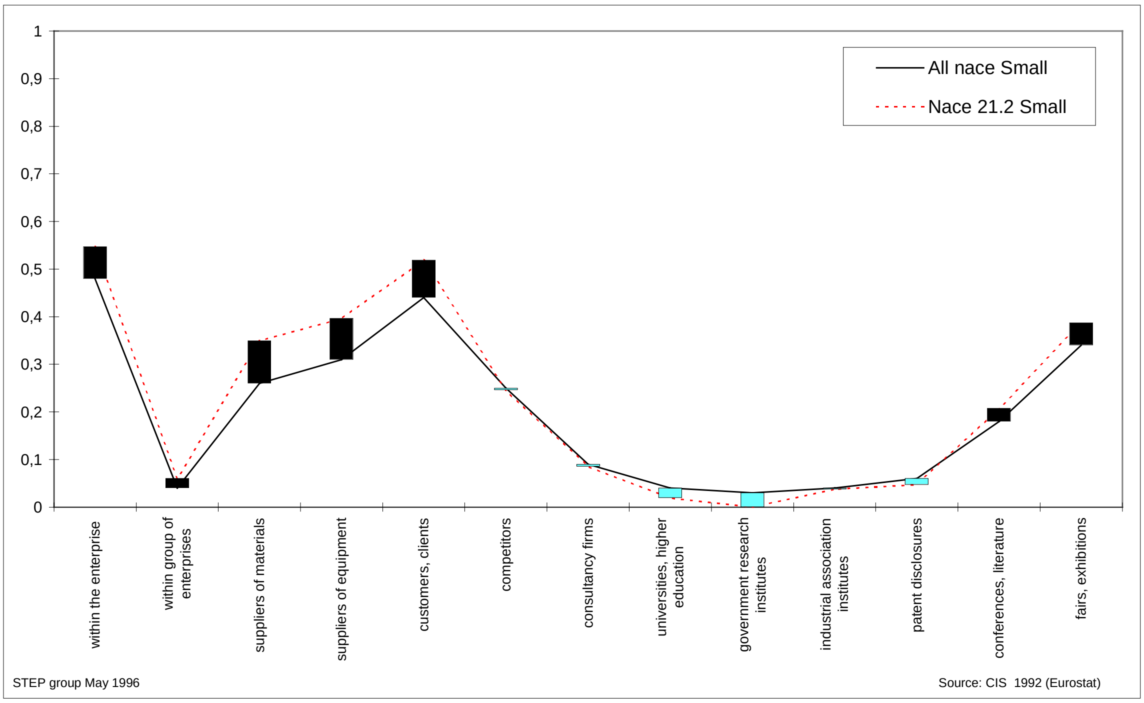


Figure 2.9: Percentage of intangible[108] innovation expenditures spent on specialist services outside the enterprise[109].

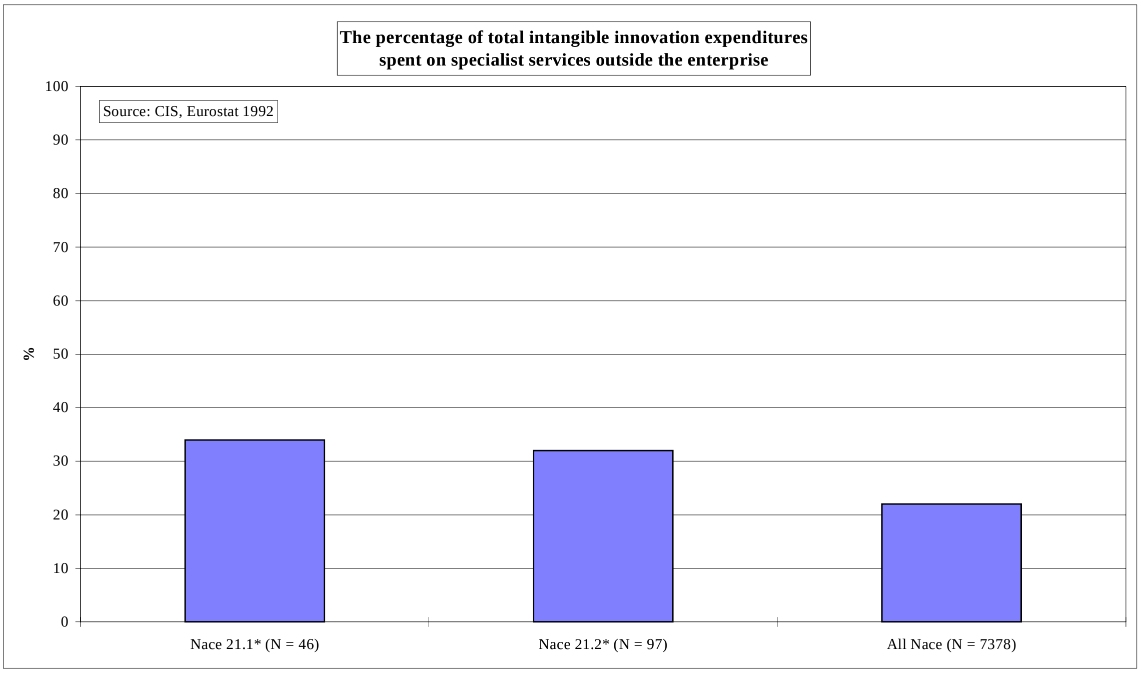
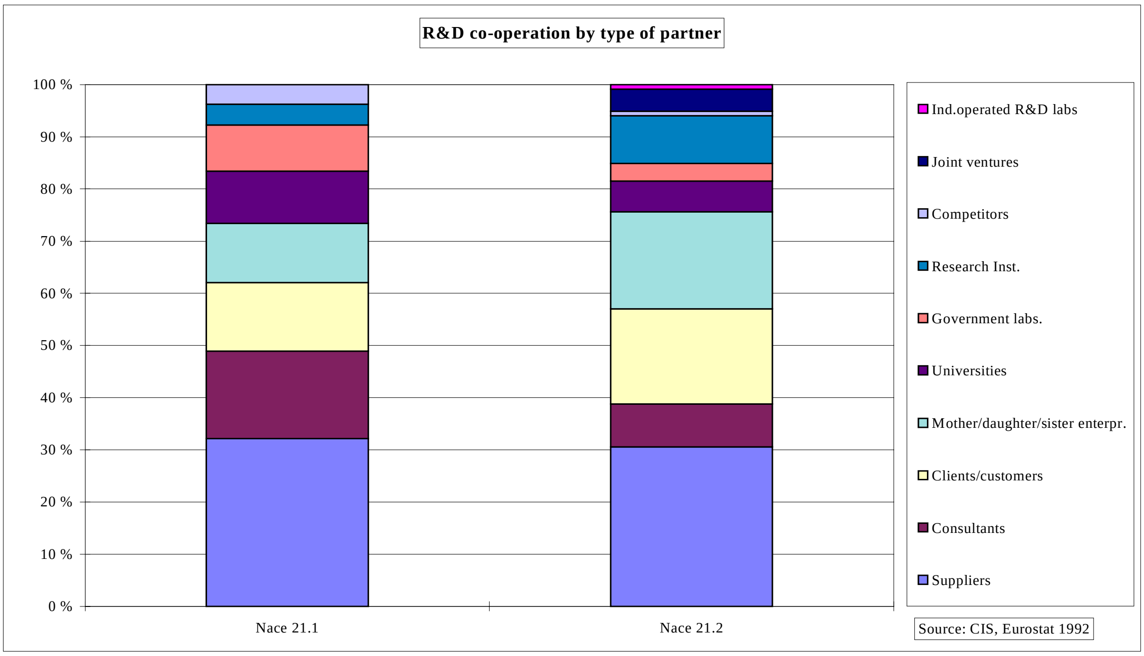


Figure 2.10: Distribution of R&D co-operations by type of partner, NACE 21.1 and NACE 21.2.



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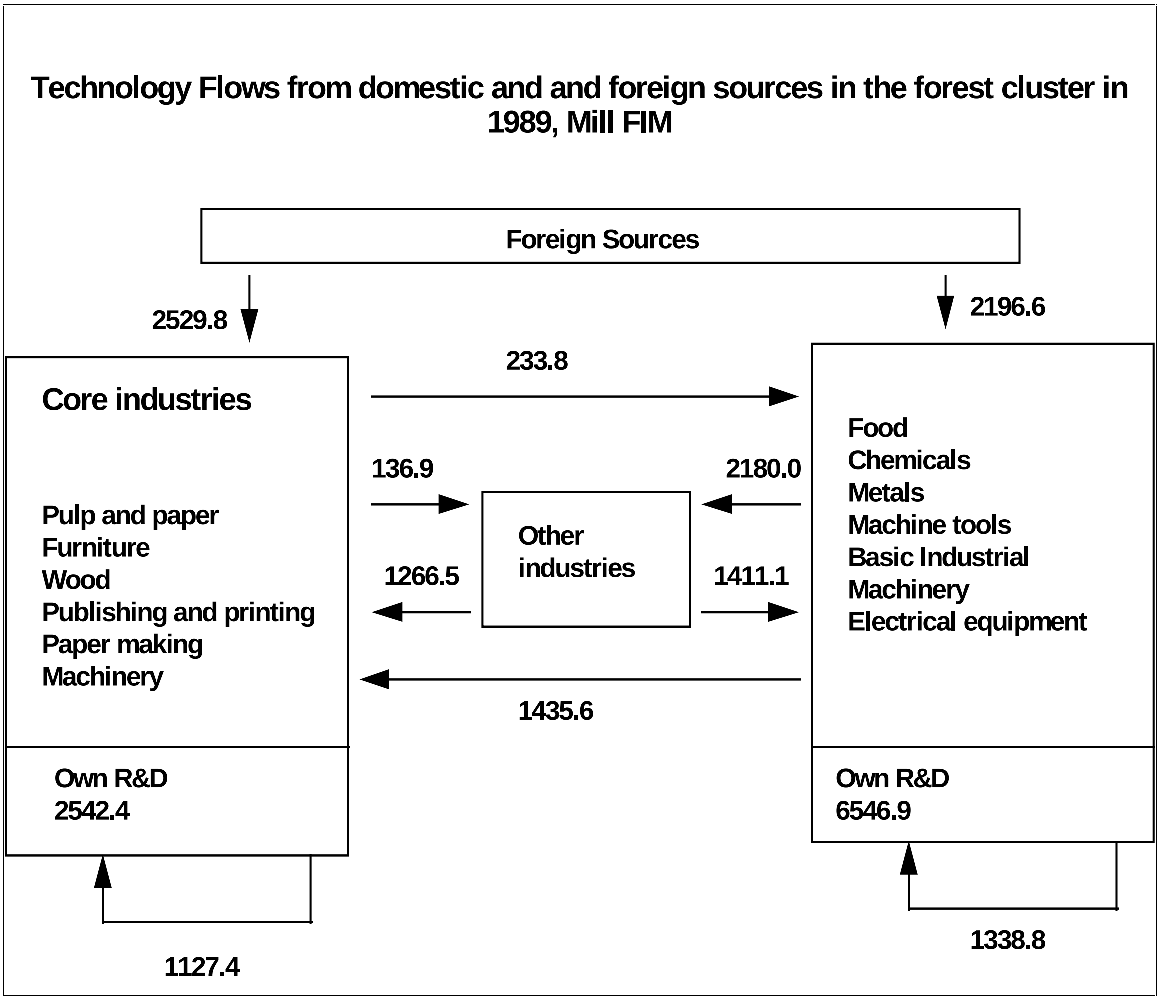
108 Intangible innovation expenditures are defined as expenditures to R&D, Acquisition of patents and licenses, product design, trial production, training and tooling up and market analysis

109 It appears that firms within pulp, paper and paper products (NACE 21.1 and NACE 21.2) use more of total current innovation expenditures on specialist services outside the enterprise than other industries. These differences are statistically significant at the 1% level (indicated by stars in the figure).

Figure 2.11: The Finnish forestry cluster.



Source: Synnove Vuori, Technology sources in Finnish manufacturing, ETLA 1995

2.1.1.3 How important are country differences?

We found above that industries differed considerably in terms of innovation structure. In the following we investigate country differences within NACE 21.1 and NACE 21.2, focusing again on information sources, intangible and tangible investments. As in Section 2.1.1.1, the scale on the importance of information sources (1-5) is transformed to binary, 1 or 0. A cross national weighted average is calculated utilising the simple average for each country weighted by the total number of firms in that country. We did not have access to the population of firms *by firm size*, hence we did not discriminate on firm size in the analysis of information sources.[110].

When dividing into three digit NACE, country and firm size, we get a very small sample within each category. Due to the very limited number of observations and

[110] A bivariate test on small vs large firms did not show large significant differences between the two categories. Out of the 13 tests within NACE 21.1 we found no significant differences between large and small firms. Out of the 13 tests within NACE 21.2 we found no significant differences between large and small firms. We must though remember that actual size differences could be hidden by other variables (for instance country). Unfortunately, we do not have a sufficient amount of data to do multiple tests.

heavily skewed distributions it is not possible to do multiple tests with dummy variables controlling for different variables (such as country). Instead we have to do a distribution free test for a limited number of countries within each NACE category, telling us something about the influence of country on innovation costs. The tests involved Italy, Netherlands and Germany. The test variable was the ratio intangible/tangible investments and we tested whether this ratio was statistically different from one country to another.

Intangible and tangible investments.[111] Out of 12 statistical tests on the ratio intangible/tangible investments, we found that 2 tests gave significant differences between countries. We found that Germany had a significantly higher ratio intangible/tangible investments than Netherlands (NACE 21.1 large firms) and Italy (NACE 21.2 large firms). This may reflects specific problems in Germany in the period the CIS were undertaken. German firms experienced major cutbacks in investments in the recession of the early 1990s. In general the early 1990s were difficult years for the pulp and paper industry world wide with oversupply and economic recession. German firms in particular had extreme difficulties, especially in East Germany. Against this background and in the face of continuing difficulties, investment plans were postponed. Many mills reduced production and operated below capacity.[112] The first half of 1993 was also a major disappointment for German firms, which performed less well than the economy as a whole. Following a virtual standstill in 1991 and 1992, production of paper and board declined 3% during the first half of 1993.[113] The second half of the year was slightly better for German firms, giving a total production increase by 0.7%. By contrast Finland had a production increase from 1992 to 1993 of 9.1%, Sweden 4.8% and Norway 16.8%. It is probably this context that reflects also the relatively low innovation output (measured as share of turnover from new products) in Germany from 1990 to 1992 (Sec.(2.2))

It is also seen that Norway had a high ratio intangible/tangible investments to innovation, probably reflecting low investment in new machines during the survey period. Nevertheless, Norwegian firms did go into some modernisation schemes; like for instance the rebuild of the PM6 machine at Union Bruk, a major firm. But in general, because of low profitability in the market most investments were postponed to 1993; this applied for example to the largest Norwegian company Norske Skog, which were preparing for major investments to be made in 1993.

Netherlands stands out with a very low ratio intangible/tangible investments. Due to major modernisation schemes in several mills, Netherlands had considerable investments in the period 1990 - 1992.

Information sources. Table 2.4 briefly sums up the statistically significant differences that were found in between countries. The full figures are in Appendix C.

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[111] As before, intangible innovation expenditures are defined as expenditures to R&D, Acquisition of patents and licenses, product design, trial production, training and tooling up and market analysis. Tangible innovation expenditures are defined as total capital expenditures spent on investments in plant, machinery and equipment linked to new product innovation.

[112] *Pulp and Paper International*, January 1993, ‘Road to recovery is no easy climb’.

[113] *Papermaker* Dec/Jan 1993-94, Germany

German, Dutch, Norwegian, Belgian and Irish firms tend to appreciate a wider spectrum of information sources than is the case for Italy and France. French firms in particular seem to lag in their willingness to exploit different kinds of information sources.

Table 2.4: The use of Information sources by country.
Statistically significant[114] *differences between a certain country and the average for all countries are displayed below.*

Country	NACE	Source	Rating of Source
France	21.1	Within the enterprise	Lower than others
	21.1	Suppliers of materials and equipment	Lower than others
	21.1	Clients or customers	Lower than others
	21.1	Competitors in your line of business	Lower than others
	21.1	Fairs/Exhibitions	Lower than others
Germany	21.1	Clients or customers	Higher than others
	21.1	Competitors in your line of business	Higher than others
	21.1	Universities/Higher education	Higher than others
	21.1	Conferences, meetings, journals	Higher than others
	21.1	Fairs/Exhibitions	Higher than others
	21.2	Suppliers of materials and comp	Higher than others
	21.2	Clients or customers	Higher than others
	21.2	Competitors in your line of business	Higher than others
	21.2	Universities/Higher education	Higher than others
	21.2	Conferences, meetings, journals	Higher than others
	21.2	Fairs/Exhibitions	Higher than others
Italy	21.1	Within group of enterprise	Lower than others
	21.1	Consultancy firms	Higher than others
	21.1	Universities/Higher education	Lower than others
	21.1	Conferences, meetings, journals	Lower than others
	21.1	Fairs/Exhibitions	Lower than others
	21.2	Within the enterprise	Higher than others
	21.2	Within the group of enterprise	Lower than others
	21.2	Competitors in your line of business	Lower than others
	21.2	Consultancy firms	Higher than others
	21.2	Technical Institutes	Lower than others
	21.2	Conferences, meetings, journals	Lower than others
Netherlands	21.2	Within the group of enterprise	Higher than others
	21.2	Clients or customers	Higher than others
	21.2	Competitors in your line of business	Higher than others
	21.2	Patent disclosures	Higher than others
Norway	21.1	Technical institutes	Higher than others
	21.1	Conferences, meetings, journals	Higher than others
		Clients or customers	Higher than others
Belgium	21.2	Within the group of enterprise	Higher than others
	21.2	Government laboratories	Higher than others
	21.2	Fairs/Exhibitions	Higher than others
Ireland	21.2	Within the enterprise	Higher than others
	21.2	Clients or customers	Higher than others
	21.2	Competitors in your line of business	Higher than others
	21.2	Technical institutes	Higher than others
	21.2	Conferences, meetings, journals	Higher than others

Due to different sample techniques in different countries, it is difficult to draw conclusions on the *population* of firms in each country. What we can do though, is to

[114] The significance level is 5% (or 95%)

say something about our sample. We see that although pulp, paper and paper products is an international industry, there are several country specific features. Countries invest in different types of resources and products and they use different types of information sources. In several cases these differences are also statistically significant, possibly reflecting different institutional/cultural/regulatory set ups in different countries. One such example is the role of the university. While universities as an information source were ranked significantly higher in Germany than in other countries, this source was ranked significantly lower in Italy than in other countries.

Table 2.5: NACE 21.1: Tests on statistically significant differences between countries on the variable: 'Share of intangible/tangible investments in innovation'. Statistical significant differences labelled 'Yes' and non-statistical differences labelled 'No'.

		Italy		**Germany (D)**	
		Large firms	Small firms	Large firms	Small firms
Italy	Small firms	-	-	-	No
	Large firms	-	-	No	-
Netherlands	Small firms	-	No	-	No
	Large firms	No	-	Yes, D highest ratio	-

Table 2.6: NACE 21.2 Tests on statistically significant differences between countries on the variable: 'Share of intangible/tangible investments in innovation'. Statistically significant differences labelled 'Yes' and non-significant differences labelled 'No'.

		Italy		**Germany (D)**	
		Large	Small	Large	Small
Italy	Small firms	-	-	-	No
	Large firms	-	-	Yes, D highest ratio	-
Netherlands	Small firms	-	No	-	No
	Large firms	No	-	No	-

Figure 2.12: Intangible investments in innovation as a percentage of sales and tangible investments in innovation as a percentage of sales by country[115]. Weighted calculations.

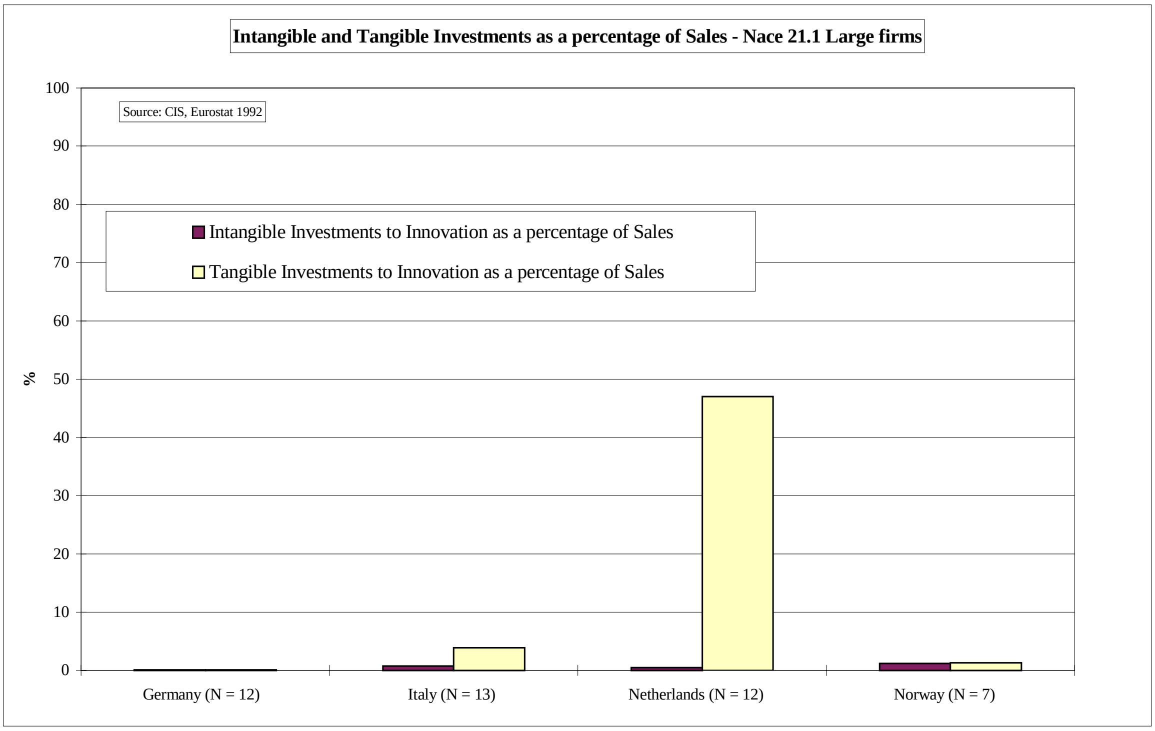
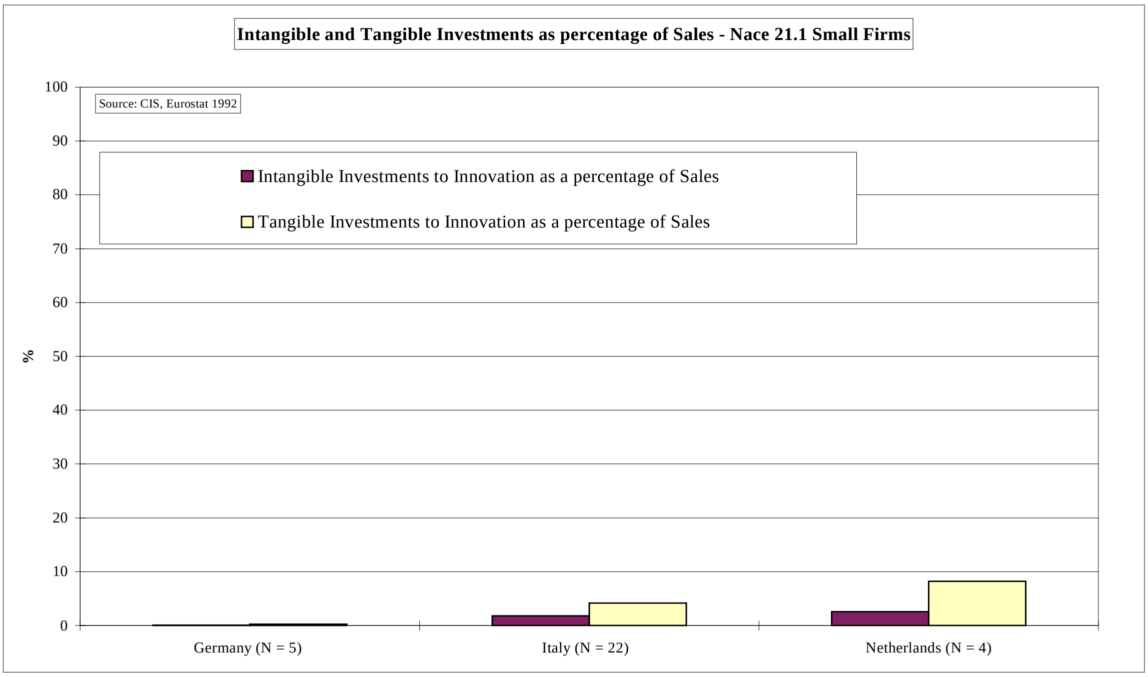


Figure 2.13: Intangible investments in innovation as a percentage of sales and tangible investments in innovation as a percentage of sales by country[116]. Weighted calculations.



[115] For a definition of tangible and intangible investments to innovation see previous figures

[116] For a definition of tangible and intangible investments to innovation see previous figures

Figure 2.14: Intangible investments in innovation as a percentage of sales and tangible investments in innovation as a percentage of sales by country[117]. Weighted calculations.

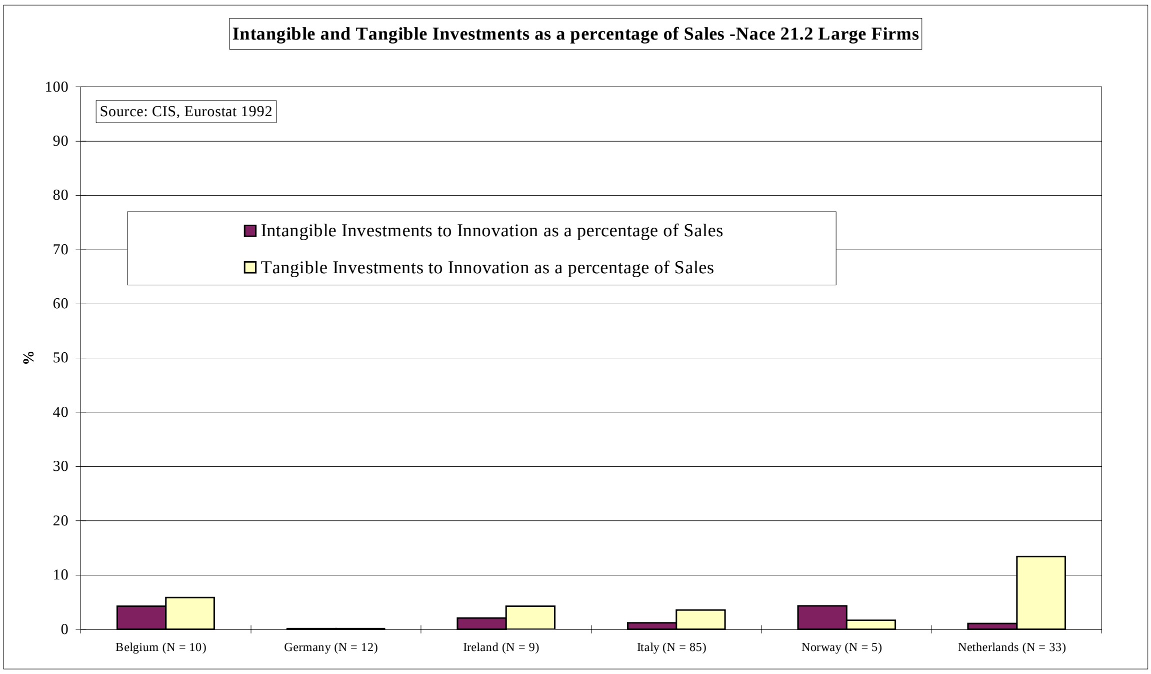
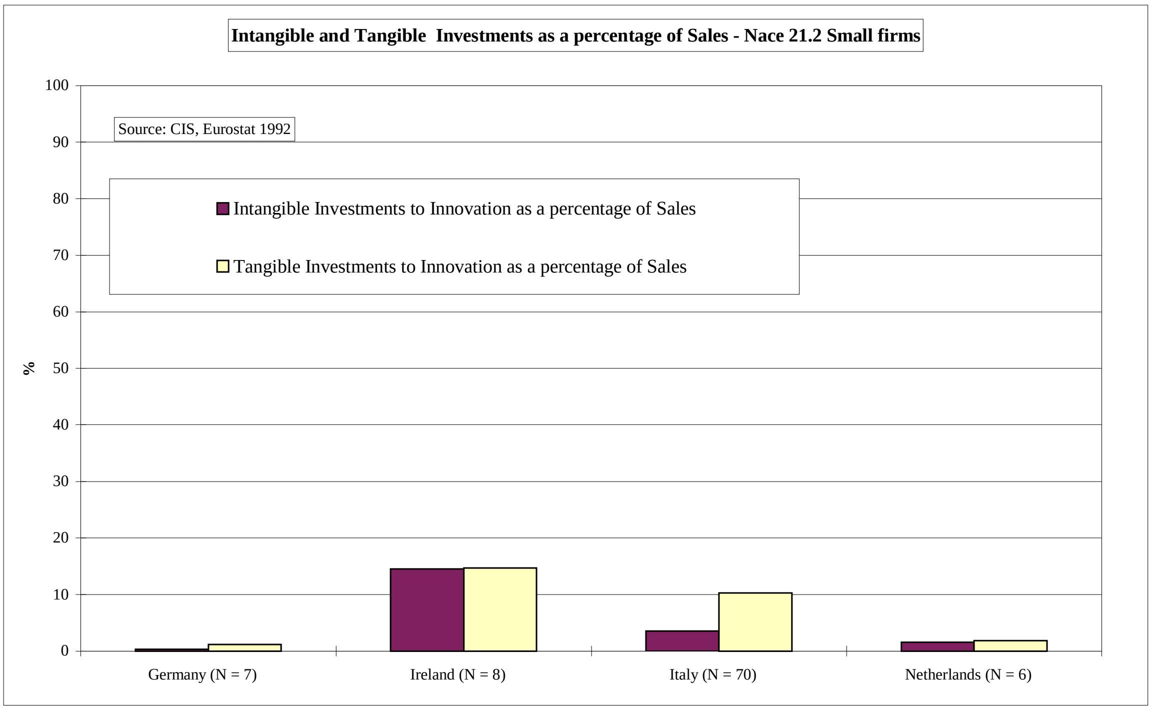


Figure 2.15: Intangible investments to innovation as a percentage of sales and tangible investments to innovation as a percentage of sales by country[118]. Weighted calculations.



[117] For a definition of tangible and intangible investments to innovation see previous figures

[118] For a definition of tangible and intangible investments to innovation see previous figures

2.1.1.5 Heterogeneity and firm strategies

The focus of this report is on inter-industry differences and inter-country differences. But we should not forget that although we may find several common features between firms within the same industry, or category, we must also bear in mind that firms within an industry often differ. There can be considerable diversity in terms of strategies, competence, innovativeness and so on. Here we look at some dimensions of this variety by analysing the cumulative distributions of relevant variables.

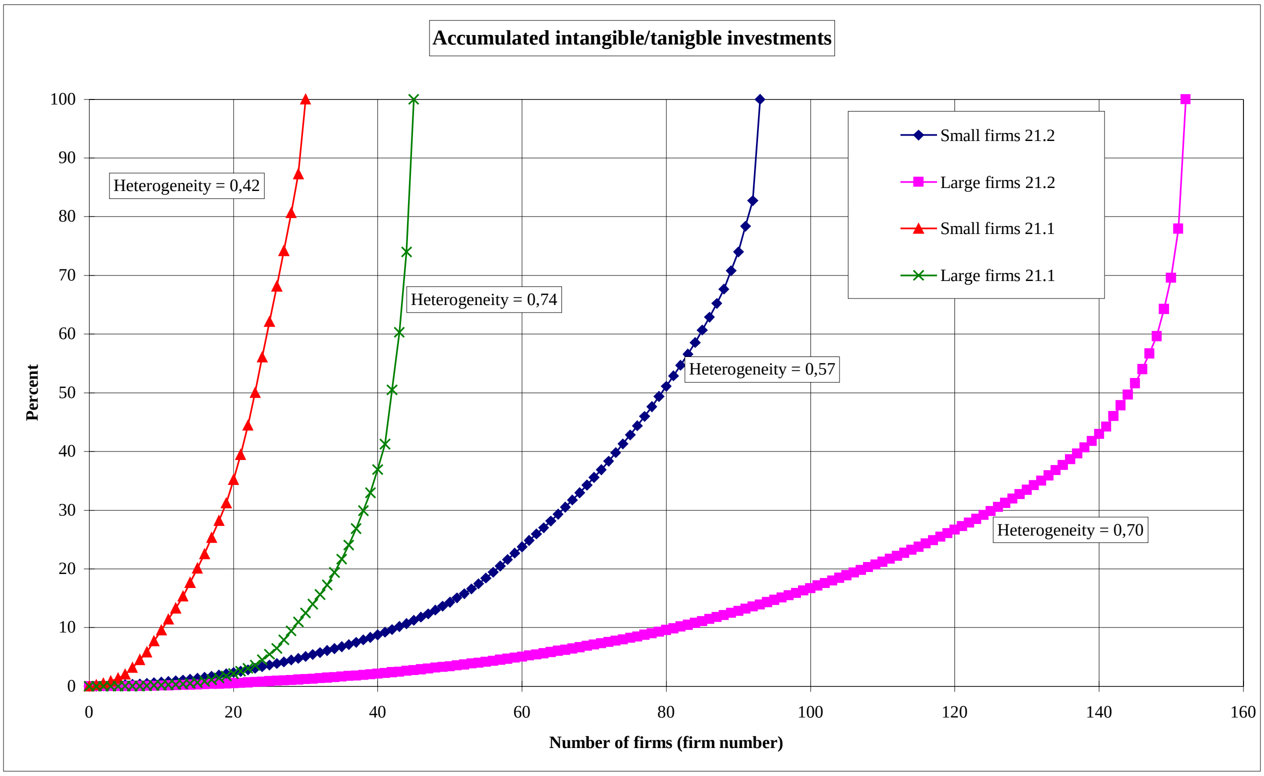
If there are no differences between firms, the cumulative distribution of a specific variable would be a straight line. If firms are very different we would get out a heavily skewed distribution. By implication it is actually possible to measure the degree of heterogeneity in any industry. We construct a heterogeneity index as

$$\textit{Heterogeneity Index} = \frac{\int (f(x) - g(x))dx}{\int f(x)dx}$$

where *f(x)* is the straight non-heterogeneity line and *g(x)* the empirical distribution for the specific variable within an industry.

Below we present the heterogeneity indexes in NACE 21.1 and NACE 21.2 on a specific variable, namely the ratio of intangible to tangible investments to innovation. Firms indeed do differ. We find the largest degree of heterogeneity in the class ‘large firms’. This may be due to the fact that this group is very big, and some of the variation might therefore be accounted for by the fact that smaller firms in general differ from the larger ones. But more fundamentally it also refers to the fact that different firms do have different strategies. While some firms invest in niches and flexible production and new machines which need considerable investments also in human resources to make the system work effectively, other invest more heavily in standard, mature and well-tested machinery which does not require the same amount of competence. Such differences among firm strategies and behaviour may be reflected in Figure 2.16.

Figure 2.16: Heterogeneity and heterogeneity indexes for NACE 21.1 and NACE 21.2, small and large firms.
For each firm the ratio' intangible to tangible investments to innovation' is calculated. The heterogeneity index is calculated on the basis of the distribution of this ratio within a certain group of firms



The Heterogeneity index is '0' for no firm heterogeneity and it is approaching '1' for extreme firm heterogeneity. Mathematically the heterogeneity is constructed as:

$$Heterogeneity\ Index = \frac{\int (f(x) - g(x))dx}{\int f(x)dx}$$

where g(x) is the empirical distribution and f(x) is the distribution without any skew (a straight line from 0% to 100%).

2.1.2 Distribution of innovation costs

A common argument in innovation theories is that industries innovate in different ways. This observation has been confirmed in the above analysis on intangible and tangible investments in innovation. In the following we explore these issues further by analysing the distribution of intangible innovation costs across industries and countries.

In the CIS Survey each firm was asked to estimate the percentage of total intangible (current) innovation expenditures attributable to the following activities

-R&D
-Acquisition of patents and licences
-product design
-trial production, training and tooling up
-market analysis
-other

The answers on these questions are analysed in the following.

2.1.2.1 How does 'Pulp, paper and paper products' differ from other industries?

In the following analysis we do a Wilcoxon rank test in order to investigate whether NACE classes are significantly different when it comes to the distribution (not the level) of innovation costs. We also display graphs that show the unweighted mean for different NACE categories, discriminating between small and large firms.

On the distribution of innovation costs we do not find large differences between NACE classes when it comes to the *distribution* of intangible innovation costs. For all groups we find that the most important innovation costs are 'product design', 'R&D' and 'trial production, training and tooling up'. However the ranking of these sources differ across industries.

Table 2.7: Ranking of the three most important intangible innovation expenditures by type of industry and by size

Industry	Size category	Rank 1	Rank 2	Rank 3
NACE 21,1	Small firms	Product design	Trial prod,, train,,	R&D
	Large firms	Trial prod, train	R&D	Product design
All NACE	Small firms	Product design	R&D	Trial prod, train
	Large firms	R&D	Trial prod, train	Product design
NACE 21,2	Small firms	Product design	Trial prod, train	R&D
	Large firms	R&D	Trial prod, train	Product design
All NACE 2	Small firms	Product design	R&D	Trial prod, train
	Large firms	R&D	Trial prod, train	Product design

For large firms within NACE 21.1 we found that the three most important innovation costs were 'trial production, training and tooling up', 'R&D' and 'product design'. This also holds for large firms within other industries (although the rank is different). There were significant differences (at the 1% level) between the two groups on trial production, training and tooling up. As we should expect, this category is considerably more important for pulp and paper than it is for the other industries. This reflects the fact that pulp and paper have considerable investments in tangible assets, which in turn requires intangible investments (in the form of training of personnel etc.).

For large firms within NACE 21.2 (articles of paper and paper products) the three most important innovation costs are 'R&D' , 'trial production training and tooling up' and 'product design'. Among these factors there were found significant differences (5%) between the two groups on the factor 'R&D'. NACE 21.2 invested considerably in less R&D (as a fraction of total innovation costs) than other industries.

For small firms within NACE 21.2 differences were more prominent. The three most important innovation factors were 'product design', 'R&D' and 'trial production training and tooling up'. NACE 21.2 and ALL NACE are significantly different (1%) on all these three factors. Product design is significantly more important in NACE 21.2 than in the ALL NACE group. On the other hand 'R&D' and 'trial production and tooling up' is significantly more important in the ALL NACE group.

Figure 2.17: Distribution of innovation costs by industries

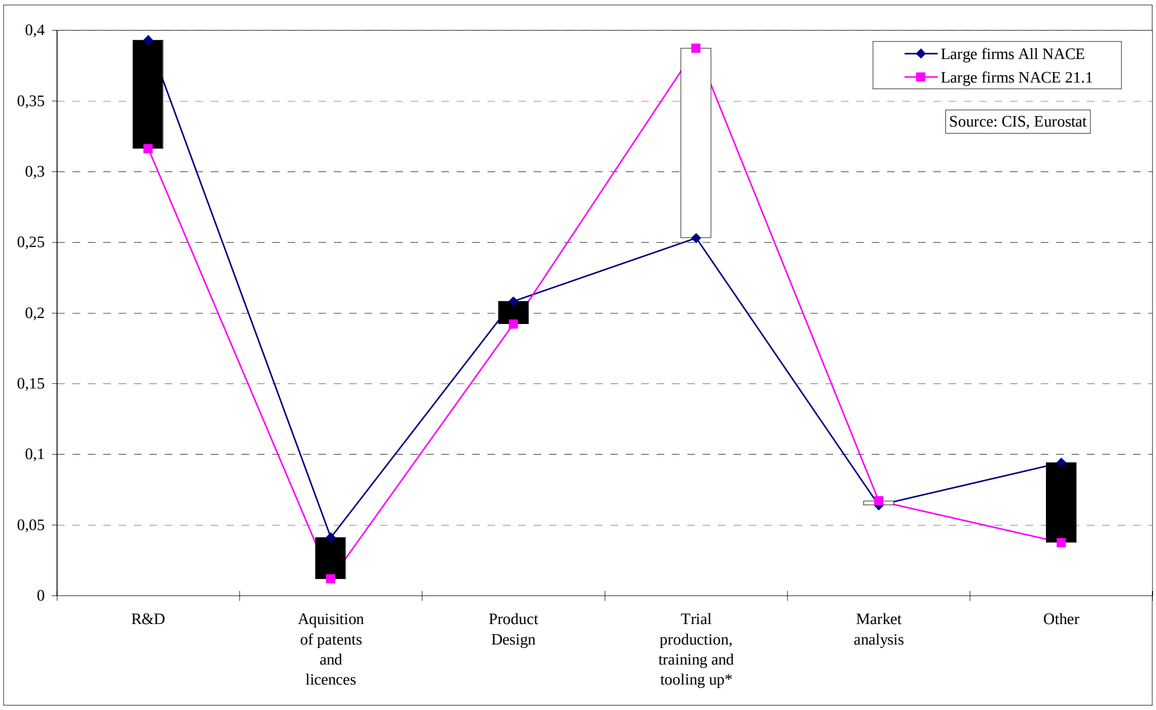


Figure 2.18: Distribution of innovation costs by industries

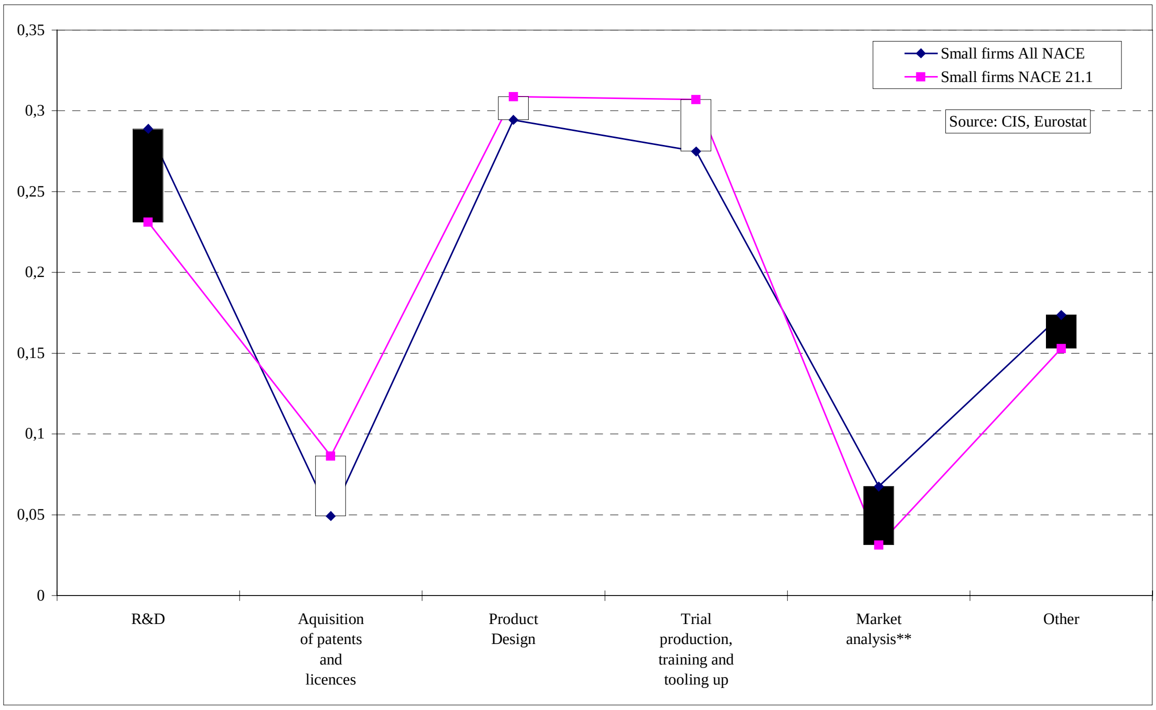


Figure 2.19: Distribution of innovation costs by industries

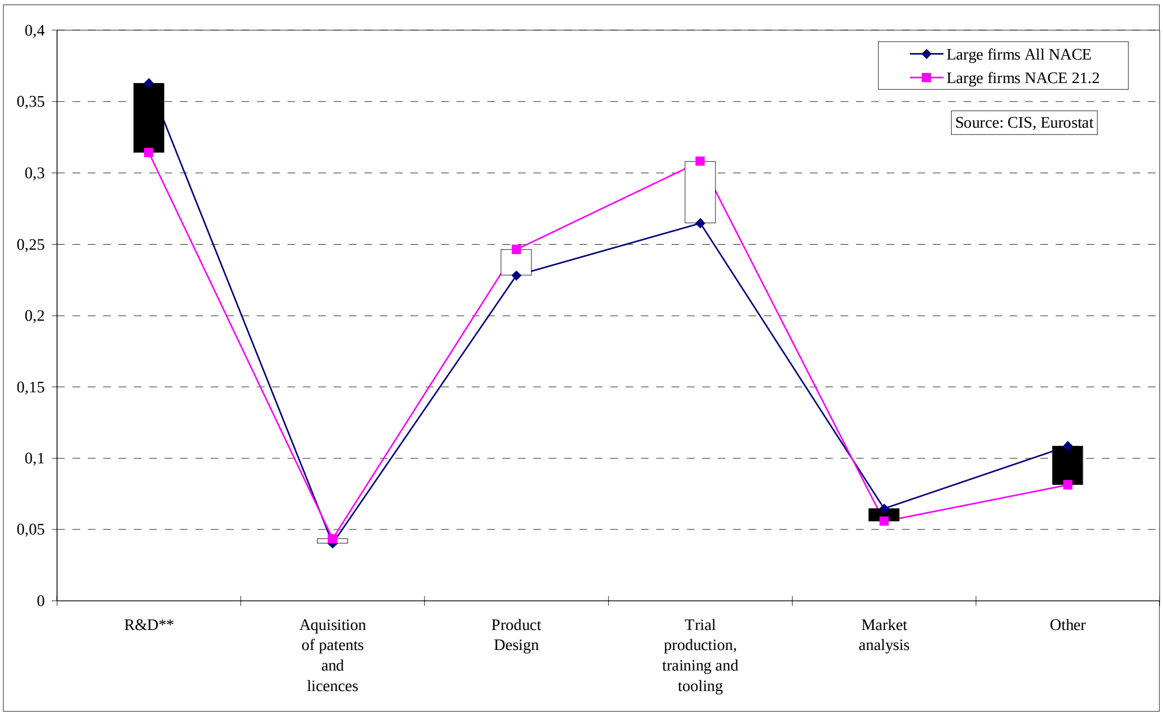
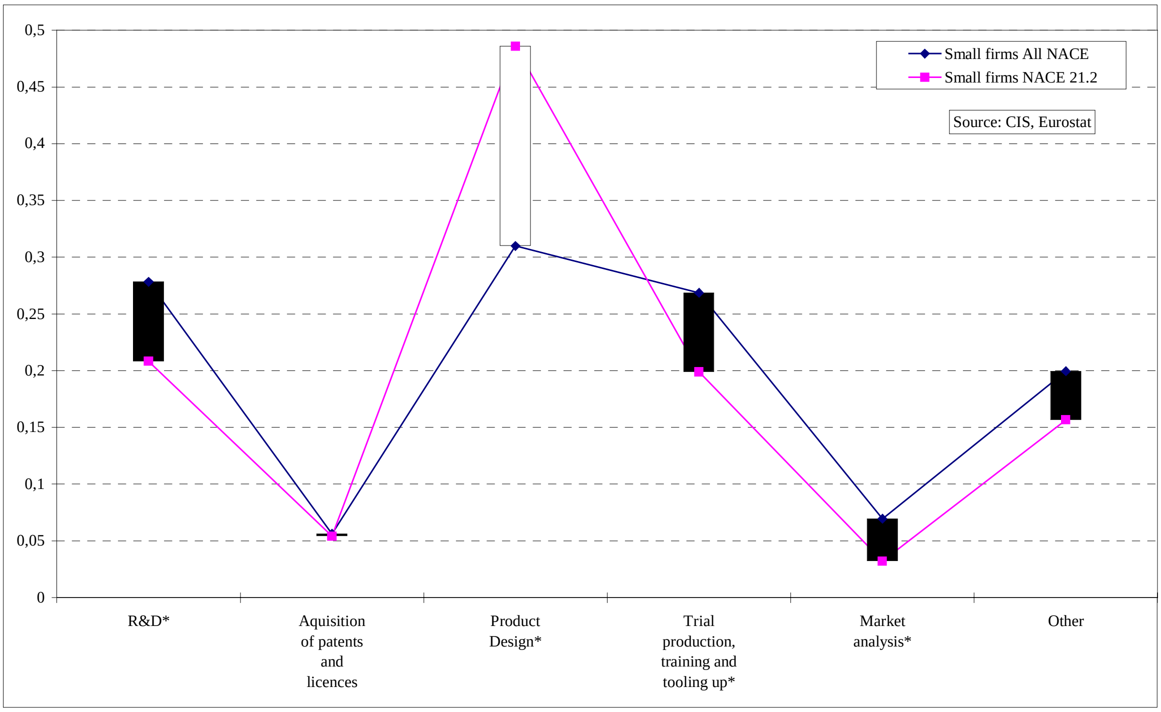


Figure 2.20: Distribution of innovation costs by industries



2.1.2.3 How important are country differences?

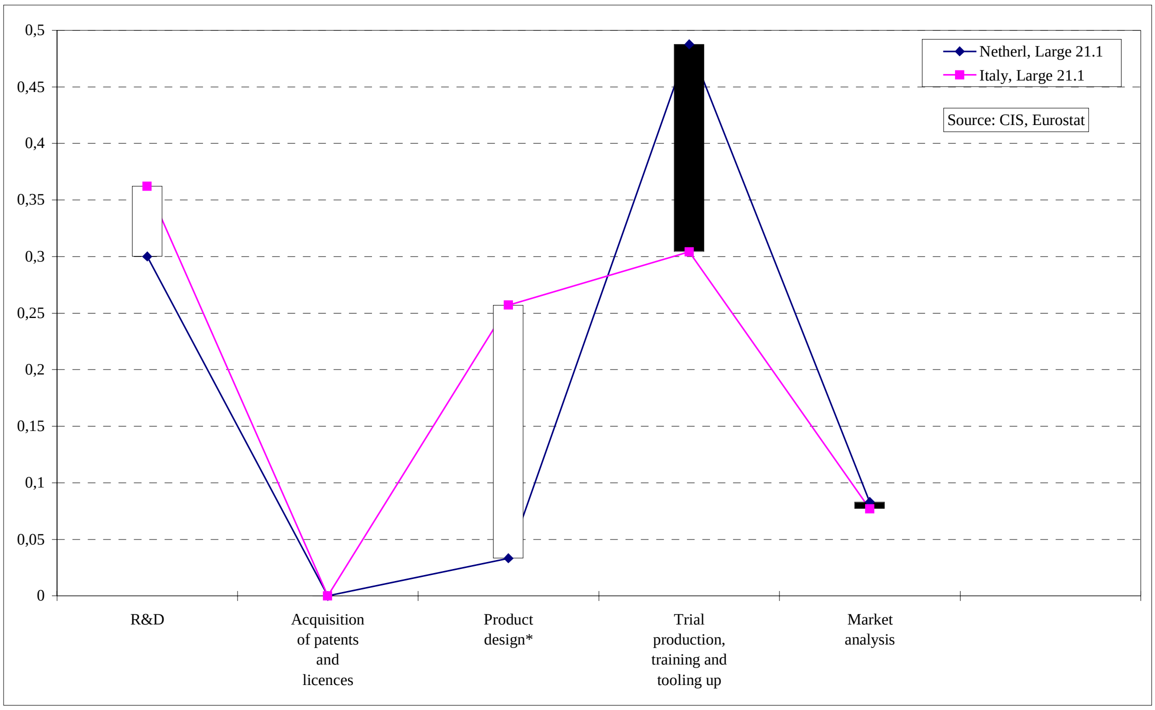
In the following we test whether we can see significant differences between countries in their distribution of innovation costs. Again our analysis is limited by the relatively small number of observations available; we focus therefore on results for Netherlands and Italy.

The data indicates that there are some quite differences between these two countries. In particular *product design* is more important in Italy than in the Netherlands. This holds for all four tests, i.e. small and large firms in both NACE 21.1 and NACE 21.2; differences are statistical significant in two of the four tests. These findings might indicate that Italian firms (which are included in the CIS survey) are operating in a different market segment than the Dutch firms (included in the CIS survey). Italian firms are in general quite small and authors on the industry write that Italian firms concentrate on the production of high-quality, high added value paper where flexibility, creativity and customer service are all-important. Extensive use of product design is an important part of this strategy.[119] Hence the CIS seem to capture some of these structures.

Trial production, training and tooling up, on the other hand, are more important in Netherlands than in Italy. As we saw above the industry in the Netherlands undertook major investments in the period in question, so it should not be surprising that these investments are accompanied by costs in 'trial, production, training and tooling up'. As argued before investments in new machinery etc. are *complementary* to 'trial, production, training and tooling up'.

From the small set of data that we have studied, it seems that differences in market orientation, strategy are to some extent reflected in the distribution of innovation costs in different countries. While Italian firms seem to emphasise small, flexible production with special focus on product design and incrementally changed products, Dutch firms seem to be more oriented towards longer production lengths and probably also more resource intensive changes of production facilities.

Figure 2.21: Distribution of innovation costs by country, NACE 21.1, Large firms



[119] Pulp and Paper International, *Italy*, May 1996

Figure 2.22: Distribution of innovation costs by country, NACE 21.1, Small firms

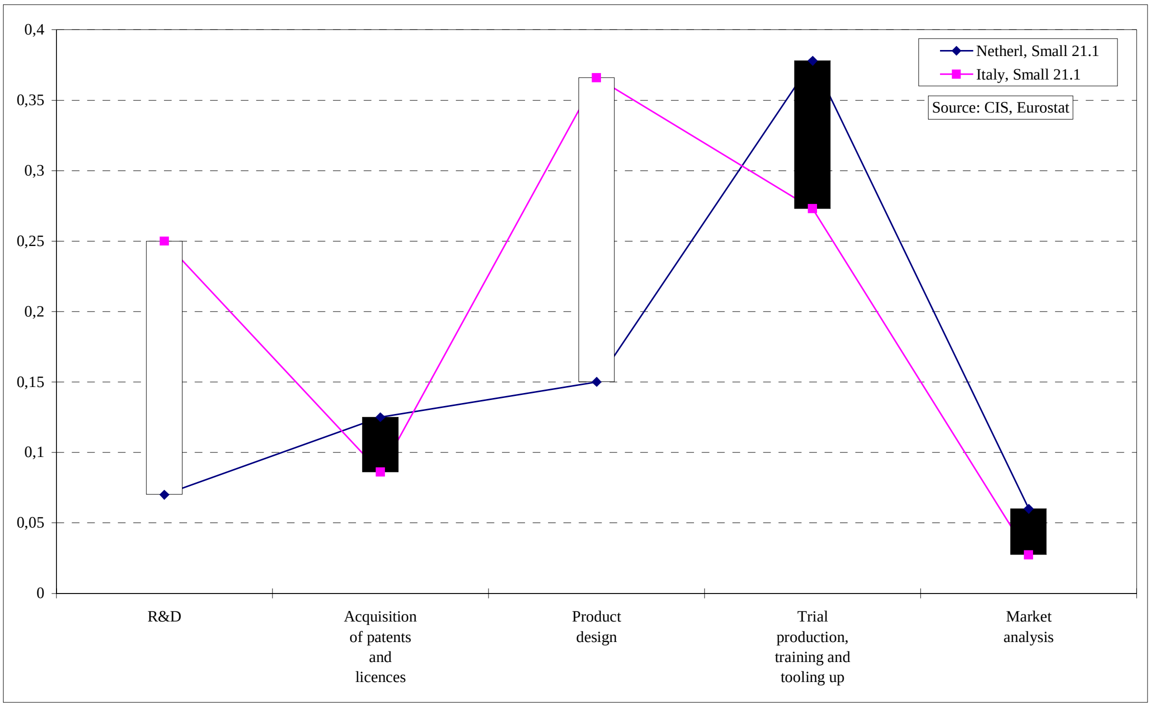


Figure 2.23: Distribution of innovation costs by country, NACE 21.2, Large firms

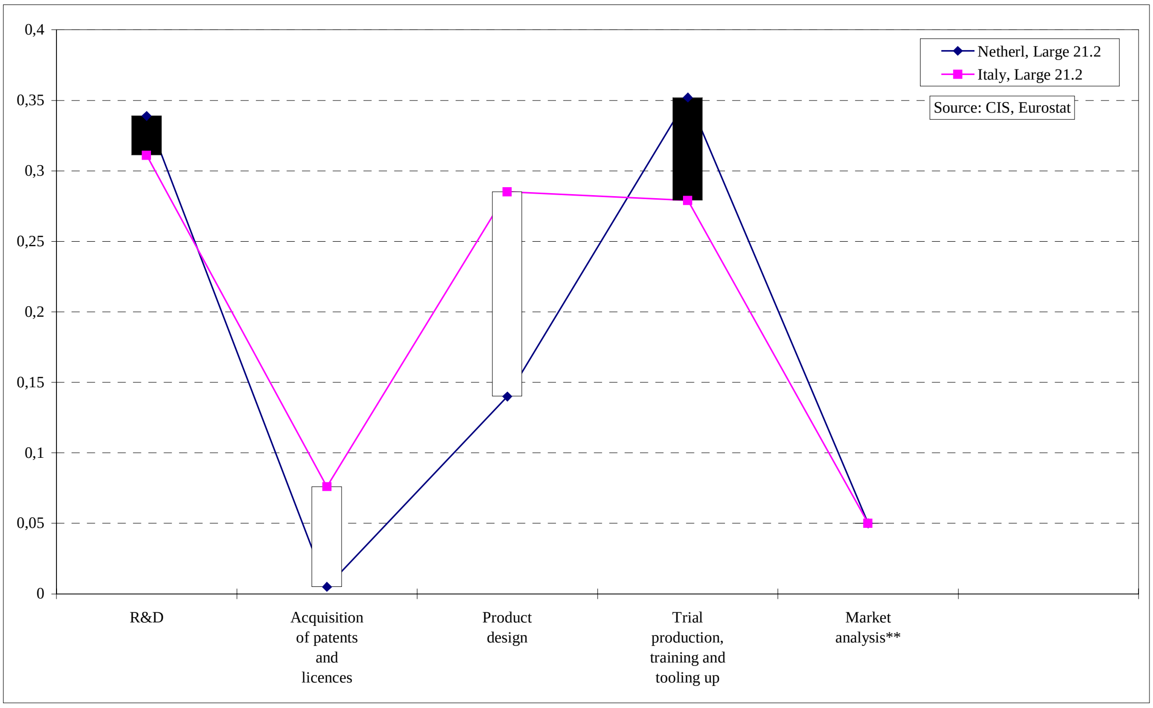
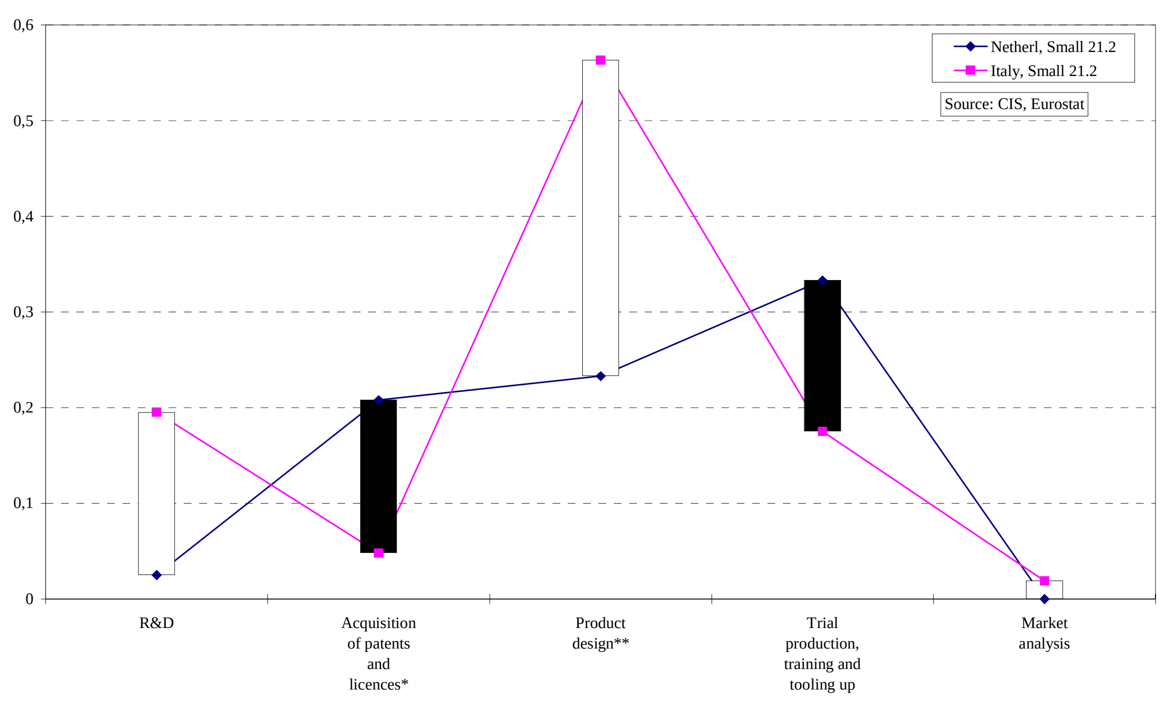


Figure 2.24: Distribution of innovation costs by country, NACE 21.2, Small firms



2.2 The impact of Innovation Activities

Measuring the impact of innovative activity is complicated. First of all: what shall we look for as an output measure? CIS measures innovations in the Schumpeterian sense of the concept by the asking firms how much of their total sales that originated from changed products. More concrete it asks:

V15a How were the enterprise's 1992 total sales distributed across these types of products?	
1) Products essentially unchanged during 1990-92	%
2) Products subject to incremental changes during 1990-92	%
3) Products significant changed during 1990 - 1992	%

In the analysis we have not discriminated between products significantly changed and products incrementally changed. This is partly due to the fact that this discrimination was not implemented in all country surveys. This analysis therefore refers to unchanged products versus incrementally and significantly changed products.

2.2.1 How does 'Pulp, paper and paper products' differ from other industries

Figures 2.26 and 2.27 shows the sum of turnover from new products as a fraction of the sum of turnover from unchanged products for NACE 21.1 (small and large firms), NACE 21.2 (small and large firms) and ALL NACE (small and large firms). The fraction is calculated as a weighted mean, i.e.

$$I = \sum_i (Turnover\ from\ new\ products)_i \ / \sum_j (Turnover\ from\ old\ products)_j$$

The data shows that turnover from new products is considerably lower in pulp, paper and paper products than in other industries. If we construct a variable 'new products' for all the firms and test for differences between NACE classes and firm size, we also see that the differences indeed are significant; see Table 2.8. This might be explained by the emphasis on new *processes* within pulp, paper and paper products; in this case, it may be that a new process does not necessarily result in a new product. Of course there is a clear measurement problem when mixing and comparing NACE classes with respect to the indicator ‘new products’. Different industries understand a ‘new product’ in different ways. Hence we should not come to any strong conclusions on this cross-NACE analysis. We can only state that small firms within NACE 21.1 are considerably more innovative than large firms within the same industry. Within NACE 21.2 the difference is not very prominent between the two categories, although large firms are slightly more innovative than smaller.

Figure 2.25: Turnover of new products as a fraction of turnover from unchanged products by industrial category and firm size

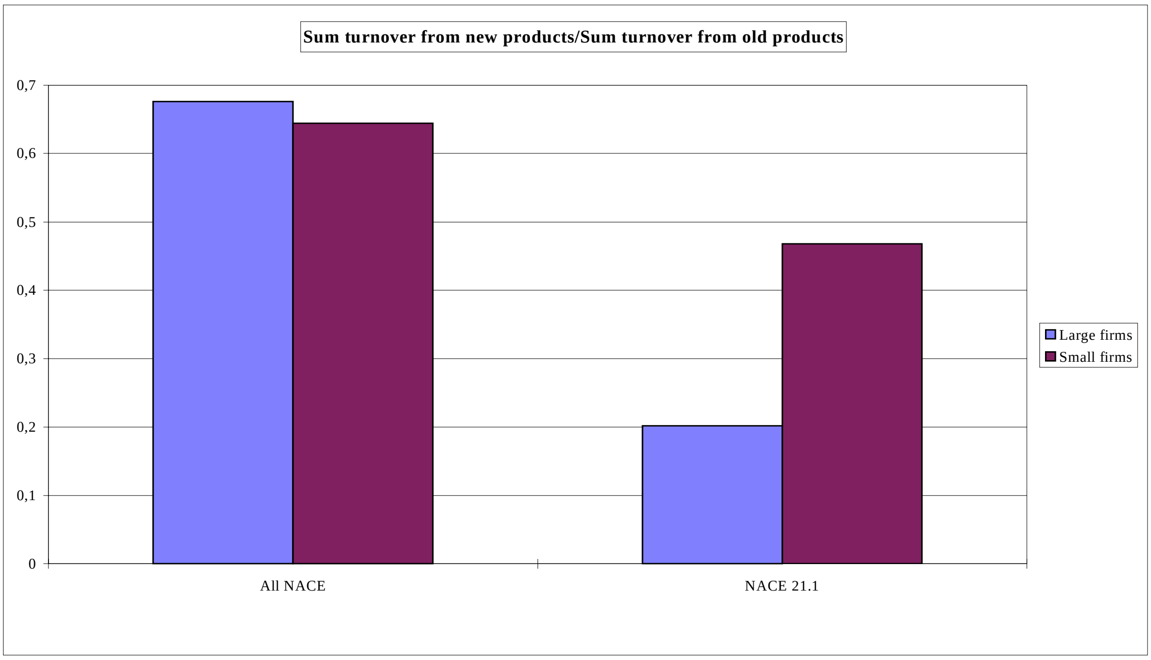


Figure 2.26: Turnover of new products as a fraction of turnover from unchanged products by industrial category and firm size

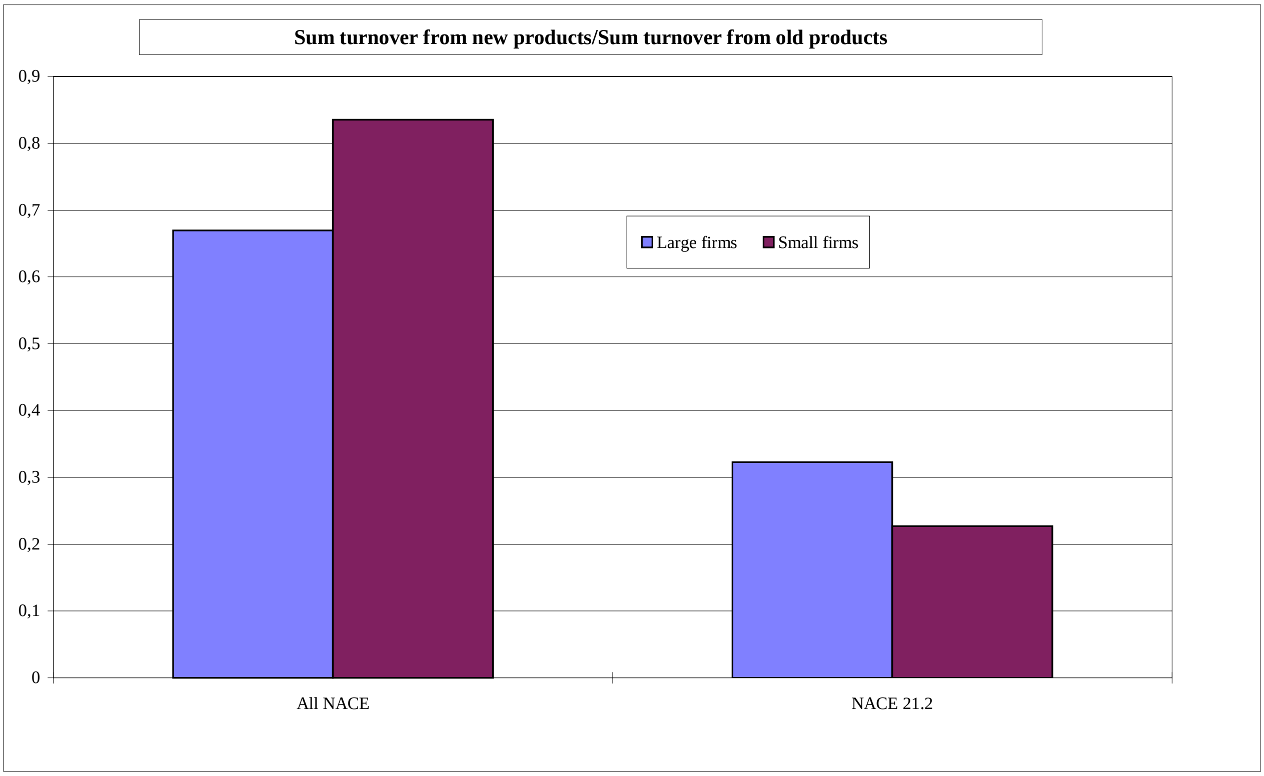


Table 2.8 : Share of new products. Statistical tests on differences between NACE categories.

Test	Highest share of new products	Is the difference statistically different?
ALL NACE vs NACE 21.1 (Large firms)	ALL NACE	Yes (on a 1% level)
ALL NACE vs NACE 21.1 (Small firms)	ALL NACE	Yes (on a 1% level)
ALL NACE vs NACE 21.2 (Large firms)	ALL NACE	Yes (on a 1% level)
ALL NACE vs NACE 21.2 (Small firms)	ALL NACE	Yes (on a 1% level)

2.2.2 How important are country differences?

We also statistically tested on differences between countries within NACE 21.1 and within NACE 21.2 on the variable ‘new products’. Out of 12 test we found that that 2 were significantly different at the 5% level.

Dutch and German firms both had a significantly higher amount of new products than Italian firms within the category small firms in NACE 21.2. In most of the groups Dutch firms have more new products than others. In general there seem to be indications that the Netherlands has quite strongly innovative firms within the industry.

If we link the above findings to the discussion above, we saw that Dutch firms had considerable investments in new machines etc. during the period in question. This seems to be accompanied by development of new products. Here however we must take into account mergers and acquisitions of other companies. A major objective in buying other companies is usually to acquire new competence and networks, thereby rapidly expanding the buying firm’s product range. Hence mergers usually result in a increase of 'new products' as defined in the CIS survey. A big merger actually occurred in Netherlands at the time the CIS was undertaken, between the papermakers KNP and Bührman-Tetterode and the mercantile group VRG. This may have had effects on the Netherlands data.

Norwegian firms had a relatively large share of new products (within NACE 21.1 large firms). This may also be related to specific firms. Ireland also had a high turnover from new products. Again, this relatively large share of new products was accompanied by high investments within intangible and tangible assets. However there are no clear or general links between investments in new machinery, new equipment, R&D, design etc. and the development of new products. These relationships are quite complex. For instance German firms (within the category NACE 21.2 small firms) did not undertake much innovation activity as measured by the CIS survey, but they had considerably more new products than other countries.

In summary, we see considerable differences between firms and countries in their ability to introduce new products into the economy. The underlying reasons for these differences are complex. Investment in machines, investments in product design, training etc. are *necessary*, but not *sufficient*, conditions for commercialisation of new products within this and other industries. There are several examples of companies investing in new machinery without being able to operate it successfully or without being able to integrate new paper products into the product mix. To develop these issues further would probably require extensive case studies aimed at grasping additional variables determining failure and success. One such new explanatory variable/indicator could be related to organisational issues with respect to innovation activities within the firm, such as the management of knowledge and the management of knowledge transfer and distribution.

Figure 2.27: Turnover of new products as a fraction of turnover from unchanged products by industrial category, firm size and country

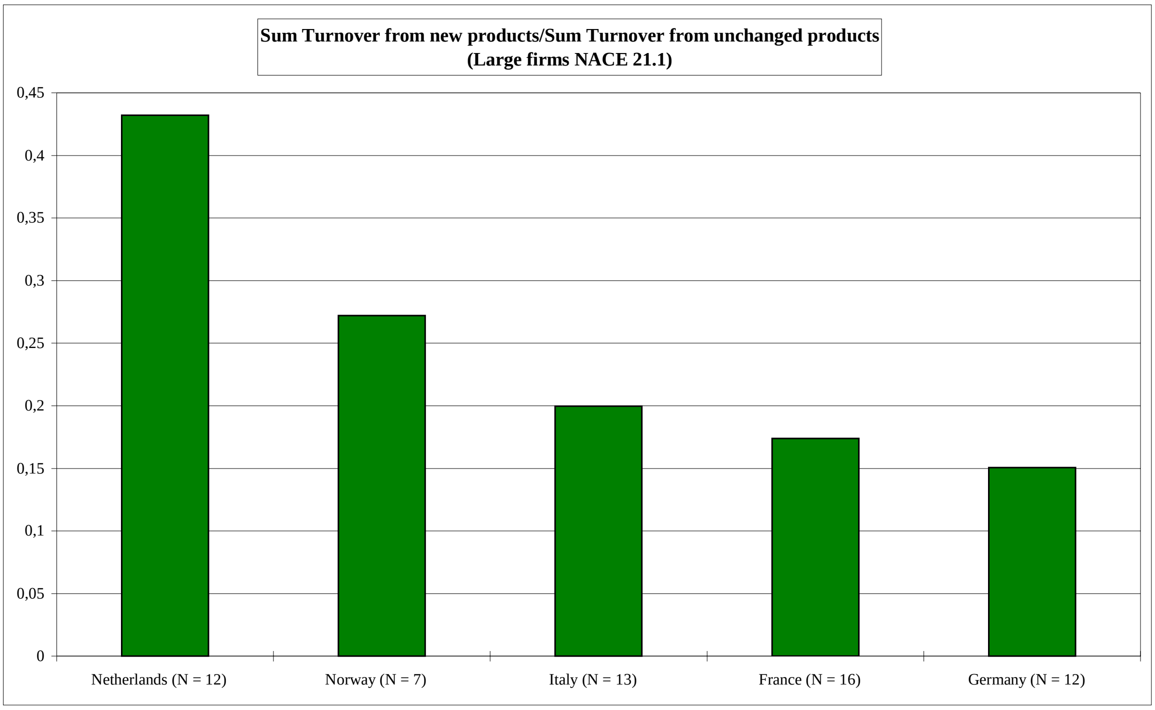


Figure 2.28: Turnover of new products as a fraction of turnover from unchanged products by industrial category firm size and country

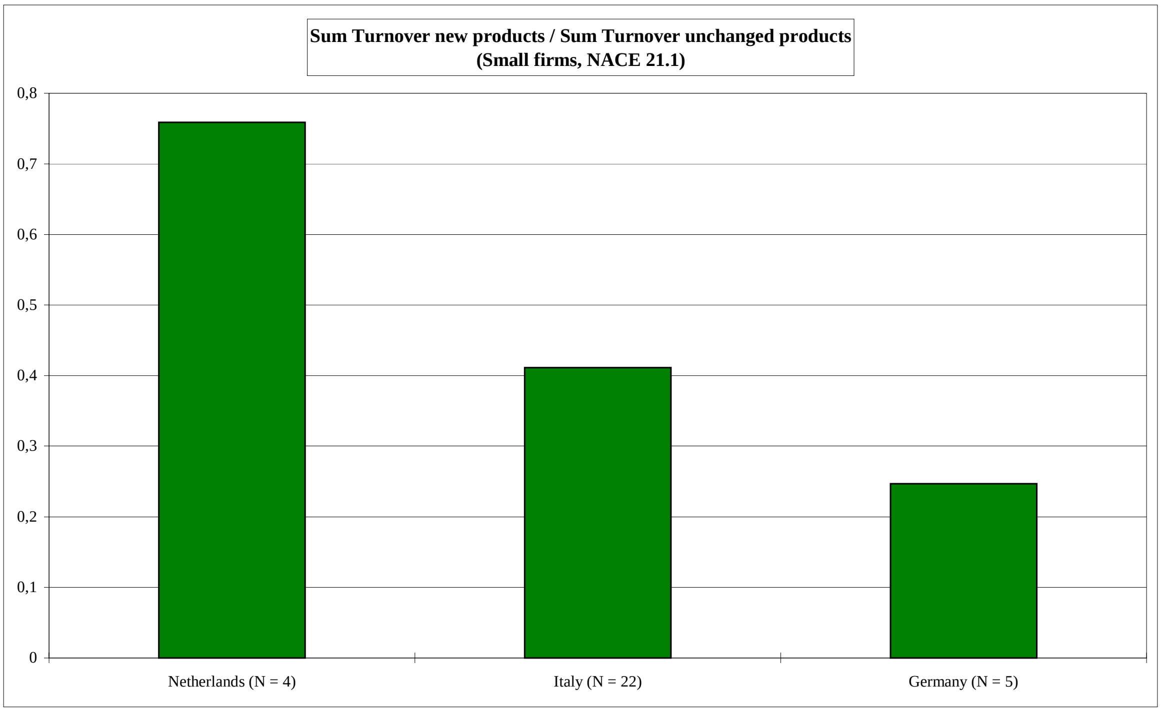


Figure 2.29: Turnover of new products as a fraction of turnover from unchanged products by industrial category firm size and country

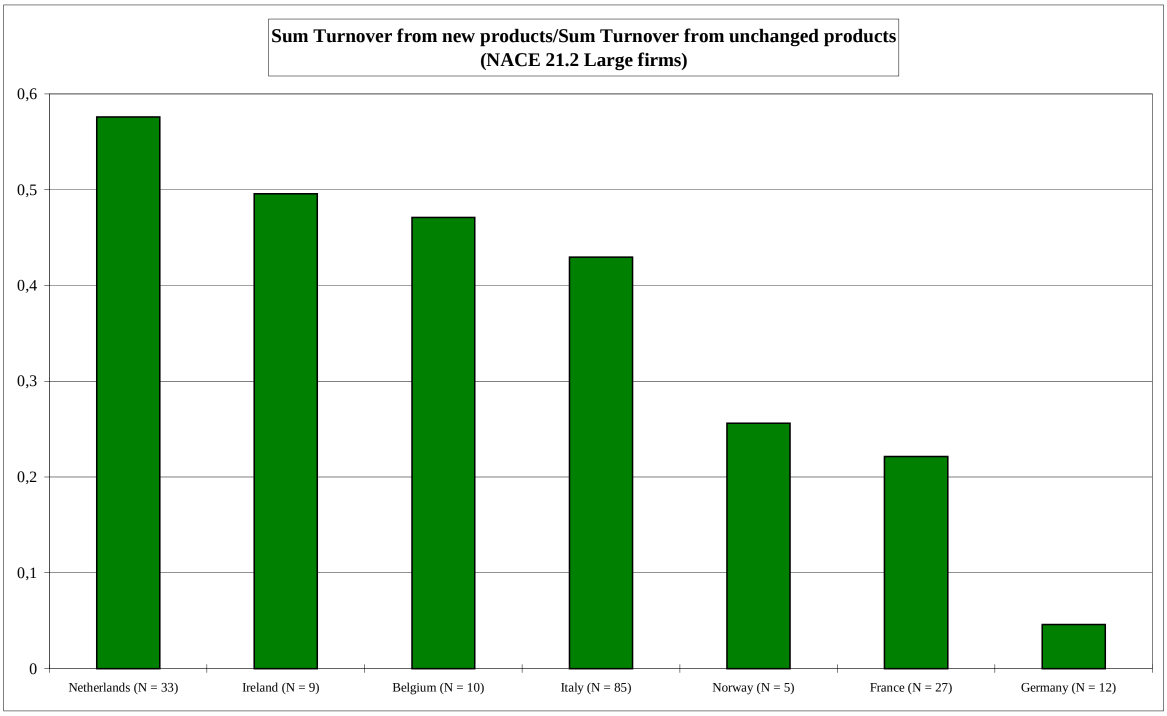


Figure 2.30: Turnover of new products as a fraction of turnover from unchanged products by industrial category firm size and country

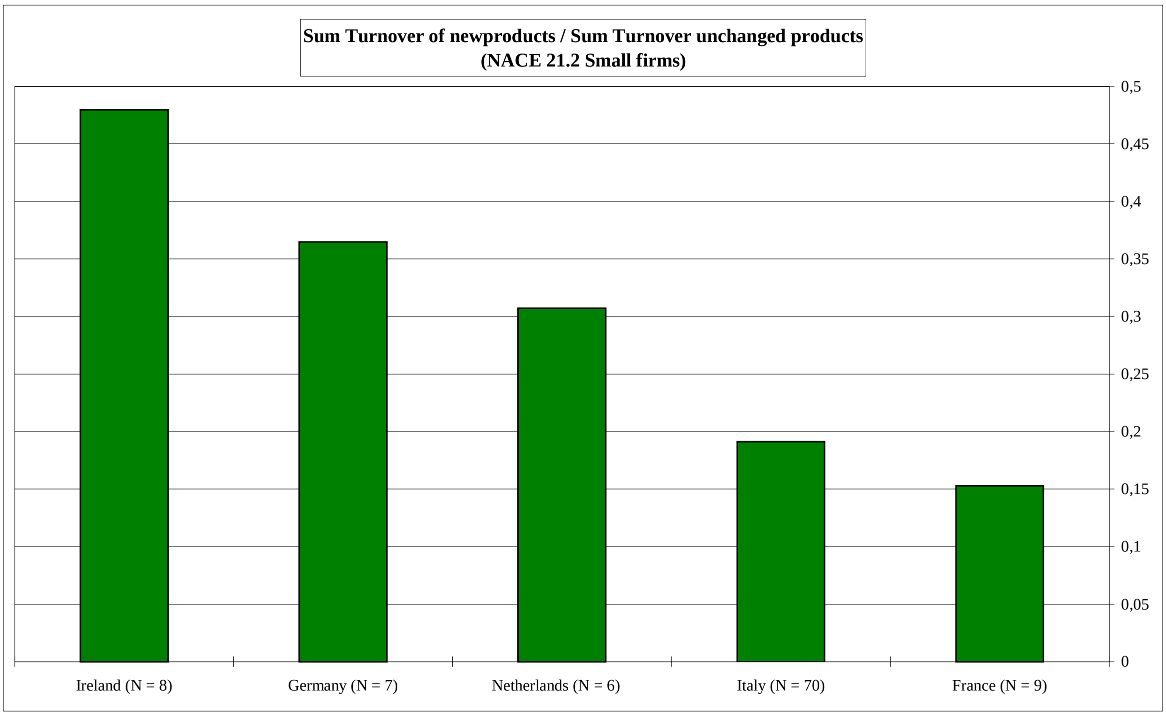


Table 2.9: NACE 21.1: Tests on statistically significant differences between countries on the variable 'new products
Statistical differences labelled 'Yes' and non-statistical differences labelled 'No'.

		Italy		**Germany**	
		Large	Small	Large	Small
Italy	Small firms	-	-	-	No
	Large firms	-	-	No	-
Netherlands	Small firms	-	No	-	No
	Large firms	No	-	No	-

Table 2.10: NACE 21.2 Tests on statistically significant differences between countries on the variable 'new products.
Statistical differences labelled 'Yes' and non-statistical differences labelled 'No'.

		Italy		**Germany (D)**	
		Large	Small	Large	Small
Italy	Small firms	-	-	-	Yes, D highest
	Large firms	-	-	No	-
Netherlands	Small firms	-	No	-	No
	Large firms	No	-	No	-

2.2.3 New products - Multivariate analysis

As pointed out in Sec.(2.2.2), firms differ in their innovativeness. In the following we try to look behind some of these differences with the aid of multivariate analysis.

Firstly, we performed a multivariate regression analysis on the relationship between new products and information sources. In this test the information sources were treated as a continuous variable. In order to get a sample which was big enough to do the analysis we pooled NACE 21.1 and NACE 21.2 together. We did a stepwise test, i.e. the independent variables are added one by one to the model. If the F statistic for the variable that is added is not significant, it is deleted from the model. If it does give a significant contribution to the model, all other variables already put in the model are checked for significance once again. Variables that are not significant are taken out of the model etc. etc. The model used was the following[120]:

New Products = $\alpha + \sum_i \beta_i V4\_i$

We found that 2 information channels significantly contributed to the development and commercialisation of new products (on the 5% level). The most important was 'suppliers of materials and components' the second most important was 'information from within the enterprise'.

Secondly, we also performed a regression analysis with innovation cost intensity[121] as the explanatory variables (and new products as the dependant variable. This regression analysis met large colinearity problems. 'R&D', 'product design', 'trial production, training and tooling up', 'market analysis' and 'capital investments' are

[120] Dependant variable: New products is defined as the percentage of the 1992 sales coming from products incrementally or radically changed in the period 1990-1992.

Independent variables:

V4_1 is Information from within the enterprise

v4_2 is information sources within the group of enterprise

v4_3 is information from suppliers of materials and components

v4_4 is information from suppliers of equipment

v4_5 is information from clients or customers

v4_6 is information from competitors in your line of business

v4_7 is information from consultancy firms

v4_8 is information from universities/higher education

v4_9 is information from government laboratories

v4_10 is information from technical institutes

v4_11 is information from patent disclosures

v4_12 is information from professional conferences, meetings, professional journals

v4_13 is information from fairs/exhibitions

There were not found any strong colinearity in the model, the largest bivariate correlation coefficient was 0.69.

[121] Dependant variable: New products is defined as the percentage of the 1992 sales coming from products incrementally or radically changed in the period 1990-1992.

Independent variables:

V13b_1*V13a/J is the share of sales devoted to R&D

V13b_2*V13a/J is the share of sales devoted to 'acquisitions of patents and licenses'

V13b_3*V13a/J is the share of sales devoted to 'product design'

V13b_4*V13a/J is the share of sales devoted to 'trial production, training and tooling up'

V13b_5*V13a/J is the share of sales devoted to 'market analysis'

v13d/j is the share of sales devoted to investments in plant, machinery and equipment, linked to new product innovation in effect the same variable in the model, having internal bivariate correlation coefficients from 0.95 to 0.99. That is a growth in one of these variables are accompanied by a growth in the others. These 6 variables were hence substituted by one variable in the regression analysis. Acquisition of patents and licences were not seen to covary with the other variables. Hence, the regression was run with two variables. There were found that none of these factors were significantly contributing to the development of new products (even with a buffer significance cut off level of 15%).

The implications of these findings are not straight forward. R&D activity etc. do surely contribute to the development of new products, but only in a very complicated way and through several other channels. For instance R&D might not result directly in a new product but nevertheless might contribute to the development of new products *via other sources*. For example it was found a statistically significant relationship between new products and the importance the firm paid to information from suppliers, networks etc. An important part of R&D is its dual role, both as a generator of new products and as a generator of learning capabilities. Part of the firms rationale to invest in R&D is to be able to utilise information that is available externally. If we go back to the CIS data we do in fact find that firms which perform R&D on a continuous basis, also rank information sources as suppliers, clients, consultants etc. as more important than those firms that do not (perform R&D on a continuos basis). And these sources were indeed found to contribute to the development of new products. Hence R&D in pulp, paper and paper products seem to be more an issue of learning to learn than *discovery*. In this sense R&D, together with several other factors, probably plays an important role in the innovation process of the firm. Again this underlines the complexity in the innovation process and the large number of factors that contribute to the innovativeness of a firm.

2.3 Concluding remarks

We have found that pulp, paper and paper products differ considerably from other industries. This is especially seen in innovation structure. Although the firms indeed perform considerable internal competence building, the pulp, paper and paper products industry is extremely capable of taking advantage of technological advances being made in other industries and sectors. Firms within pulp, paper and paper products exploit very advanced research undertaken by a whole range of players like for instance suppliers of material and equipment. Firms within pulp, paper and paper products rank these agents as essential both as an information source for innovation and as a R&D partner. In general external agents are ranked as more important by firms within pulp, paper and paper products than by other firms (within other industries). Cross firm networking which promote interactive learning is hence the crucial aspect for enhanced innovation in pulp, paper and paper products. This point will also be elaborated on in the next sections: firms that are more successful in their networking activities also are more innovative.

3 Analysis of Innovation Performance

3.1 Introduction into the Analysis of Innovation Performance

3.1.1 Research Goals

The objective of this chapter is to determine the characteristics of very innovative, innovative and uninnovative firms in the European pulp and paper industry by drawing upon the data compiled in the CIS survey. The analysis consists of two elements:

2.1 Mapping the characteristics of high, average and low performing firms with respect to innovation
2.2 Discussing and evaluating the findings

A third goal of this study is to present the conclusions which could be drawn from the analysis. This also entails hints to future research and suggestions how to optimise the CIS database so that innovation performance in the European pulp and paper industry can be more accurately analysed in the future.

3.1.2 Scope of Research

The scope of this part is largely defined by the kind of information that can be retrieved from the CIS database. The following list shows the aspects covered in the survey:

1 general information on the enterprise
2 sources of information for innovation
3 objectives of innovation
4 acquisition and transfer of technology including methods for protecting competitive advantage
5 R&D activity
6 factors hampering innovation
7 costs of innovation
8 impact of innovation activities

A second limitation arises from item non-response, varying response rates in countries, and, related to the former point, the availability of suitable performance indicators. This issue is illustrated in Table 3.1. The grey shaded cells indicate the seven samples from Italy, The Netherlands, Germany and Ireland which seemed appropriate to be analysed with respect to the availability of suitable indicators and sufficient sample size. Previous research has shown that the data cannot be regarded as representative. Under this condition statistical projections on the population would be unreasonable, and therefore the focus of this study is on presenting the characteristics of the enterprises in the database. Conclusions about the population are consequently of more or less speculative nature. In the Italian case, however, data was collected in a census so that those findings can claim significance for the population.

Table 3.1: Availability of data -the shaded samples are analysed[122]

country	NACE 21 no. of observations			NACE 21.1 no. of observations			NACE 21.2 no. of observations		
	population	sample: total number of observations	sample: obs. for which sel. Indicators are available	population	sample: total number of observations	sample: obs. for which sel. Indicators are available	population	sample: total number of observations	sample: obs. for which sel. Indicators are available
BEL	120 (1989)	23	14	10 (1989)	2	2	110 (1989)	19	12
DEN	67 (1992)	27	13	7 (1992)	0	0	60 (1992)	0	0
ESP	1070	74	0	149	0	0	921	0	0
FR	708	145	0	94 (1992)	33	0	612	112	0
GER	918	57	31	124	21	17	794	34	12
GR	79 (1992)	5	0	23 (1992)	0	0	56 (1992)	0	0
IRL	36 (1990)	29	16	-	3	3	36 (1990)	26	16
ITL	695	496	190	140	81	35	555	415	155
LUX	-	4	3	-	0	0	-	4	3
NL	163 (1992)	78	54	28 (1992)	19	16	135 (1992)	59	38
NOR	?	22	15	?	11	8	?	11	7
POR	115	9	0	36	0	0	79	0	0
UK	949	6	6	138	0	0	811	0	0
total in CIS database		975	342		170	81		680	243

3.1.3 Research Methods

3.1.3.1 Determining Innovation Performance

The central methodological issue in analysing innovation performance is to decide whether an enterprise is a 'high', 'average' or 'low' performer. This decision is difficult because the abstract notion of innovativeness has so many facets that it defies exact descriptions based on objectively measurable indicators. Therefore the present study will use a heuristic approach suggested in the project proposal. The main idea is as follows: A measure of innovativeness is constructed by calculating the mean of the ranks across several innovation indicators available in the CIS database. Those enterprises which score the top 25% on the average rank are termed as highly innovative. Firms answering that they had neither product or process innovation during 1990-1992 are classified as low performers. The remaining firms are considered average performers. This heuristic requires some further specifications which will be described in the following.

A prerequisite for the analysis of innovation performance is the question of what are actually the possible performance indicators in the CIS database. The CIS database comprises a number of input-output variables that can be linked with the innovative performance of the firm. In addition, the questionnaire contains some variables that can be used as proxies for various kinds of process efficiency. Following the

[122] Data on the population was retrieved from Eurostat CD 1994 which contains the most recent data on 1991. If the reference year differs from 1991, the year is mentioned in parenthesis. Eurostat data refers to the older NACE classification with 471 and 472; differences with the new data are negligible, however.

sequence in the CIS-questionnaire*, the list below shows the readily available indicators and other computable measures that can be used as innovation indicators:

1 sales per employee
2 growth of total firm sales in the period between 1990 - 1992
3 development or introduction of new products and processes between 1990 - 1992
4 R&D activity between 1990 - 1992
5 share of R&D expenditures in relation to firm sales (R&D intensity)
6 share of innovation expenditures in relation to firm sales (intensity of innovation)
7 share of capital investments pertaining to innovation projects in relation to firm sales (intensity of innovation-related capital investment)
8 share of sales related to introductory and growth products
9 share of sales related to incrementally and radically changed products
10 share of sales related to products new to the industry

In addition, there are other measures in the CIS database that are ultimately assumed to be correlated with innovativeness. Examples of such indicators are the market share of the firm and the relative importance of export activities. These measures are more indirect than the above listed ones, being influenced by the strategy chosen by the firm. From the innovation performance measurement point of view, they are of limited use, however, because of a number of shortcomings:

- while market share bears relevance for bulk products, they can be misleading for SMEs, who often follow niche strategies

- market share is not a measure of current innovation performance, rather an indication of the success of past performance

- export shares for firms operating in small countries are naturally higher than for firms operating in large countries

-

In the following the strengths and weaknesses of selected indicators are discussed with a special note on the pulp and paper industry

- *development or introduction of new products and processes between 1990-1992.* This indicator occupies a central position in the CIS sector studies, as it does in most other innovation studies. The CIS study defines a firm as innovative if it introduced any new product or process during 1990 - 1992. Unfortunately, two years is perhaps too short a time to capture product innovation in the pulp and paper production industry (NACE 21.1), where new product introduction can easily take several years. For fashion clothing, this time scale is probably far too long. Because of such ambiguity, we have chosen not to use this variable as an indicator of innovative activity in the pulp and paper industry

- *R&D intensity versus innovation intensity between 1990 and 1992.* The use of R&D intensity as a performance indicator for the pulp and paper industry does not reveal the full scale of the innovative activities of the firms in the pulp and paper

* A copy of the questionnaire can be found in the appendix

industry. A substantial part of innovation in the pulp and paper industry is based on R&D performed in horizontally linked industries outside NACE 21, for example, by chemical producers and by process equipment producers. This fact reflects in the R&D intensity of the pulp and paper sector which is approximately one tenth of that of average manufacturing sectors. This indicator has sometimes led people to mistakenly consider the pulp and paper sector as a low-technology sector. We have thus decided not to use R&D intensity as and indicator of innovation performance in the pulp and paper industry, and to replace it with the innovation intensity and the intensity of innovative investment.

- *share of introductory and growth products in the product portfolio, expressed as fraction of sales*. This variable reflects the relative importance of new products better than the development and introduction of new products between 1990 and 1992. This is, again, because of the long life cycles of products in the pulp and paper production sector (NACE 21.1.). We have chosen to use this variable as an indicator of innovative activity instead of the above discussed variable relating to the introduction of new products and processes.

- *growth of sales between 1990 - 1992*. The development of a firm's sales over time seems an excellent indicator for innovative performance. In the long-run, there is certainly justification for this view. For the pulp and paper industry, however, two years is too short a time to balance the influence of business cycles. We have therefore chosen not to use this variable as an indicator of the innovative performance of firms in the pulp and paper industry

- *sales per employee*. This indicator capturing labour productivity seems, generally speaking, an appropriate indicator for the innovative performance. Because of the high capital intensity of the pulp and paper production, labour costs are a minor consideration, however. The increasing use of automation in this industry is likely to decrease the relative importance of labour costs even further. We have chosen not to use this variable as an indicator of the innovative performance of firms in the pulp and paper industry.

- *share of sales related to products new to the industry*. This indicator seems less appropriate for the analysis of innovation performance because it rather refers to inventions. Using this indicator would contravene the broader concept of innovativeness so that we decided not to use this indicator.

Summarising the discussion on innovation indicators, we present the selected innovation indicators below and describe how they were calculated on the variables available in the CIS database:

1. Indicator ‘percentage of incrementally or radically changed products’ CHPROD

CHPROD = V15A_2 + V15A_3 [%]

Variable V15A_2	”products subject to incremental changes during 1990-92 [%]”
Variable V15A_3	”products significantly changed or introduced during 1990-92 [%]”

2. Indicator ‘intensity of innovation expenditures as a percentage of sales’ INNINT

INNINT := 100 * V13A / J [%]

Variable V13A	”Estimated total current expenditures on innovation activity in 1992 [national currency units]”

3. Indicator ‘intensity of innovative capital investment: capital investments linked to innovation as percentage of sales’ INVINT

INVINT := 100 * V13D / J [%]

Variable V13D	”Estimated total capital expenditure spent on investment in plant, machinery and equipment in 1992, linked to new product innovation [in national currency units]”
Variable J	Turnover in 1992 [ECU]

4. Indicator ‘share of sales obtained from products in the introductory or growth phase of their lifecycle PRDPORTF

PRDPORTF:= V14_1+V14_2

Variable V14_1	“share of sales obtained from products in the introductory phase of their lifecycle“
Variable V14_2	“share of sales obtained from products in the growth phase of their lifecycle“

The analysis of innovation performance has to take into account that answers will depend not only on the firms’ innovation performance but also on other factors, most notably the firms’ country of origin, size, and field of activity (manufacture of pulp, paper and board NACE21.1 and manufacture of articles of paper and board NACE21.2).

In the following will be outlined why those factors likely to have an influence on the analysis of innovation performance:

Country matters because the structure of the pulp and paper industry is not at all homogenous in Europe. In Scandinavia, for example, the sector holds an outstanding position in the national economy whereas it plays no particular role on the Iberian peninsula. In spite of some convergence due to the European integration process, such diversity endures with respect to the factors of production, market characteristics , the availability of supporting and related industries, and legislation. Yet, cultural differences may account for different management styles and firm strategies in the countries of Europe. It seems evident that this diversity will also reflect in the answers to the CIS survey.

Secondly, it is very likely that a firm's field of activity matters. As noted in chapter One the pulp and paper industry is a sector with a variety of products[123] ranging from pulp to special products made of paper such as, for example, containers for beverages. Similarly, the characteristics of the enterprises are very different. The following list illustrates why manufacturers of pulp, paper and board and converters of paper and board are likely to exhibit significant differences in their answers to the questionnaire:

- modern paper mills exhibit the highest capital intensity. In no other industry is the size of capital investments for production facilities equivalent to the aggregate sales of three years. Converters of paper and board, on the contrary, are less capital intensive. The capital needs imply that paper mills tend to be larger enterprises whereas converters can also be small entrepreneurial firms.

- the technology of papermaking is of a much more intricate nature than conversion processes which can be rather simple mechanical operations such as the cutting of paper or folding of cardboard boxes.

- pulp, paper and board are commodities that are traded in specified grades with comparatively little room for product differentiation. Articles of paper and board, on the other hand, offer much more potential for product differentiation and niche strategies with tailor-made products for distinct customers.

- related to the previous point, manufacturers of pulp, paper, and board are prone to business cycles caused by fierce fluctuations of the demand and the price of raw materials

Thirdly, firm size matters because small firms and large firms have different characteristics which will also affect the answers in the questionnaire. For example, the small entrepreneurial enterprise that manufactures hand made paper definitely uses another technology than a modern paper mill for newsprint and it is very likely that the two enterprises also differ with respect to their innovation objectives and the rating of innovation barriers, just to name two aspects. Although there is justification for discriminating also between small and large enterprises, this distinction cannot be made because most of the obtained samples would become so small that reasonable statistics cannot be obtained.

Taking into account those points, it has been decided to analyse innovation performance separately for manufacturers and converters of paper and board. Unfortunately, a NACE 3-digit level classification is not available for all 13

[123] see for example, the Nace classification

countries: Denmark, Spain, Greece, Portugal and UK are only available in NACE 2-digit classification so that firms from these countries are excluded from the analysis of innovation performance. As a summary of the discussion on research, we describe here the heuristic approach by drawing on the style of programming languages:

Figure 3.1: Algorithm of the heuristic to classify enterprises according to their innovation performance

start;
subset the whole sample S by c countries and n NACE-3-digit classes into cn subsamples S_{cn};
for all S_{cn} do
    for all performance indicators do
        for all enterprises do
            where performance indicator j is available for enterprise i
                calculate the enterprise's rank Rk_{ij} on performance indicator j in S_{cn}
        end do
    end do
    for all enterprises do
        where all performance indicators are available
            calculate the average rank ARk_i for enterprise i in S_{cn}: $ARk_i = \frac{1}{4}\sum_{j=1}^{4} Rk_{ij}$
    end do
    calculate 75% percentile (ARk)
    for all enterprises do
        where ARk_i is available
            if $ARk_i \geq$ 75% percentile (ARk) in S_{cn} then enterprise i is high performer
        if enterprise i has neither product innovation nor process innovation then enterprise i is low performer
            else enterprise i is average performer
    end do
end do;
end

3.1.4 Statistical Methods

The heuristic applied in this study identifies three distinct, independent analysis groups in the CIS database: high, average, and low performing enterprises. The objective of the present analysis is to map their characteristics and to determine eventual deviations between the groups. This chapter explains the selection of statistical methods used to detect those differences. The CIS-database contains 202 nominal, 59 ordinal, and 33 metric variables. Their scale type and distribution governs the selection of statistical analysis tools. In the following we justify the selection of statistical tools according to the variable type.

3.1.4.1 Nominal Variables

Bivariate analysis is used to analyse nominal variables. If this data is available for all three analysis groups, nominal variable with s different items can be analysed as a 3 x s contingency table. An important subgroup consists of those cases in which there are only two distinct analysis groups and two items for the nominal analysis table to be analysed. For 3xs s, the present study uses the frequently employed Chi-square test to examine whether the analysis group variable and the nominal variable are independent from each other. The test examines the degree of deviation to which two variables differ under the assumption of no association between the two variables. For each cell, the difference between the observed frequency and the expected frequencies calculated from row and column frequency. Then the Chi-square value is computed as the squared sum of all differences. The use of Chi-square is subject to two important limitations[124]:

1 for all cells, the expected absolute frequencies must be > 1
2 a maximum of 20% of the expected absolute frequencies must be < 5

SAS software computes the probability for the null-hypothesis of independence between the variables. If this probability is less than 5%, statistically significant dependency is assumed.

In case that the contingency table has 2x2 format, the study uses Fisher's exact test to determine statistically significant differences. Fisher's exact test also suits for small sample sizes and strong asymmetry but its computation is more cumbersome due to the underlying hypergeometric distribution. Compared to other unbiasing tests, Fisher's exact test shows the best quality properties[125] so that it is the tool of choice for 2x2 tables. The hypothesis of independence between two variables is rejected if the corresponding two-tailed significance level is less than 5%.

3.1.4.2 Ordinal Variables

Ordinal variables in the CIS-database range from 1 to 5 on a topological scale. Non-parametric significance tests based on the analysis of rank variances are appropriate tools to determine whether locations of ordinal variables vary across independent subgroups such as high, average, or low innovation performance. Often data is only available for two analysis groups, e.g. average and high performing enterprises. In this case the present study uses Wilcoxon's Rank Sum test, which is equivalent to Mann-Whitney's U-test[126]. If subgroups have different locations, the sums of the ranks pertaining to observations vary. If a computed ranksum trespasses certain critical values, the hypothesis of identical location in the two samples will be rejected. Wilcoxon's rank sum test is carried out with SAS statistics software. Instead of tabulated critical values, SAS uses an approximation method based on the standardised normal distribution to determine critical values and performs a

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124 Wittenberg, R. (1991), *Computer-unterstützte Datenanalyse.* Stuttgart: G. Fischer

125 Hartung, J. (1991), *Statistik: Lehr und Handbuch der Statistik.* München, Wien: Oldenbourg, pp. 416

126 Hartung, J. (1991), *Statistik: Lehr und Handbuch der Statistik.* München, Wien: Oldenbourg, pp. 513

continuity correction[127]. The hypothesis of equal ranksums will be rejected if the computed probability is less than 5%. The goal of analysis to compare the median values of k independent samples can be accomplished with the Kruskal-Wallis test. This test extends the idea underlying the Wilcoxon test to k samples. SAS uses a chi-square approximation to calculate the Kruskal-Wallis statistics.
Although Kruskal-Wallis statistics could also be calculated for two samples, the study prefers the Wilcoxon tests for it renders slightly more conservative in the rejection of the zero-hypothesis. SAS software uses asymptotic methods to compute the above-mentioned statistics. These asymptotic methods are inadequate for very small sample size because of intolerable inaccuracy. Therefore, some of the tests were performed manually with exact tables.

3.1.4.3 Metric Variables

Different locations of distributions in independent samples can be detected through analysis of variance tools. The selection of appropriate methods depends very much on the available information about the location parameters. Generally speaking, parametric methods outperform non-parametric ones in terms of exactness because they utilise more information about the properties of the variable in question. This advantage is opposed to the work arising from the identification of distribution types and eventual data transformations. As a first approach to analyse the metric data, non-parametric analysis of variance seems the more efficient way. The analysis tools have already been introduced in the previous chapter. Depending on the number of samples, either Wilcoxon's rank sum test or the Kruskal-Wallis test will be performed.

3.1.4.4 Presentation Methods

The presentation of the nominal data pertaining to questions six, seven, eight, and eleven is based on bar-charts displaying the relative frequency. The authors are well aware that it is somewhat delicate to present percentages on a few observations but, in order to make the data comparable, this decision seemed the best possible solution.

The presentation of the ordinal data on sources of information for information, objectives of innovation, the protection of competitive advantage, and the factors hampering innovation is based on median values.

Since simple arithmetic means on skewed metric variables can be very misleading, the present study uses a special presentation method that borrows from boxplots. The lower end of the box represents the 25% percentile, the asterisks in the middle the median, and the upper end the 75% percentile. These boxes will be called 'truncated boxplots' in the study.

Bar-charts and truncated boxplots on data for the analysis groups can be distinguished by their grey shade: the three shades range from slight for low performing enterprises, medium for average performance to dark grey shade for high innovation performance.

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[127] SAS Institute Inc (1990), *SAS/STAT User's Guide, Version 6, Fourth Edition, Volume 2.* Cary, NC (USA): The SAS Institute, p.1200

3.2 Analysis

3.2.1 Correlation between Performance Indicators

Due to the definition of high performing enterprises as those scoring top 25% on the average of four innovation indicators it is evident that high performing enterprises exhibit higher values for the indicators. On the other hand poses the question about functional relationships between the indicators themselves. Figure 3.2 displays the statistically significant coefficients of a correlation analysis, subset for the seven samples. Figure 3.2 confirms that there is no general linear dependency between the performance indicators. With coefficients less than 0.5, the Italian samples and the Dutch sample of converters of paper and board exhibit the weakest correlation. This is opposed to a value of 0.7724 for the correlation between CHGPROD and PRDPORTF among Irish enterprises, which denotes that the share of changed products is clearly linked with the aggregated share of introductory and growth products in this sample. Correlation in the other samples is located in between these extreme cases.

Figure 3.2: Spearman's correlation coefficients for the four performance indicators+

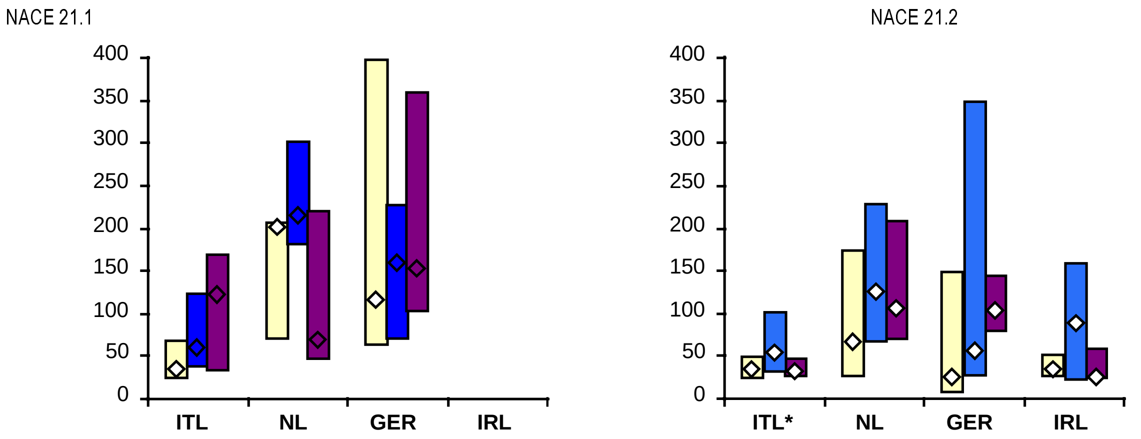
	INNINT	INVINT	PRDPORTF
INVINT	ITL 21.1 coeff. 0.4255 sig. 0.011 ITL 21.2 coeff. 0.2068 sig. 0.001 GER 21.2 coeff. 0.5386 sig. 0.017		
PRDPORTF		NL 21.1 coeff. 0.5558 sig. 0.025 GER 21.2 coeff. 0.6007 sig. 0.039	
CHGPROD	ITL 21.2 coeff. 0.2760 sig.0.001 NL 21.1 coeff. 0.5112 sig. 0.043 NL 21.2 coeff. 0.3510 sig. 0.028 GER 21.1 coeff. 0.4941 sig. 0.044	ITL 21.2 coeff. -0.1702 sig. 0.034 GER 21.1 coeff. 0.5547 sig. 0.021	ITL 21.1 coeff. 0.3404 sig. 0.045 ITL 21.2 coeff. 0.3370 sig. 0.000 IRL 21.2 coeff. 0.7724 sig. 0.000

Medium correlation with coefficients slightly above 0.5 can be found for several other samples but -with one exception- they can only be observed for one sample each. Only PRDPORTF and INVINT are linked in two samples. Both the German sample of converters of paper and board and the Dutch sample of paper

+ only statistically significant results are presented manufacturers exhibit this correlation. Other marked functional dependencies, e.g. U-shaped relationships, could not be detected in the data.

3.2.2 General Information about the Enterprise

Figure 3.3 Number of employees - truncated boxplots



COUNTRY	Italy		The Netherlands		Germany		Ireland
NACE	*21.1*	*21.2*	*21.1*	*21.2*	*21.1*	*21.2*	*21.2*
Observations							
low performers	46	260	3	20	4	15	9
average performers	26	116	12	29	13	16	12
high performers	9	39	4	10	4	3	5

Figure 3.3 shows the number of employees in truncated boxplots. The size of the firms varies between countries and between manufacturers and converters of pulp and paper. On the average, converters are smaller firms than pulp and paper manufacturers. The data show that Italian and Irish enterprises tend to have fewer employees than their Dutch and German counterparts. Eurostat data on the average firm size largely confirms these proportions (Table 3.1) although the average German firms size is discernibly larger than the scarce sample of the German population might suggest.

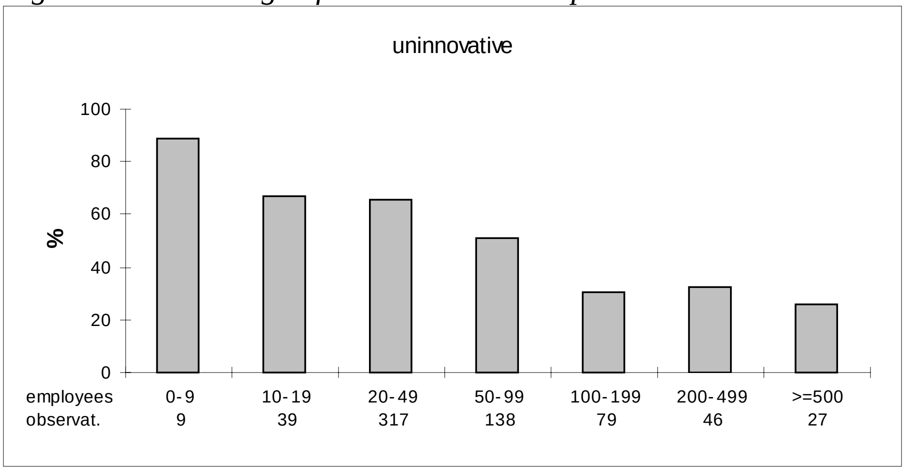
Table 3.2: Average firm size

COUNTRY	Italy		The Netherlands		Germany		Ireland
NACE	*21.1*	*21.2*	*21.1*	*21.2*	*21.1*	*21.2*	*21.2*
average firm size[128]	156	69	317	127 (1988)	432	157	86 (1988)

In the following, the relationships between firm size and innovation performance will be discussed. The Italian data on manufacturers of pulp and paper suggest that innovation performance is positively correlated with firm size. And in fact, Figure 3.4 shows in an overall perspective on the pooled observations that there are more small enterprises without innovation activity during 1990-1992 than bigger ones.

[128] Data from Eurostat CD 1994. Data on 1992 is not yet completely available so that the 1991 data was taken instead. In two cases data on 1988 had to be taken. This inaccuracy has no discernible effect on the comparability because there were no drastic changes since 1988.

Figure 3.4 Percentage of uninnovative enterprises



On the other hand, one can reasonably expect such results. Firstly, large enterprises tend to have a broader production program so that it is more likely that they have changed or newly introduced at least one product or process. Secondly, this correlation seems plausible for an industry characterised by economies of scale, high capital intensity, and technological complexity. But the CIS survey indicates that also small enterprises can be highly innovative. The boxplots show clearly that Italian and Irish high performing enterprises in the conversion sector are smaller than enterprises with average innovation performance and still innovative. The author holds the opinion that this apparent discrepancy can be explained through the level of technological sophistication and the firm's ability to acquire resources. The following consideration may elucidate this argument. For example, the production of TCF newsprint paper in closed water loops certainly requires another type of innovator than the creation of a new, hand made paper grade. A small, entrepreneurial company might well succeed with the latter innovation whereas the former could only be implemented by an enterprise which is well endowed with technological and financial resources. In spite of the very distinct technological contents both paper manufacturers are considered highly innovative according to the definition used in the present analysis. Small enterprises in the conversion sector, on the other hand, are in a more advantageous position to compete technologically with larger firms because the technology in this sector is not so sophisticated and capital intensive. Moreover, the diversified market for paper and board products creates favourable conditions for small firms. There is an almost infinite variety of things to be transported, protected or embellished in any kind of paper product. Small enterprises can succeed in this market for more or less tailor made products if they concentrate on their strengths -flexibility, responsiveness to customer needs, and innovativeness. Apart from those technological aspects one should be aware that the number of employees may often be inappropriate to assess its innovation performance. The salient point is whether enterprises can access markets, finance, and technological know how albeit they are small. Generally speaking, this seems possible by any kind of networking with suppliers, customers, and particularly through being part of a group.

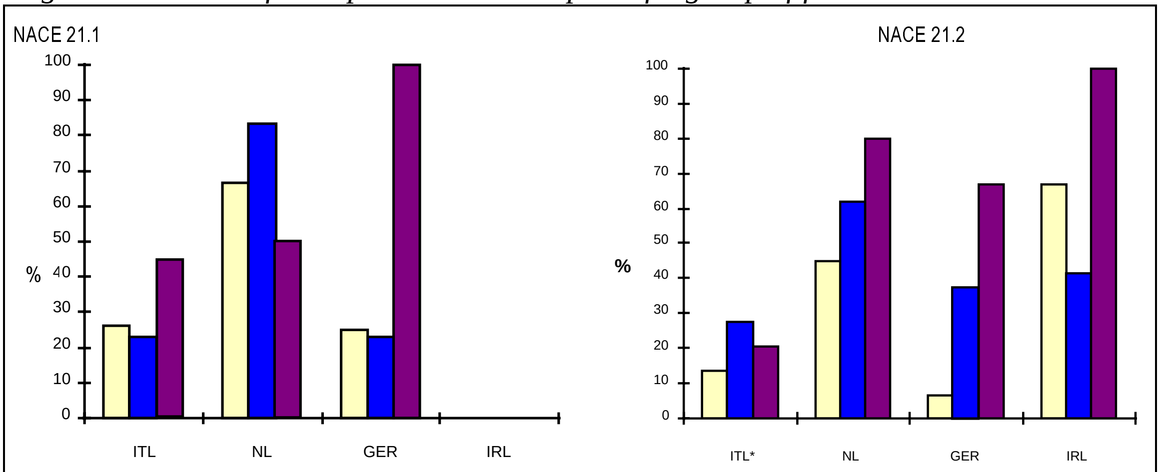
Since the present study will elaborate more on the those points later, this hint may suffice and the above discussion can be concluded as follows:

⇒ **the share of enterprises without innovative activity during 1990-1992 decreases with firm size.**

⇒ **both small and larger enterprises in the pulp and paper industry can be very innovative according to the definition used in this study but smaller enterprises are not so likely to pursue innovation projects with high technological complexity.**

The CIS database contains data on firm status such as dependent/independent and country of headquarters, so that we can be analysed whether enterprises embedded in a group of firms tend to be more innovative than independent ones. This question is particularly interesting in the face of the recent history of the European pulp and paper industry in which numerous mergers and acquisitions are a central feature. Figure 3.5 maps the share of enterprises which are part of a group. The bar-charts show no clear relationship between innovation performance and firm status. Only the samples on Dutch and German converters confirm a positive relationship whereas the other samples rather refute this hypothesis.

Figure 3.5: Share of enterprises which are part of a group of firms

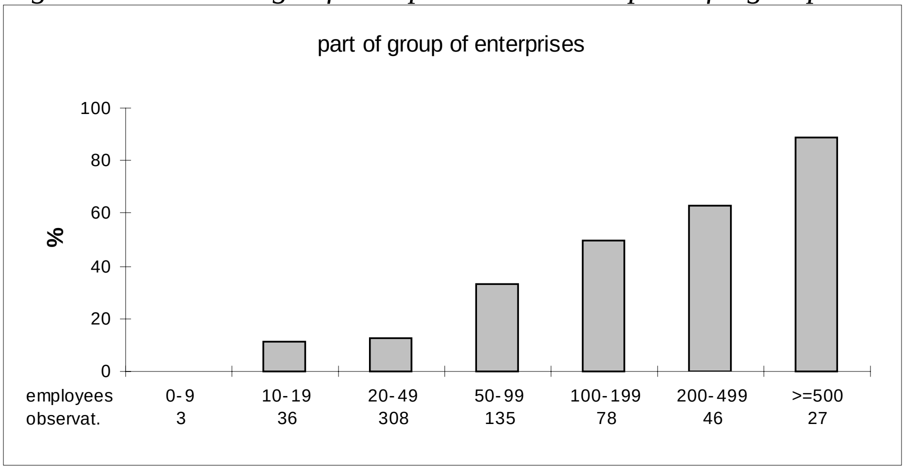


COUNTRY	Italy		The Netherlands		Germany +		Ireland
NACE	*21.1*	*21.2*	*21.1*	*21.2*	*21.1*	*21.2*	*21.2*
Observations							
low performers	46	260	3	20	3 (4)	5 (15)	9
average performers	26	116	12	29	10 (13)	9 (16)	12
high performers	9	39	4	10	4 (4)	2 (3)	5

It seems that the variation in Figure 3.5 is rather the result of country and firm size effects. In order to assess the effect of firm size, the share of firms which are part of a group was calculated on the pooled sample of all observations; the results are presented in Figure 3.6). The chart shows that larger firms are more likely to be part of a group than small enterprises. In this context one should be aware that being part

+ Some German firms did not answer the question. The number in parentheses contains the number of observations of a group does not only include affiliates of other companies but also the case that a respondent is the parent company of other enterprises.

Figure 3.6: Percentage of enterprises which are part of a group - classified by size



A comparison of the Italian and Irish samples of converters implies that country differences also play a significant role. The firm size proportions in both samples are rather similar but Italian enterprises are predominantly independent whereas Irish firms frequently belong to groups. This fact is likely to be the reflection of both cultural differences and techno-economic factors. The history of pulp and paper sector is not at all homogenous in the four countries; nor are the attitudes towards entrepreneurship and management styles the same. On the other hand, the surge of mergers and acquisitions in the pulp and paper industry implies that being part of a group offers tangible advantages such as access to technology, finance and markets. The latter aspect might be particularly relevant for smaller countries such as Ireland and The Netherlands if their sectors want to survive in an increasingly international business. In order to conclude the discussion on firm status and innovation performance, on can infer the following:

⇒ **innovation performance and firm status are, generally speaking, not linked with each other. The ownership status of an enterprise is rather determined by factors resting with the country and by firm size.**

Table 3.2 shows the country of headquarters of those firms which are part of a group. Unfortunately, item non response among the few enterprises which are actually part of a group creates limitations: Interesting analysis such as the comparison of shares of foreign owned enterprises across countries and performance groups cannot reasonably be performed with the scarce data. Hence, the following insights are confined to some general aspects. Since the leading companies are located in Scandinavia and Northern America, one might expect that European enterprises with owners from these countries are more innovative. The available data does not support such a conjecture: there are also enterprises in the CIS database which are owned from those countries. But nevertheless the data shows that companies from those countries are important international players: At least 9 firms in the database are owned by Scandinavian firms (N.B. that ‘EUR’ comprises firms from European countries outside the EU of 1992 so that some of them are likely to be Scandinavian, too) whereas American and Canadian companies own seven of the enterprises.

Table 3.3: Country of headquarters of those enterprises which are part of a group of firms

COUNTRY	ITL			NL			GER			ITL			NL			GER			IRL		
NACE	*21.1*			*21.1*			*21.1*			*21.2*			*21.2*			*21.2*			*21.2*		
performance	L	A	H	L	A	H	L	A	H	L	A	H	L	A	H	L	A	H	L	A	H
Observations	46	26	9	3	12	4	4	13	4	260	116	39	20	29	10	15	16	3	9	12	5
Part of group	12	6	4	2	10	2	1	3	4	35	32	8	9	18	8	1	6	2	6	5	5
Missing	0	0	0	2	5	1	0	0	0	0	0	0	4	8	6	0	2	0	2	1	0
Country of headquarters																					
Austria					3									1				1			
Belgium		1								1			1	1							
Canada																				1	
Germany	1						1	2	3		1					1	3	1			
EUR		1								2	2	3									
France						1					2			2							
Finland					1			1	1												
Italy	9	4	4							25	25	5									
Ireland										1				2					3	3	3
The Netherlands	1									2	1			1							
Norway													1								
Sweden					1								2	1					1		
Switzerland																	1				
United Kingdom	1									1				2	1						2
USA										3	1		1		1						

The number of foreign owned enterprises reveals some interesting differences between the countries in this analysis. Firstly, Italian enterprises do not own any of the Dutch, German or Irish enterprises in the database whereas companies from these countries own Italian enterprises. It remains speculation, however, whether this observation points to a strong national focus of Italian enterprises or whether they are more active in countries which are not subject of this analysis. Secondly, only one out of the 24 Dutch enterprises belonging to groups has a Dutch parent company. This points to a particular attractiveness of The Netherlands for foreign investments in the pulp and paper sector. As before, elaborated answers on these issues cannot be given within the scope of this study. But it seems likely that the geographical proximity of the Netherlands to the main markets in Europe play a role.

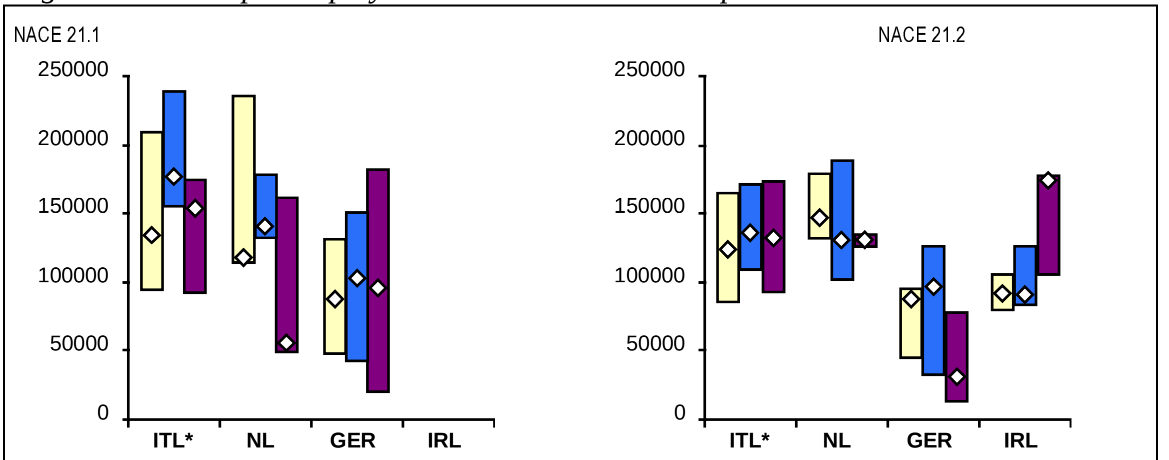
Summing up the discussion about the relation between innovation performance and country of origin can be stated:

⇒ **the CIS-database does not provide evidence that enterprises with owners from particular countries are more or less innovative than others.**

⇒ **The Netherlands have the highest share of enterprises owned by foreign companies.**

In the following the relation between innovation performance and the sales per employee will be in focus. The annual sales yielded per employee is a measure which should be closely related to innovation performance in an industry where the reduction of labour costs has traditionally been an important objective of innovation. Data on labour productivity is also available on the population so that the analysis can integrate this material for the national aspects of innovation performance. Figure 3.7 maps the labour productivity of the firms in the CIS database. As a comparison, Table 3.3 shows the 1991 average sales per employee which was calculated on Eurostat data of the aggregate sales and the total number of employees in the national sectors. The values for Italian paper manufacturers in the database roughly correspond to the averages calculated on the population whereas Dutch and specially German firms in the survey display much lower figures than one could expect. This discrepancy might be rooted in both the representativeness of the sample and the impact of the recession in the early 1990s.

Figure 3.7: Sales per employee in ECU - truncated boxplots



COUNTRY	Italy		The Netherlands		Germany		Ireland
NACE	*21.1*	*21.2*	*21.1*	*21.2*	*21.1*	*21.2*	*21.2*
Observations							
low performers	46	260	3	20	4	15	9
average performers	26	116	12	29	13	16	12
high performers	9	39	4	10	4	3	5

Figure 3.7 and Table 3.3 indicate that Italian enterprises in the conversion sector yield very high labour productivity. Eurostat time series on the years 1987 to 1992, on which the above table is based, confirm that Italian firms assume a leading position among the European countries.

Table 3.4: Average sales per employee 1991

COUNTRY	Italy		The Netherlands		Germany		Ireland
NACE	*21.1*	*21.2*	*21.1*	*21.2*	*21.1*	*21.2*	*21.2*
average sales per employee[129]	176 551	161 737	178 309	-	179 984	123 370	122 443

Eurostat data for The Netherlands is not available but, as the boxplots indicate, they are also very likely to have high labour productivity. In the light of its overall economic performance one would also expect German converters to yield high sales per employee. But both the CIS data and the time series confirm that Germany just maintains a medium position. One reason for the time after 1989 surely is German reunification. Some of the observations in the sample could belong to those many East German enterprises which found were at that time in the throes of a severe transition process from collective combines towards market-oriented undertakings with private ownership. But this cannot be the sole truth of the matter: Even Irish enterprises with a lower wage level (23093 ECU for Ireland in 1990 compared to 26730 ECU in Germany[130]) slightly outstripped the Germans between 1987 and 1990 so that the comparatively low labour productivity of German enterprises must be considered as a rather permanent characteristic. The underlying reasons for this odd situation remain unclear and would require additional research. Apart from the national aspect, there are questions about differences on the firm level. The truncated boxplots imply that highly innovative firms display lower labour productivity, which seems reasonable for the pulp and paper sector. Changed products or processes may involve reconstruction which can be followed by longer periods of trial production during which marketable output decreases. However, this hypothesis does not receive very strong confirmation from a correlation analysis performed on the pooled observations. The coefficients -0.3532 and -0.4307 show indeed a negative correlation between labour productivity (SALESPC) and innovation intensity (INNINT) but the effects are not very marked.

Table 3.5: Correlation tables, Spearman's correlation coefficients

NACE 21.1

	INNINT	INVINT	PRDPORTF	CHGPROD
NVINT	.2729 N(62) Sig. .016			
PRDPORTF	.1110 N(59) Sig. .201	-.0932 N(59) Sig. .241		
CHGPROD	.1746 N(62) Sig. .087	.2903 N(62) Sig. .011	.0843 N(59) Sig. .263	
SALESPC	-.3532 N(62) Sig. .002	-.0670 N(62) Sig. .302	-.0654 N(59) Sig. .311	-.0081 N(62) Sig. .475

(Coefficient / (Cases) / 1-tailed Significance)

NACE 21.2

	INNINT	INVINT	PRDPORTF	CHGPROD
INVINT	.3277 N(217) Sig. .000			
PRDPORTF	-.1266 N(211) Sig. .033	-.0177 N(211) Sig. .399		
CHGPROD	-.2222 N(217) Sig. .000	-.1836 N(217) Sig. .003	.3346 N(211) Sig. .000	
SALESPC	-.4307 N(217) Sig. .000	-.1114 N(217) Sig. .051	.0980 N(211) Sig. .078	.0721 N(217) Sig. .145

(Coefficient / (Cases) / 1-tailed Significance)

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129 Data from Eurostat CD 1994. Data on 1992 is not yet completely available, so that the 1991 data was used. Figures on Ireland were not available for 1991 so that the 1990 values were taken instead. The figures were calculated as: total sales of the sector divided by number of employees in the sector.

130 Data based on data from Eurostat CD 1994. The average wage was calculated as: Total sectoral expenditures on wages divided by the total number of employees in the sector.

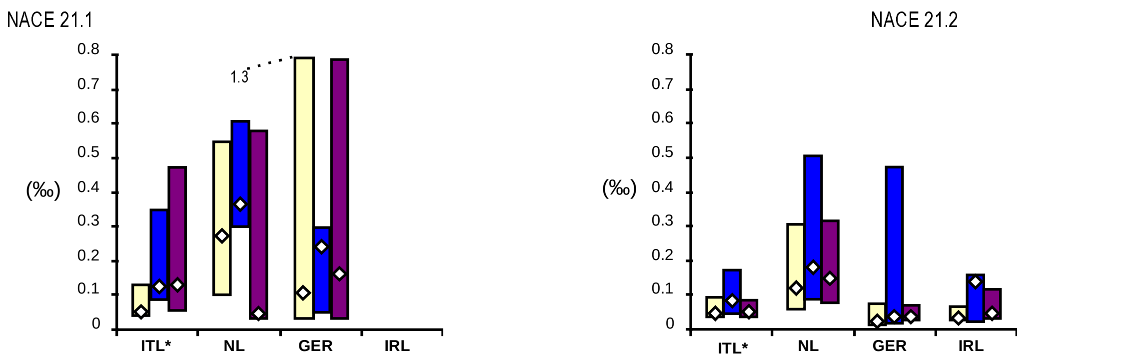
A complementary explanation might be that enterprises with lower labour productivity have to innovate in order to catch up to the industry average. This hypothesis is difficult to test, though: Almost all firms assigned great importance to variable V5_10, which asks the respondent to rate the importance of reducing the share of wage costs as an innovation objective. Hence this variable is not suitable for the above hypothesis. In order to conclude the discussion on the links between innovation performance and annual sales per employee, we can summarise as follows:

⇒ **German converters of paper and board yield significantly lower sales per employee than one could expect. The reasons remain unclear and would need follow-up research.**

⇒ **highly innovative firms sometimes tend to exhibit lower labour sales per employee which might, in some cases, be caused by production halts due to machine set-ups and trial production.**

Figure 3.8 displays the market share of the enterprises in the CIS survey. The extremely high correlation (Pearson's correlation coefficient 0.9507, significance 99.999%) corroborates the truism that larger firms hold higher market shares. The remaining variation is of course intimately intertwined with labour productivity.

Figure 3.8: Market share in per mill of the European consumption of paper products [+]



COUNTRY	Italy		The Netherlands		Germany		Ireland
NACE	*21.1*	*21.2*	*21.1*	*21.2*	*21.1*	*21.2*	*21.2*
Observations							
low performers	46	260	3	20	4	15	9
average performers	26	116	12	29	13	16	12

[+] Originally it was proposed to use a company's share of the total market in the industry. This turned out not to be feasible. Reliable figures on global sales are not available. Instead the present study uses the enterprise's share of the EU-market. This is based on the total EU consumption of goods produced by NACE 21.1 and 21.2; the data is available in Eurostat's *Panorama of European Industry*, 1994

Apparent consumption NACE 21.1 42.328.000.000 ECU

Apparent consumption NACE 21.2 44.396.000.000 ECU

86.724.000.000 ECU

high performers	9	39	4	10	4	3	5

It has already been mentioned in the section on research methodology that the evolution of a firm's sales over the years is an excellent indicator for economic success and, more implicitly, also for innovation performance. But the CIS-database only incorporates sales figures on 1990 and 1992 - a time span which is likely to be too narrow to obtain a realistic picture in an industry which is characterised by business and investment cycles extending over longer periods. The growth of sales cannot be calculated for Germany because the pertinent question was not included in the national questionnaire. Irish data had to be left out due to missing deflators. Consequently the truncated boxplots in Figure 3.11 display only Italy and the Netherlands. On the other hand, Eurostat also provides time series of the aggregate sales in the populations which help assessing the relation between innovation performance and growth of sales on a national and sectoral level.

Figure 3.9: Change of aggregate industry sales in relation to the reference year 1985, figures deflated with the pertinent producer's price index[131] NACE 21.1

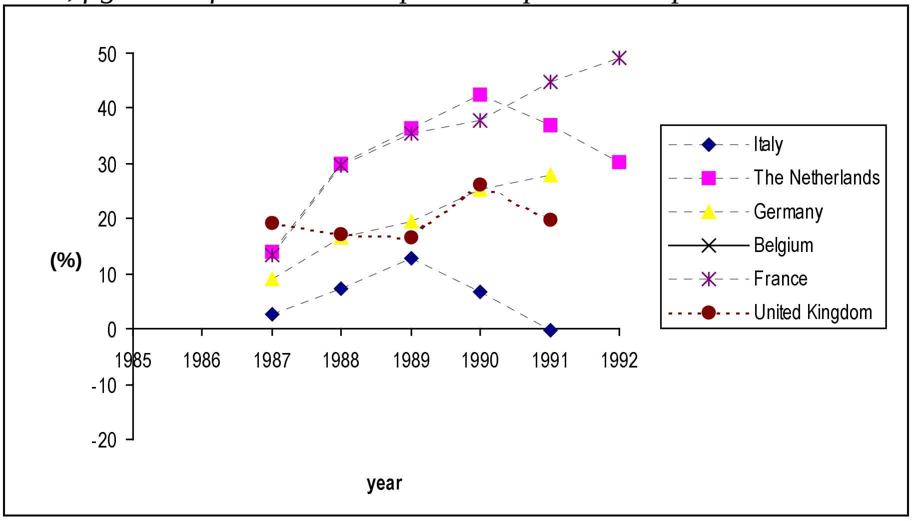


Figure 3.9 and Figure 3.10 show that the sectors in several countries experienced very different growth since the mid-eighties, particularly with France in a leading position in both sectors. Ireland is not included here, again because of missing deflators. Figure 3.9 clearly renders the impact of the recession of the early 1990s in the paper manufacturing sector. Italy, The Netherlands and United Kingdom record a sharp downward trend at that time. The recession does not appear so severely in the growth rates of the conversion sector, with only Italy and the United Kingdom exhibiting a moderate downswing. From a longer term perspective can be observed

131 The change in aggregate sales is calculated as follows:

$$\Delta S_{x,R} = \frac{100 \cdot \left\{ \frac{1}{P_{x,R}} \cdot S_x - S_R \right\}}{S_R}$$

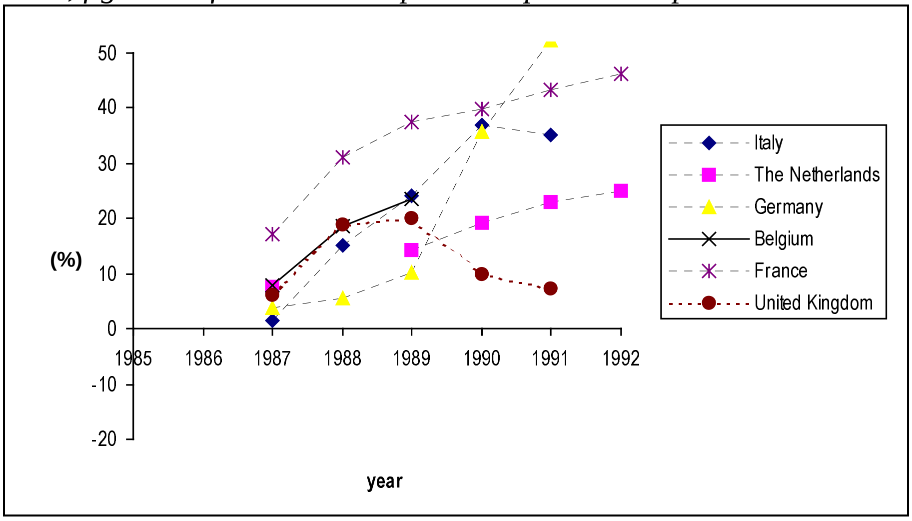
with $\Delta S_{x,R}$:= *percentual change of sales between year x and reference year R*

S_R:= *sales in reference year*

S_x:= *sales in year x*

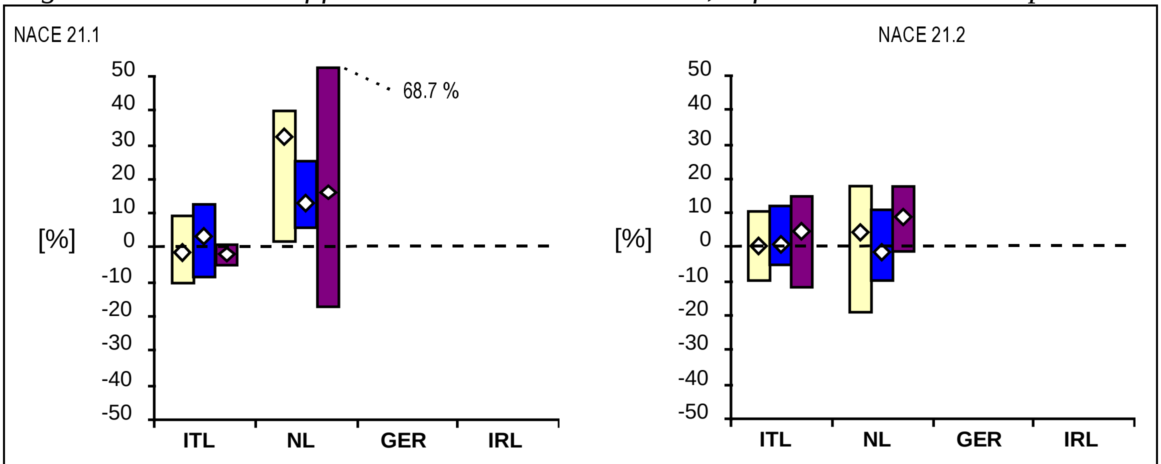
$P_{x,R}$:= *producer price index for year x, based on reference year* that the Dutch paper manufacturing sector could yield impressive growth whereas Germany occupies a medium position. The Italian paper manufacturing sector exhibits the lowest growth rate of all the selected European countries while the Italian conversion sector yields clearly higher growth rates than the Dutch (Figure 3.10).

Figure 3.10: Change of aggregate industry sales in relation to the reference year 1985, figures deflated with the pertinent producer's price index NACE 21.2



Germany represents a case of its own. Until 1989 the enterprises' sales grew very modestly but then grew rapidly towards a leading position within a short period of time. The turning point does certainly not coincide with the German reunification which suddenly opened additional sales opportunities in an area of some 17 million inhabitants. Does the CIS data also reflect these country differences?

Figure 3.11: Growth of firm sales between 1990-1992, deflated - truncated boxplots



COUNTRY	Italy		The Netherlands		Germany		Ireland+
NACE	*21.1*	*21.2*	*21.1*	*21.2*	*21.1*	*21.2*	*21.2*
Observations							
low performers	46	260	3	20	0	0	0 (9)
average performers	26	116	12	29	0	0	0 (12)
high performers	9	39	4	10	0	0	0 (5)

+ For Ireland deflators were not available so the growth of sales has not been calculated.

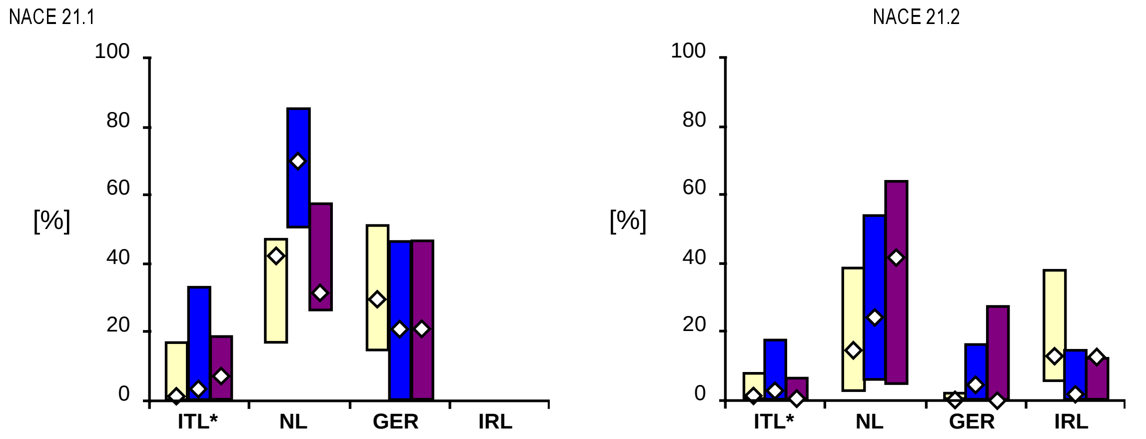
Figure 3.11 shows that the CIS data on Italy and the Netherlands exhibits these proportions but it also shows that the high performing enterprises are not always the ones with the highest growth rates. The median values for converters would in fact confirm such a trend but the lower quartiles and the data on manufacturers seriously contest such a generalised hypothesis. The truth of the matter of innovation performance on the enterprise level probably rests with a number of factors: some of them are in fact innovative and could thus grow, others pursued innovation projects with negative short-term effects on production and some are laggards with aspirations to catch up with the industry average. In conclusion of the discussion on the relation between the growth of sales between 1990 and 1992 we can suggest the following:

⇒ **on a national level the Dutch paper manufacturing sector and the Italian conversion sector yielded sustainable growth rates since the mid 1980s which point to innovative strengths. The Italian paper manufacturing sector, on the other hand, exhibits the slowest growth rate between 1985 and 1992.**

⇒ **on the firm level there is no evidence that high innovation performance is linked with high growth rates in a two years period. However one should expect that innovation performance and growth are positively related on the longer run.**

In the following the study addresses the relationship between innovation performance and export activity on the enterprise level and on the sectoral level. Unfortunately, Eurostat data on the aggregated export activity is not available so that the CIS data on samples cannot be cross-checked with the population. Figure 3.12 shows that Italian firms are very much focused on the domestic market. Dutch firms, on the other side, are very internationalised: Dutch manufacturers of pulp, paper and board sell about half of their production abroad. Dutch converters are not so internationally oriented but they still sell more of their production to foreign customers than their German or Italian counterparts. Several factors may account for this above-average export activity. Many Dutch enterprises are part of internationally operating companies, a fact that certainly fosters the movements of goods across national borders. Moreover, the favourable geographical location in Europe provides good opportunities for exportation. Last but not least it might also be that the products manufactured by Dutch enterprises are more in demand on international markets. Also with respect to Ireland, which is remote from continental Europe, the CIS data seems to confirm the small country hypothesis stating that small countries have a higher share of foreign trade shares than larger nations.

Figure 3.12: Export share truncated boxplots



COUNTRY	Italy		The Netherlands		Germany		Ireland
NACE	*21.1*	*21.2*	*21.1*	*21.2*	*21.1*	*21.2*	*21.2*
Observations							
low performers	46	260	3	20	4	15	9
average performers	26	116	12	29	13	16	12
high performers	9	39	4	10	4	3	5

Apart from those national aspects it seems that export share and innovation performance are unrelated on the firm level. Hence we have the question whether ownership status and market share are the potential factors governing export activity in the pulp and paper industry. In order to investigate this problem a partial correlation analysis of export share (Variable EXPHSH92) and market share (Variable MARKETSH) was performed, with firm status (C_1) as a control variable. The results presented in Table 3.5 display statistically significant correlation for the paper manufacturing sector that ranges between weak for Italy and fairly strong for Dutch and German enterprises. This correlation both underlines the low export activity of Italian firms and the increasing internationalisation of a scale-intensive bulk industry.

Table 3.6: Partial correlation between EXPSH92 and MARKETSH, controlling for C_1

COUNTRY	Italy		The Netherlands		Germany		Ireland
NACE	*21.1*	*21.2*	*21.1*	*21.2*	*21.1*	*21.2*	*21.2*
Partial correlation coefficient	0.2098	0.0505	0.6686	-0.0548	0.5251	0.6745	-0.0487
Degrees of freedom	78	412	16	56	14	13	23
Two-tailed significance	0.062	0.306	0.002	0.683	0.037	0.006	0.817

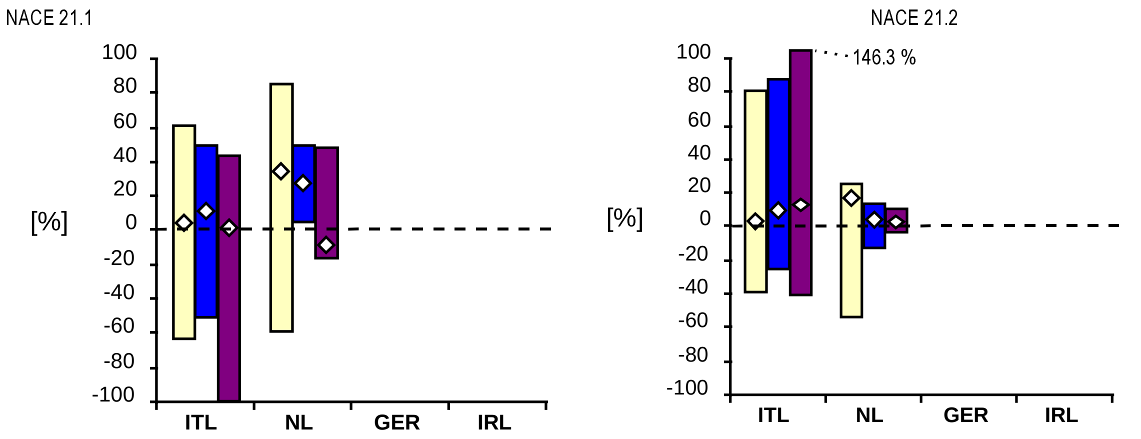
The values for converters of paper and board, on the other hand, show that scale is not a determinant for export shares in this sector. Here in fact firm status plays a significant role: converters exhibit higher export shares if they belong to a group of firms. Non-parametric ANOVA reveals that these differences bear statistical significance in the Italian and Irish sample. Two-tailed Wilcoxon rank sum tests on EXPSH92 (Export share 1992) with C_1 (firm status) as a group variable produced significance levels of 99.99% for Italian and 95.92% for Irish converters. Put forward as a hypothesis, it seems that most of the converters are small enterprises with a national focus that cannot successfully market their products abroad unless they have access to the broader distribution channels of a group of firms. In conclusion of the above discussion we can argue that:

⇒ **innovation performance and export activity are unrelated on the enterprise level. Export activity rather depends on the country, firm size and firm status.**

⇒ **on the national level the data supports the hypothesis that smaller countries tend to have higher export shares.**

Finally the present study addresses to the question whether innovation performance might manifest in rapid growth of the export sales.

Figure 3.13: Growth of exports sales between 1990-1992, deflated - truncated box-plots



COUNTRY	Italy		The Netherlands		Germany		Ireland+
NACE	*21.1*	*21.2*	*21.1*	*21.2*	*21.1*	*21.2*	*21.2*
Observations							
low performers	32 (46)	172 (260)	3	19 (20)	0	0	0 (9)
average performers	22 (26)	91 (116)	11 (12)	20 (29)	0	0	0 (12)
high performers	9	24 (39)	4	9 (10)	0	0	(0) 5

Though not statistically significant, the truncated boxplots in Figure 3.13 seem to both confirm and refute such a hypothesis. High performing manufacturers in Italy and The Netherlands exhibit lower growth of export sales than enterprises with average or low innovation performance. Italian converters of paper and board, on the other hand, boosted their export sales between 1990 and 1992. The low export share of Italian converters in 1992 hints, however, that this increase must be based on almost marginal shares in 1990 whereas Dutch enterprises have advanced most on the road towards internationalising sales activities, as the 1992 export shares confirms. Hence it is plausible that the increase of Dutch total sales in the paper manufacturing sector is also reflected in increased export growth. But in the face of small samples it seems impossible to derive any general conclusion about the growth of export sales and innovation performance.

3.2.3 Sources of Information

This section addresses the question whether high performing enterprises assign different importance to potential sources of innovation. Figure 3.14 displays the median values that respondents assigned to the relevance of a source in the shape of black squares.

+ As noted above, for Ireland deflators were not available so growth of sales has not been calculated.

Figure 3.14: Sources of information for innovation

COUNTRY	Italy		The Netherlands		Germany		Ireland
NACE	*21.1*	*21.2*	*21.1*	*21.2*	*21.1*	*21.2*	*21.2*
Observations *average performers* *high performers*	 26 9	 116 39	 12 4	 29 10	 13 4	 16 3	 12 5
Source of information INTERNAL SOURCES:							
- within the enterprise	■■■■ ■■■■	■■■■ ■■■■	■■■ ■■■▌	■■■ ■■■▌	■■■ ■■▌	■■■▌ ■■■■■	■■■■ ■■■■
- within the group of enterprises	■ ■	■ ■	■ ■	■ ■■	■ ■■▌	■ ■	■ ■■■
- within group of enterprises (those firms which are part of a group)	■ (6) ■ (4)	■ (32) ■ (8)	■ (10) ■■▌ (2)	■■■ (18) ■■ (8)	■ (3) ■■▌ (4)	■ (6) ■■■ (2)	■ (5) ■■■ (5)
EXTERNAL MARKET / COMMERCIAL SOURCES:							
- suppliers of materials and components	■■■ ■■	■■■ ■■■	■■■■ ■■■▌	■■■ ■■	■■■■ ■■■■▌	■■■■ ■■■■	■■■▌ ■■■■
- suppliers of equipment	■■■ ■■■	■■■ ■■■■	■■■ ■■■▌	■■■ ■■■■	■■■ ■■■■	■■■■ ■■■■	■■■■ ■■
- clients or customers	■■■ ■■■■	■■■ ■■■	■■■■ ■■	■■■■ ■■■	■■■■ ■■■■■	■■■■■ ■■■■	■■■■ ■■■■■
- competitors in your line of business	■■■ ■■■	■■ ■■■	■■■ ■■▌	■■■ ■■■■	■■■ ■■■■▌	■■■ ■■■■	■■■■ ■■■
- consultancy firms	■■ ■	■ ■■	■■ ■	■■ ■■■	■ ■■■	■■ ■■	■■ ■
EDUCATIONAL/RESEARCH ESTABLISHMENTS:							
- universities / higher education	■ ■	■ ■	■■ ■	■■ ■■	■ ■■	■ ■	■■ ■
- government laboratories	■ ■	■ ■	■■ ■▌	■■ ■▌	■ ■▌	■ ■	■ ■
- technical institutes	■ ■	■ ■	■▌ ■	■■ ■■	■ ■▌	■ ■	■■ ■
GENERALLY AVAILABLE INFORMATION:							
- patent disclosures	■ ■	■ ■■	■ ■	■■ ■▌	■ ■	■■ ■	■ ■
- professional conferences, meetings, professional journals	■■ ■■	■■ ■■	■■■▌ ■■	■■■ ■■■	■■■■ ■■■■	■■■■ ■■■	■■■ ■■■■
- fairs / exhibitions	■■■ ■	■■■ ■■■	■■■▌ ■▌	■■■ ■■■	■■■■ ■■■■	■■■■ ■■■	■■■■ ■■■
OTHER EXTERNAL SOURCES	■■ ■■■	■■■ ■■	■ ■	■ ■			

Scale:
- ■ unimportant
- ■■ slightly important
- ■■■ moderately important
- ■■■■ very important
- ■■■■■ crucial

The first line of a cell shows the median that average performing firms assigned to a source of information, the second line shows the median for high performing firms.

Statistically significant differences between average and high performing firms are shaded.

In the cases where differences are statistically significant between enterprises with average and high innovation performance the pertinent cells are grey shaded. For the source of information "within the group of enterprises" values are presented twice because the coding of the variable is apparently inconsistent: The question refers to group of firms, and therefore independent enterprises should display missing values for this variable. However, also independent respondents exhibit the value one, which points to an erroneous result of the estimation procedure for missing values applied by Eurostat.[132]

[132] See Eurostat, Annex no. 6

The cells in Figure 3.14 show indeed that high performing firms often assign different importance to sources of innovation. For example Italian, Dutch and German high performing converters seem to consider competitors more important than average performers although this difference only has statistical significance for German high performing paper manufacturers. The Irish and Dutch samples, on the other side, provide some evidence for the opposite case, namely that high performing enterprises consider competitors less important than the average. This kind of diversity is symptomatic for the importance of innovation source: Therefore the following discussion will focus on those sources of innovation for which at least four samples show the same pattern:

- high performing enterprises which are part of a group rate the importance of internal sources within the group higher than average performers. This applies for Dutch manufacturers of pulp, paper and board, the two German samples and the Irish sample.

- high performing firms rate the importance of suppliers of equipment higher than average performers. This observation can be made for the Dutch samples, for Italian converters and German manufacturers of paper and board. The finding fits the view of the pulp and paper sector as a supplier based industry, in which innovation involves interaction with manufacturers of equipment and machinery.

- Italian, Dutch and German converters of paper and board and German paper manufacturers consider competitors more important than average performers. The success of the benchmarking concept in the early 1990s perhaps underlines the importance of competitors for improvements. No matter whether the slogan 'collaborate with your competitors and win'[133] applies for the majority of firms, competitive intelligence is certainly a very important tool for acquiring information for innovation and is thus likely to be linked with innovation performance.

- Italian and Dutch paper manufacturers as well as German and Irish converters consider fairs and exhibitions less important than average performers. This finding is difficult to interpret since those events are also good opportunities to find new ideas or to conduct competitive intelligence.

Varying cross country patterns and -to a lesser extent- varying inter-sectoral patterns in the use of sources of innovation are also worth investigation in this study because they provide some interesting insights into the performance of national systems of innovation. In order to elucidate those patterns the median values of various sources of innovation have been aggregated into average values for the five categories. These categories are printed in capital letters in Figure 3.14)[+]. In a subsequent step, the four

[133] See Camp, C. (1989), *Benchmarking: The Search for Industry Best Practices that Lead to Superior Performance*, Milwaukee: ASQC Quality Press

[+] for example, the average on Educational/Research establishments is calculated as {median (V4_8) + median (V4_9) + median (V4_10)} / 3. 'Internal' is identical with variable (V4_1) 'within the enterprise' aggregated average values have been summed up as a proxy for the outward orientation of countries and sectors. The obtained values are presented in Table 3.6.

Table 3.7: Importance of categories of innovation sources- median values

COUNTRY	Italy		The Netherlands		Germany		Ireland
NACE	*21.1*	*21.2*	*21.1*	*21.2*	*21.1*	*21.2*	*21.2*
Source							
I. Internal	4	4	3	3	3	4	4
II. External	2.8	2.6	3.2	3.2	3.2	3.4	3.4
III. Educational	1	1	1.5	2	1	1	2
IV. General	2	2	2.67	2.33	3	3	3
V. Other	2.5	2	1	1	(1)+	(1)	1
Index outward orientation I.+II.+III.+IV.+V	8.3	7.6	8.37	8.53	7.2	6.4	9.4

The above table indicates that Italian enterprises consider external/market sources and general sources of innovation less important than other countries. Instead, so called ‘other’ sources, which are not specified further in the CIS database, play a significant role in Italy. The underlying reasons for this distinct pattern of Italian enterprises remain unclear and cannot be answered within the scope of this study. Nevertheless it seems likely that factors such as the performance of supplier industries, the attitude towards collaboration with others, and language skills play a role. Geography is probably not so important because Irish exhibit high outward orientation in spite their remote location from continental Europe. Other marked differences reveal with respect to educational/research establishments. The bulk of Italian enterprises and the German paper converters in the sample do not obtain information through universities, government labs, or technical institutes, whereas they are at least slightly important for Dutch and Irish enterprises. This raises other interesting questions for follow-up research: Do Dutch and Irish firms simply have a different attitude towards those institutions, do research institutions perform better, or is the interface between science and industry better managed?

Last but not least there is question whether those country differences may be rooted in different firm sizes. Scatter plots of the five aggregate variables of Table 3.6 and variable F (no. of employees) exhibit the following patterns:

- while the relevance of external sources ranges between marginal and crucial among small firms, this variation is limited towards the lower end for larger firms. This limit seems to increase in a linear manner with firm size. German converters do not show this pattern.

- the lower limit for the relevance of general sources also increases with firm size. The exceptions are German and Italian converters of paper and board.

+ the values are in parentheses because the German data exhibits missing values here. In order to make it comparable, we have adopted Eurostat’s assumption that missing values indicate marginal importance.

- the lower limit for the relevance of educational sources is country and sector dependent. For example, the minimum relevance and firm size are positively correlated in the Dutch samples whereas the Italian sample of converters suggests an inverse relationship between firm size and the relevance of educational/research establishments.

In summarising this discussion on the sources of innovation and links with innovation performance we can suggest the following:

⇒ **very innovative enterprises do not show uniform preferences for particular innovation sources. However, in four out of seven samples high performing enterprises tended to rank the following sources higher: internal sources within the group of enterprises, suppliers of equipment, and competitive intelligence. Fairs and exhibitions, on the other hand, were ranked lower by high performing enterprises in four out of seven samples.**

⇒ **with respect to national aspects of innovation Italian enterprises are the most inward oriented.**

⇒ **Dutch and Irish enterprises rank educational resources higher than in other countries, which is a pointer for future research dealing with the capacity and suitability of national research institutions to serve the needs of the industry.**

3.2.4 Objectives of Innovation

Figure 3.15 shows the importance that respondents assigned to objectives of innovation. Again the differences between average and high performing firms vary very much with the sample. Otherwise the data reflects quite well the characteristic innovation objectives which are frequently discussed in publications on the pulp and paper industry: the reduction of production costs, the reduction of environmental damage, and the improvement of quality, which is perhaps the most important objective at all. If one disregards the Italian manufacturers for a moment, the data shows that high performing firms consider an objective almost always as important or more important than average performers. The differences raise the very interesting question why high performing firms are more concerned with the objective: because they are laggards or because they are industry leaders and more aware of the issue.

Figure 3.15: Objectives for innovation

COUNTRY	Italy		The Netherlands		Germany		Ireland
NACE	*21.1*	*21.2*	*21.1*	*21.2*	*21.1*	*21.2*	*21.2*
Observations *average performers* *high performers*	26 9	116 39	12 4	29 10	13 4	16 3	12 5
Objective							
Replace products being phased out	■ ■	■ ■	■■■ ■■▮	■■■■ ■■■■	■■■■ ■■■■	■■■▮ ■■	■■■▮ ■■■■
EXTEND PRODUCT RANGE:							
- within main product field	■■■ ■■■■	■■ ■■■■	■■■■ ■■■■	■■■■ ■■■■	■■■■ ■■■■	■■■■■ ■	■■■■ ■■■■
- outside main product field	■ ■	■ ■	■ ■▮	■■ ■■	■ ■■	■ ■	■■▮ ■■
Increasing or maintaining market share	■■■■ ■■■■	■■■■ ■■■■	■■■■ ■■■▮	■■■■ ■■■■	■■■■■ ■■■■▮	■■■■■ ■■■■	■■■■ ■■■■■
CREATING NEW MARKETS:							
- nationally	■■■■ ■■■	■■■ ■■■■	■■ ■■■	■■■ ■■■■	■■■■ ■■■■■	■■■■ ■■■■	■■■▮ ■■■
- within EU	■■■■ ■■■■	■■■ ■■■	■■■■ ■■▮	■■■ ■■■■	■■ ■■■▮	■■■ ■	■■■▮ ■■■■■
- in North America	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■▮ ■
- in Japan	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■
- in other countries	■ ■	■ ■	■ ■	■ ■■▮	■■ ■▮	■■ ■	■ ■■
Improve production flexibility	■■■■ ■■■■	■■■■ ■■■■	■■■ ■■■▮	■■■ ■■■■	■■■ ■■■■	■■■■▮ ■■■■	■■■ ■■■■■
LOWER PRODUCTION COSTS BY:							
- reducing the share of wage costs	■■■■ ■■■■	■■■■ ■■■■	■■■■ ■■■	■■■■ ■■■■	■■■■ ■■■■▮	■■■■■ ■■■■■	■■■ ■■■■■
- reducing materials consumption	■■■■ ■■■	■■■ ■■■	■■■ ■■■	■■■■ ■■■■	■■■■ ■■■■	■■■■ ■■■■■	■■■▮ ■■■■■
- reducing energy consumption	■■■■ ■■	■■■ ■■■	■■■ ■■■	■■■ ■■■	■■■■ ■■■■▮	■■■ ■■■■	■■ ■■
- reducing product design costs	■■ ■	■ ■■	■▮ ■■	■■ ■■	missing	missing	■■▮ ■■
- reducing production lead times	■■■■ ■■■■	■■■■ ■■■■	■■■ ■■▮	■■■ ■■■	missing	missing	■■■▮ ■■■■■
Reducing environmental damage	■■■■ ■■■	■■■ ■■■	■■■ ■■■▮	■■■ ■■■■	■■ ■■■■	■■■■ ■■■■■	■ ■■■
Improving product quality	■■■■■ ■■■■■	■■■■ ■■■■	■■■■ ■■■■▮	■■■■ ■■■■▮	■■■■■ ■■■■▮	■■■■■ ■■■■■	■■■■ ■■■■■
Improving working conditions, safety	■■■■■ ■■■	■■■■ ■■■■	■■■ ■■■▮	■■■ ■■■■	■■ ■■■▮	■■■ ■■■■■	■■▮ ■■■
OTHER INNOVATION OBJECTIVE	■■■ ■■■■	■■■ ■■■	■ ■	■ ■	missing	missing	missing

Scale:
■ unimportant
■■ slightly important
■■■ moderately important
■■■■ very important
■■■■■ crucial

The first line of a cell shows the median that average performing firms assigned to an objective, the second line shows the median for high performing firms.

Statistically significant differences between average and high performing firms are shaded.

Unfortunately, such a question is difficult to answer with the given data and hence the present study focuses on the more tangible aspects, which are highlighted in the following discussion. The first striking difference is revealed with respect to the replacement of products being phased out. Unlike enterprises from other countries Italian enterprises rate the replacement of products being phased out as unimportant. This answer seems logical because Italian enterprises exhibit the lowest share of products in the decline phase of their lifecycle (see Figure 3.32)). This cannot be said about German high performing converters, which merely found this objective slightly important. The extension of the product range within the main product field is an objective which is widely considered as very important. However, Italian average performers in the conversion sector and the three German high performing enterprises answered that this objective was minor for their innovation processes. The German high performers might be exceptional cases that are not representative for the population but the Italian case certainly reflects a marked difference. The reasons remain unclear since these enterprises did not emphasise other innovation objectives as more important. Differences between enterprises with average and high innovation performance reveal differences with respect to the creation of new markets and the improvement of production flexibility:

⇒ **in four of the seven samples high performing enterprises exhibit higher median values for the creation of new national markets than average performers.**

⇒ **the improvement of production flexibility is considered more important among high performing enterprises from The Netherlands, Ireland, and Germany whereas Italian enterprises and German converters consider this objective unanimously as very important.**

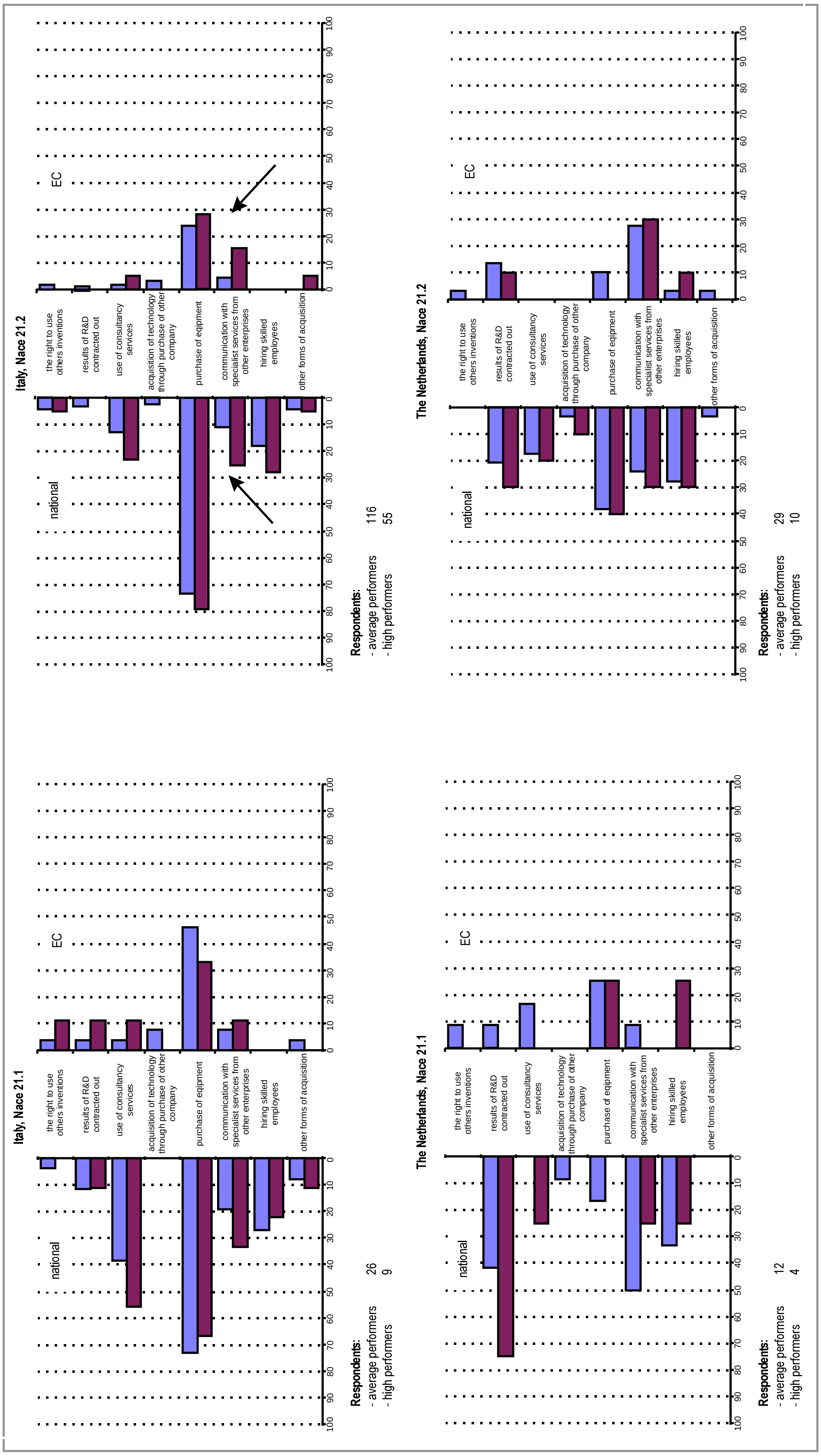
3.2.5 Technology Flows

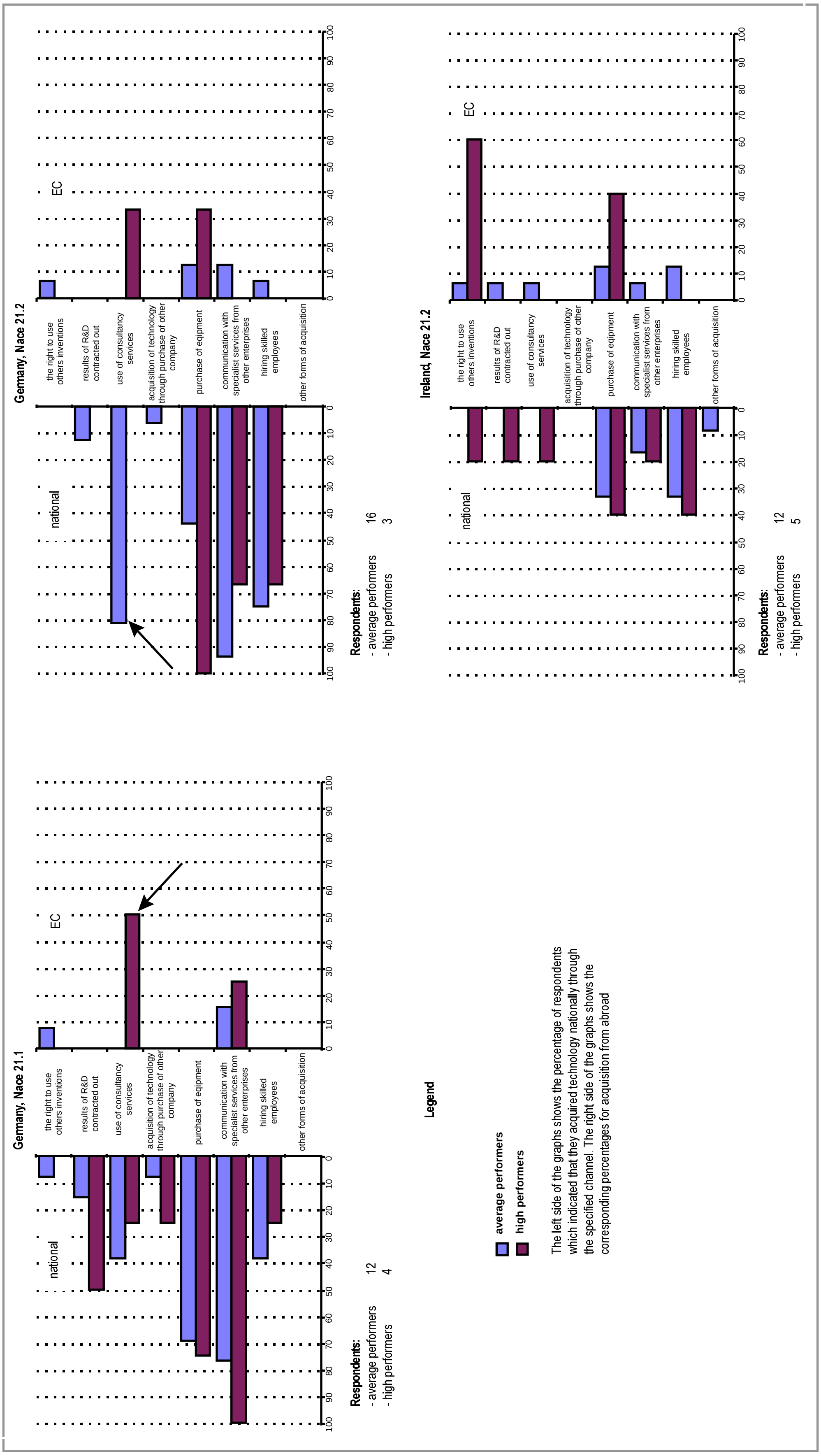
Figure 3.16 and Figure 3.17 we show how frequently the respondents used certain channels for the acquisition or transfer of technology. Since technology flows predominantly exist within the national borders and with other EU countries, the presentation of data concentrates on the frequency of national sources and sources within the EU. With respect to technology flows it remains true that the patterns are very much country and sector specific.

In the first instance the present study addresses to the channels of technology acquisition which are mapped in Figure 3.16. The bar-charts indicate that the enterprises in the pulp and paper sector acquire technology predominantly through national channels. Yet, differences between average and high performing firms have the same direction, both for acquisition from national channels and from within the EU. For example, if high performing enterprises in a sample mentioned communication with domestic specialist firms more often they also had more frequently communication with foreign firms from within the EU. This example leads to the analytical question whether high performing enterprises use certain channels more frequently than average performing firms. With some limitations two differences appear, which as yet lack statistical significance. Firstly, high performing enterprises except German converters of paper and board answered more frequently than average performers that they acquired technology through the results of R&D contracted out and through consultants. High performing enterprises in the conversion sector mention more often that they acquired technology through the purchase of equipment. Other channels of technology acquisition, such as communication with specialist services and the hiring of skilled employees exhibit varying patterns. One reason might be that enterprises in different countries and sectors use certain channels only in particular combinations with others. In the following, the links with at least medium correlation are presented. Communication with specialist services from other enterprises is strongly correlated with the use of consultancy services among German converters (Spearman's correlation coefficient 0.86, sig. 99.99%). Medium correlation[134] also exists between communication and the hiring of skilled employees (Dutch paper manufacturers and German converters), between communication and the purchase of equipment (both Dutch samples), and between communication and the right to use other's inventions (Italian paper manufacturers).

[134] This implies a Spearman correlation coefficient between 0.50 and 0.70. For a scale see Wittenberg, R. (1991), *Computerunterstützte Datenanalyse*, Stuttgart: Gustav Fischer Verlag, p.125

Figure 3.16: Acquisition of technology

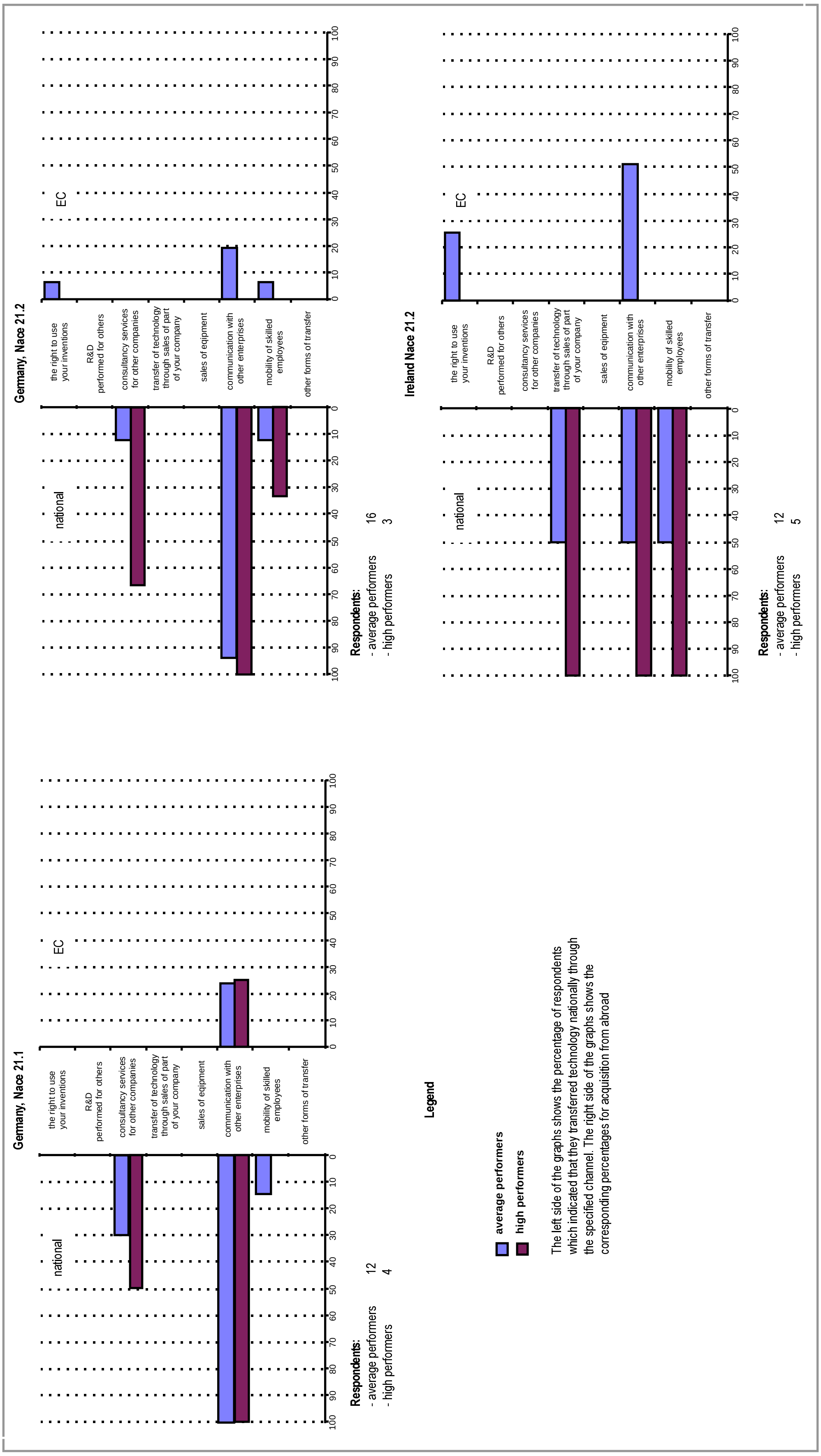



Germany, Nace 21.2
national
EC
the right to use others inventions
results of R&D contracted out
use of consultancy services
acquisition of technology through purchase of other company
purchase of eqipment
communication with specialist services from other enterprises
hiring skilled employees
other forms of acquisition
Respondents:
- average performers 16
- high performers 3
Ireland, Nace 21.2
national
EC
Respondents:
- average performers 12
- high performers 5
Germany, Nace 21.1
national
EC
Respondents:
- average performers 12
- high performers 4
Legend
average performers
high performers
The left side of the graphs shows the percentage of respondents which indicated that they acquired technology nationally through the specified channel. The right side of the graphs shows the corresponding percentages for acquisition from abroad

The hiring of skilled employees shows the following links. Medium correlation exists between hiring employees and the purchase of equipment (Dutch paper manufacturers), between hiring employees and the acquisition of another firm (German paper manufacturers), and between hiring skilled employees and communication with specialist services (German converters).

Having outlined the most important aspects of technology acquisition, there remains the question of outflows of technology from enterprises in the pulp and paper to other entities. Figure 3.17 maps how frequently the respondents used certain channels for technology transfer. Again it turns out that the patterns of technology transfer are largely country and sector dependent. The bulk of technology transfer in Italy, Germany and Ireland is a national affair while Dutch firms also have an impressive number of transfers abroad. The destinations are not only in EU Europe but extend to non-EU European countries and North America, so that the charts in Figure 3.17 do in fact under-represent the extent of technology transfer in the Dutch case. Two aspects deserve attention. Firstly, communication with other enterprises and consultancy services for other countries are quite frequently mentioned across the samples. If one bears in mind that the distinction between consultancy services and communication with other enterprises is sometimes difficult to make one can say that the ‘communications mode’ is the most important channel for the transfer of technology in the pulp and paper industry. Secondly equipment ranks behind communication as a transfer channel, which is remarkable in so far as equipment was the most important means of technology acquisition. Only Italian enterprises mentioned frequently that they transferred technology through the sales of equipment. The Dutch and Irish samples suggest that the sale of part of the enterprise is an alternative way to transferring technology to the sales of mere equipment. Sales to non-EU countries and North America are reported twice each for the 12 Dutch paper manufacturers with average innovation performance, and three times each for the four high performing enterprises. Moreover, half of the 10 high performing Dutch paper and board converters said that they sold part of their company to other firms in those regions. Figure 3.17 displays a similar situation for Irish enterprises which frequently sold their part of their operations to other firms in Ireland. Interestingly, the buying enterprises are either outside the pulp and paper sector, or they are not included in the survey.

Figure 3.17: Transfer of technology

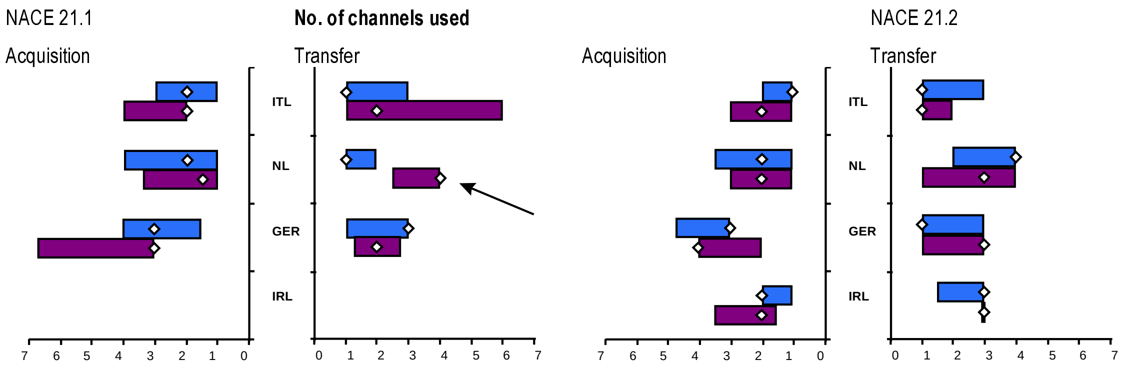


If one understands the sales of equipment and the sale of part of the company as two related modes of ‘hardware’ transfer, the following conclusion can be drawn with respect to innovation performance: High performing enterprises transfer more ‘hardware’ than enterprises with average innovation performance.

Though not directly related to innovation performance on the firm level, it seems also worthwhile highlighting some of links between transfer channels. Dutch paper manufacturers seem to perform either consultancy services or communication with other enterprises (Spearman’s correlation coefficient -0.57, Sign. 99.99%), which supports the hypothesis that consultancy services and communication are perceived as complementaries. Communication with enterprises and the mobility of employees are correlated in both Dutch samples (NACE 21.1: Spearman’s correlation coefficient 0.61 Sign. 99.99%; NACE 21.2 Spearman’s correlation coefficient 0.76 Sign. 99.99%). Extremely high correlation exists between consultancy services and the sale of part of the company for Dutch converters of paper and board (Spearman’s correlation coefficient 0.95 Sign. 99.99%). The latter correlation underlines the importance of tacit knowledge in the pulp and paper industry: Complex production equipment such as a whole manufacturing line cannot be operated successfully without an initial period of training provided by someone who is familiar with the material. This argument might also explain why all these soft factors such as communication with specialist services, the hiring of skilled employees and the use of consultants are crucial for innovation processes in the pulp and paper industry.

The latter aspect raises the question whether highly innovative enterprises use more channels than average performers. The CIS database does not contain information on the number of, for example, equipment purchases the than that it must have been at least one. But it contains information on the location from which or to which technology was acquired/transferred.

Figure 3.18: Number of different acquisition/transfer channels - truncated boxplots



COUNTRY	Italy		The Netherlands		Germany		Ireland
NACE	*21.1*	*21.2*	*21.1*	*21.2*	*21.1*	*21.2*	*21.2*
Observations							
average performers	26	116	12	29	13	16	12
high performers	9	39	4	10	4	3	5

Thus we can ask the question whether high performing firms have higher technology flows with respect to the number of different channels in different locations, i.e. national, EU, non-EU, North America, Japan, and other countries. Therefore the variables V6ALL+ and v7ALL were introduced, counting the number of different channels.

Figure 3.18 shows that there is no evidence for the hypothesis that all high performing enterprises in the pulp and paper industry generally use more channels than enterprises with average innovation performance. The data rather suggests that the acquisition of technology in the pulp and paper industry involves two different channels. On the country level, however, two marked differences can be observed. German enterprises use more channels for the acquisition of technology than the other countries whereas Dutch enterprises use the most channels to transfer technology.

Concluding of the discussion on innovation performance and technology flows we summarise the findings as follows:

- ⇒ **high performing enterprises mentioned more frequently that they used R&D contracted out and consultants to acquire technology.**

- ⇒ **high performing enterprises in the conversion sector mentioned more frequently that they acquired technology through the purchase of equipment.**

- ⇒ **high performing enterprises transfer more 'hardware' than enterprises with average innovation performance.**

- ⇒ **with respect to the national aspects of innovation it can be said that Germany uses the most channels for the acquisition of technology whereas Dutch enterprises use the most to transfer technology.**

3.2.6 Protection of Competitive Advantage

The analysis in this section focuses on the protection of competitive advantages with respect to product and process innovation. The relevant questions 9a and 9b in the harmonised questionnaire were not included in the Italian survey so that the discussion has to be limited to The Netherlands, Germany, and Ireland. The data shows very clearly there is virtual unanimity among the enterprises in the pulp and paper industry that having a lead time advantage over competitors is the most effective means of protection for both product and process innovations. Similarly the vast majority of respondents consider patents unimportant with respect to process innovation. A third observation concerns the registration of design.

+ $V6ALL := \sum_{i}^{9} \sum_{j=1}^{6} V6\_ij$, ($V7ALLis$ analogous)

Figure 3.19: Effectiveness of methods used to maintain or increase competitive advantage

COUNTRY	Italy		The Netherlands		Germany		Ireland
NACE	*21.1*	*21.2*	*21.1*	*21.2*	*21.1*	*21.2*	*21.2*
Observations *average performers* *high performers*	 26 9	 116 39	 12 4	 29 10	 13 4	 16 3	 12 5
Effectiveness of the method used							
PRODUCT INNOVATIONS							
- patents			■▌ ■	■■■ ■■	■ ■■	■▌ ■	■ ■■■ (shaded)
- registration of design			■ ■	■ ■■	■ ■■	■■ ■	■ ■■
- secrecy			■▌ ■■■	■■■ ■■■	■■■▌ ■■■■	■■■ ■■■	■■■ ■■■
- complexity of product design			■▌ ■■	■■■ ■■■	■■■ ■■■■	■■■ ■■■	■■■ ■■■■
- having a lead time advantage over competitors			■■■■ ■■■▌	■■■■ ■■■■	■■■■▌ ■■■■▌	■■■■ ■■■■	■■■■ ■■■■
PROCESS INNOVATIONS							
- patents			■ ■	■ ■■	■ ■	■ ■	■ ■
- registration of design			■ ■	■ ■■ (shaded)	■ ■▌	■■ ■	■ ■■
- secrecy			■■■▌ ■■■■	■■■ ■■■■▌	■■■ ■■■■	■■■ ■■■	■■■ ■■
- complexity of process design			■ ■■▌	■■■ ■■■▌	■■■ ■■■▌	■■■ ■■■	■■■■ ■■■
- having a lead time advantage over competitors			■■■■ ■■■■	■■■■ ■■■■	■■■■ ■■■■▌	■■■■ ■■■■	■■■■▌ ■■■■■

Scale:
■ unimportant
■■ slightly important
■■■ moderately important
■■■■ very important
■■■■■ crucial

The first line of a cell shows the median that average performing firms assigned to a method used to protect or maintain competitive advantage, the second line shows the median for high performing firms.

Statistically significant differences between average and high performing firms are shaded.

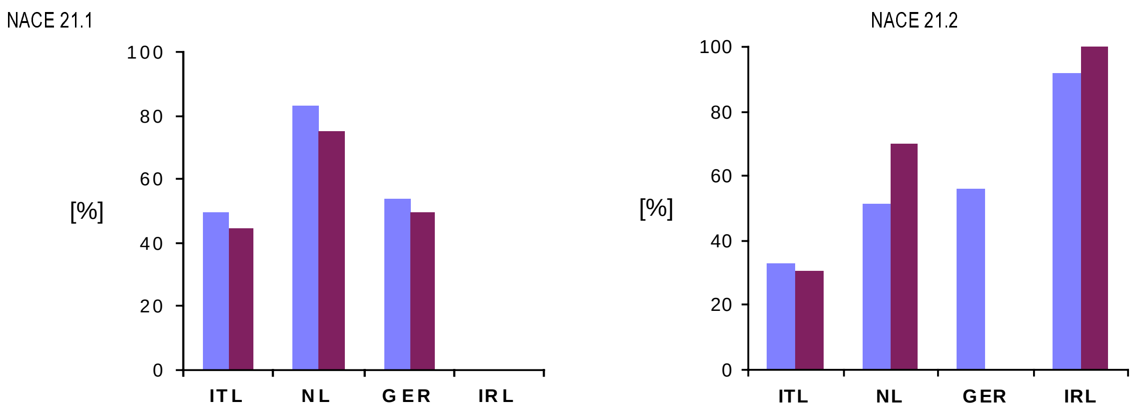
The high degree of congruence between the patterns for product innovation and process innovation suggests that the respondents rated factors according to their general attitude towards to that factor rather than to the characteristics of the innovation. Apart from those common points, much of the diversity between enterprises with average high innovation performance seems again sample specific and not necessarily related to innovation performance. For example, Irish high performing enterprises consider patents significantly more important than average performers but on the other hand these firms are also the most extensive users of patents in order to acquire technology (see Figure 3.16). If one considers these Irish enterprises as a special case and looks at the Dutch and German data, it turns out that enterprises with high innovation performance seem to put more emphasis on secrecy and the complexity of their product/process design. However, those differences lack statistical significance and the small number of high performing enterprises on which the assumption is based, do not permit any other conclusion than:

⇒ **innovation performance is not linked to particular preferences for certain methods used to protect the competitive advantage of product or process innovation.**

3.2.7 R&D Activity

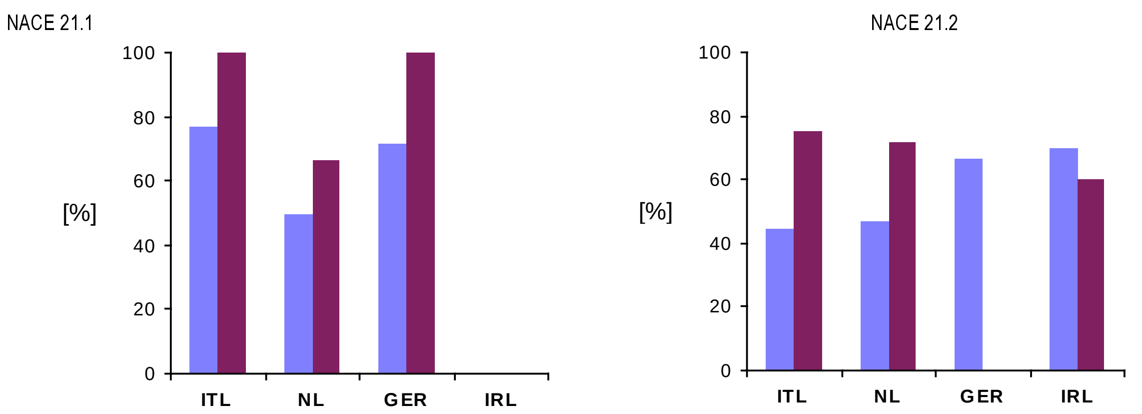
This section deals with the relation between innovation performance and R&D activity in the pulp and paper industry. In the first instance the present study focuses on the organisational aspects of innovation.

Figure 3.20: Percentage of firms which engaged in R&D in 1992



COUNTRY	Italy		The Netherlands		Germany		Ireland
NACE	*21.1*	*21.2*	*21.1*	*21.2*	*21.1*	*21.2*	*21.2*
Observations							
average performers	26	116	12	29	13	16	12
high performers	9	39	4	10	4	3	5

Figure 3.21: Percentage of firms which engaged in R&D and perform it on a continuous basis

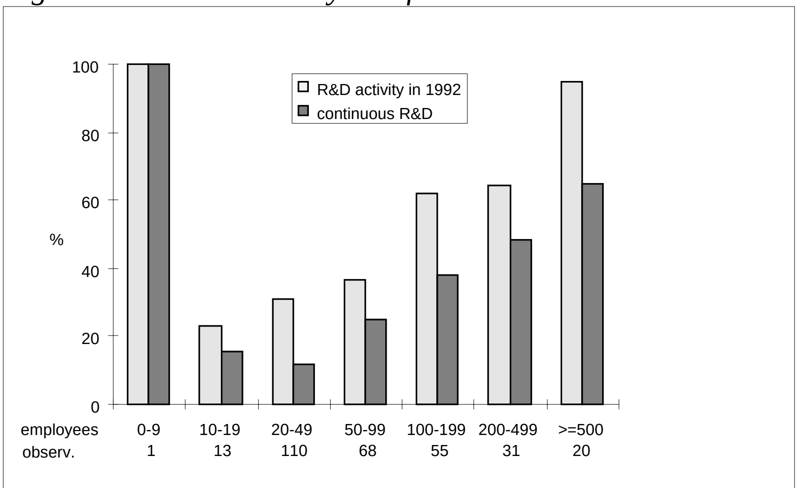


COUNTRY	Italy		The Netherlands		Germany		Ireland
NACE	*21.1*	*21.2*	*21.1*	*21.2*	*21.1*	*21.2*	*21.2*
Observations							
average performers	13 (26)	38 (116)	10 (12)	15 (29)	7 (13)	9 (16)	11 (12)
high performers	4 (9)	12 (39)	3 (4)	7 (10)	2 (4)	0 (3)	5

Figure 3.20 shows the percentage of enterprises with R&D activities during 1992. Two points deserve attention. Firstly, the level of R&D activity varies, as one might expect, from the previous analysis, with country and sector. Secondly, a significant share of the enterprises achieve high innovation performance in spite of missing R&D activities during 1992. The latter point confirms the hypothesis put forward at the beginning of this study that innovation performance in the pulp and paper industry cannot be explained with R&D let alone. Figure 3.21 shows that not all of the enterprises which had R&D during 1992, perform this activity on a continuous

basis, e.g. in a permanent R&D laboratory. It must be emphasised at this place that the bar-charts in Figure 3.21 represent percentages in order to make the data comparable. But one should be aware that they are calculated on extremely few observations (The numbers in parentheses in Figure 3.21 refer to the number of observations in a group, the preceding numbers refer to those firms which actually had R&D in 1992 and on which the percentages are calculated). As far as one can reasonably deduce from such few cases it could be possible that high performing enterprises perform R&D more frequently on a continuous basis than average performers. On the other hand there is much more evidence for the hypothesis that R&D activity is a matter of firm size. Therefore all observations were grouped into seven size classes on which the frequencies for R&D activity were calculated. The bar-chart is presented in Figure 3.22. It shows clearly a linear relationship between firm size and R&D activity: the larger the firm the more likely to perform R&D. The leftmost bar cannot seriously negate this finding because it concerns one enterprise that must be considered as an idiosyncratic case. Such a relation seems reasonable: small enterprises or business units often simply don’t have the resources to perform effective R&D on their own.[135]

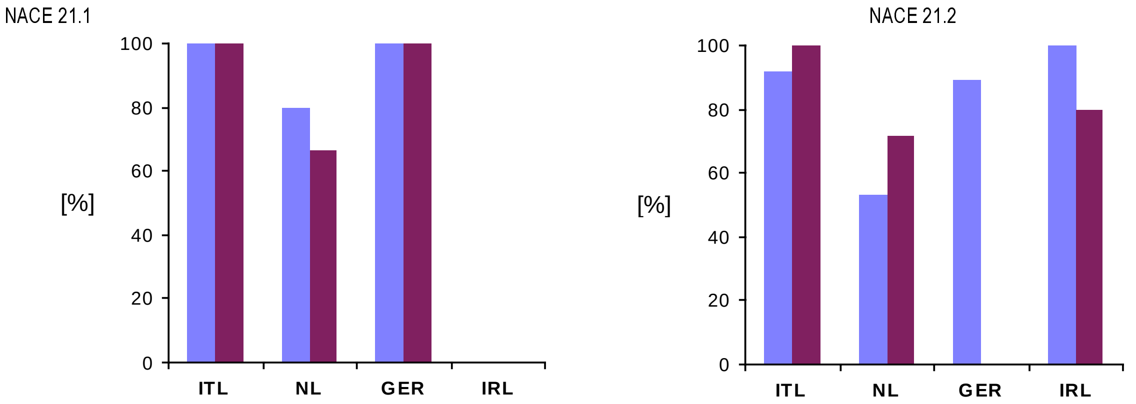
Figure 3.22: R&D activity and firm size



The CIS database also contains information on the plans of enterprises tin terms of carrying out R&D in the future. Figure 3.23 and Figure 3.24 depict two marked cases, firstly the share of enterprises with R&D activity that also have plans for R&D in the future and secondly, the share of enterprises without R&D in 1992 and without plans to undertake R&D in the subsequent years. The data is again so scarce that relevant differences between average performers and high performing enterprises cannot be detected.

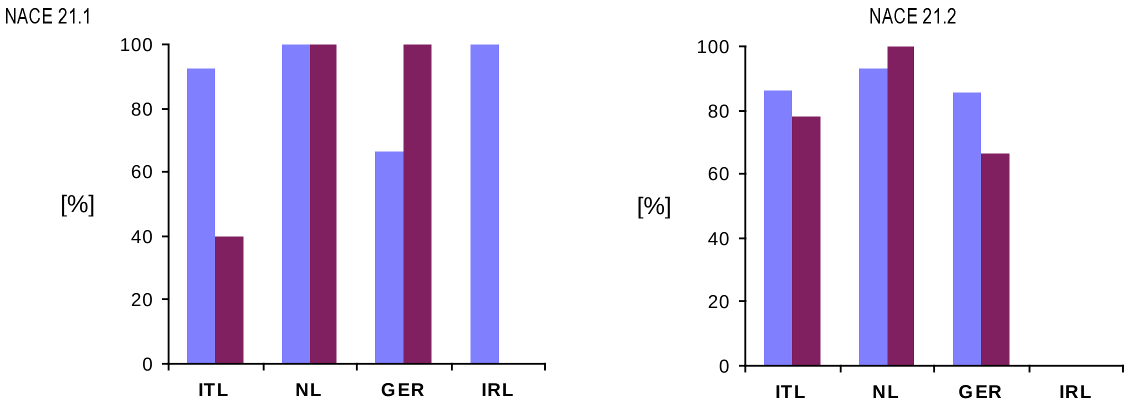
[135] Mawson, A. (1983) ‘Organization requirements for innovation and economic growth’ *The Role of Fundamental Research in Papermaking,* London: The British Paper and Board Industry Federation, vol 2, pp. 1079-1087

Figure 3.23: Plans of enterprises with R&D activity in 1992 for undertaking R&D in the following three years



COUNTRY	Italy		The Netherlands		Germany		Ireland
NACE	*21.1*	*21.2*	*21.1*	*21.2*	*21.1*	*21.2*	*21.2*
Observations							
average performers	13 (26)	38 (116)	10 (12)	15 (29)	7 (13)	9 (16)	11 (12)
high performers	4 (9)	12 (39)	3 (4)	7 (10)	2 (4)	0 (3)	5

Figure 3.24: Plans of enterprises without R&D activity in 1992 not to undertake R&D in the following three years

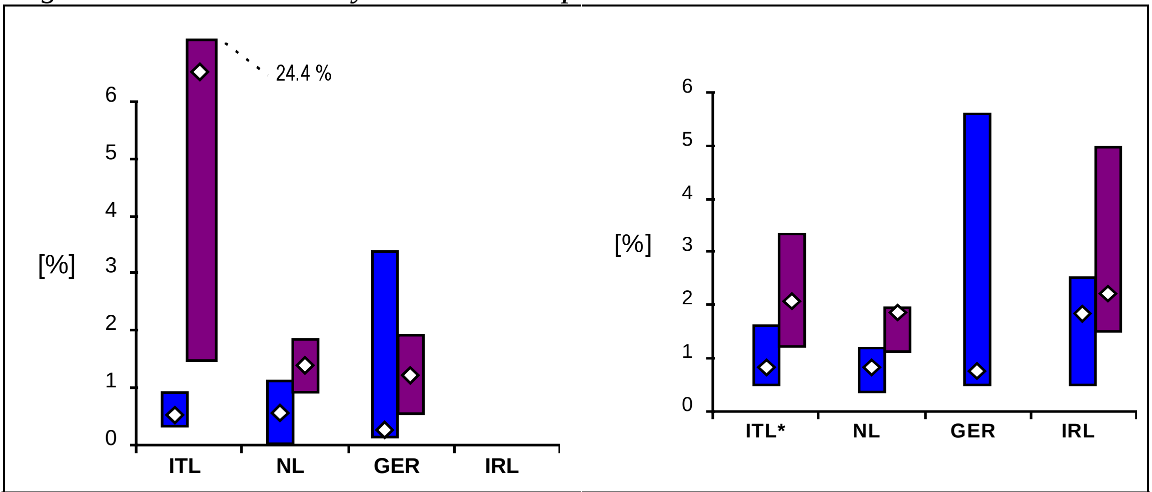


COUNTRY	Italy		The Netherlands		Germany		Ireland
NACE	*21.1*	*21.2*	*21.1*	*21.2*	*21.1*	*21.2*	*21.2*
Observations							
average performers	13 (26)	78 (116)	2 (12)	14 (29)	6 (13)	7 (16)	1 (12)
high performers	5 (9)	27 (39)	1 (4)	3 (10)	2 (4)	3	

But the data shows that there are only few firms with single R&D projects and no plans for follow up research. In other words, enterprises either carry R&D on a more or less continuous basis or they don't do it at all.

In the following the extent of R&D activity will be in focus. Figure 3.25 shows boxplots of the enterprises' R&D expenditures as a fraction of total sales. As before, the data is very scarce so that the results must be interpreted with considerable reserve. However, the larger samples on Italian and Dutch converters of paper and board show that high performing enterprises have higher R&D expenditures than the average if they carry out R&D. In the former case these differences are statistically significant. Yet Figure **3.26** suggests that high performing enterprises spend less of their R&D on extramural services.

Figure 3.25: R&D intensity -truncated boxplots



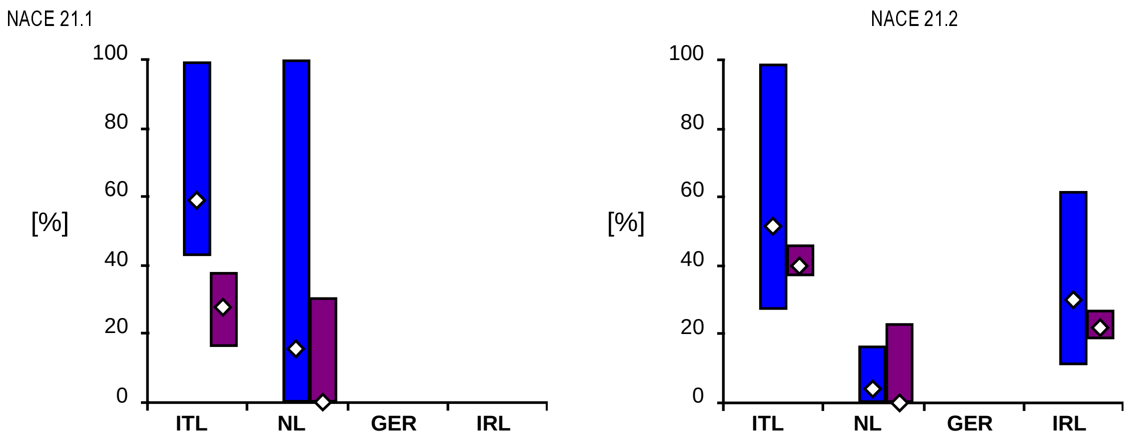
COUNTRY	Italy		The Netherlands		Germany		Ireland
NACE	*21.1*	*21.2*	*21.1*	*21.2*	*21.1*	*21.2*	*21.2*
Observations *average performers* *high performers*	13 (26) 4 (9)	38 (116) 12 (39)	10 (12) 3 (4)	15 (29) 7 (10)	7 (13) 2 (4)	9 (16) 0 (3)	11 (12) 5

How should these findings be interpreted? We suggest that R&D activities and the level of expenditures must be seen in relation to the characteristics of the particular innovation. The data on the frequency of R&D activities has already indicated that many enterprises in the pulp and paper industry can innovate without internal R&D because there are other ways available to acquire the necessary knowledge, such as suppliers or the centralised R&D laboratories in larger groups of enterprises. But there are situations in which internal R&D is indispensable. A characteristic example is the transformation of basic research into improved or new products and processes. Basic research in the pulp and paper industry, as in most other sectors, is largely carried out in government laboratories, research institutes, universities and industry-operated R&D labs. This knowledge is more or less publicly available but requires additional research to be applied in concrete products and processes. The latter type of applied research is predominantly undertaken within the enterprise, for reasons ranging from the protection of competitive advantage to the simple necessity to solve suddenly occurring problems during implementation. Moreover, the strategic aspect must be integrated in the explanation of R&D intensities. In their study on technology strategy in the pulp and paper industry, Maspons et al[136] emphasise that the level of R&D expenditures and the objectives of R&D depend very much on the strategy pursued by the firm. The authors see three distinct classes: The first class is made up by firms with R&D expenditures around 0.8% of the total sales. These firms use R&D as a strategic weapon with different objectives. In market segments with a high content of technology, such as special paper, internal R&D is indispensable because the ownership of technology constitutes an important competitive advantage. Firms operating in mass segments may perform R&D in order to achieve technological leadership or to support their diversification strategy. The second class of enterprises exhibits R&D intensities between 0.4% and 0.8%. According to

[136] Maspons, R., Escorsa, P., Colom, J.F. (1993), *La gestión de la tecnología en el sector de las pastas y papel*, Terrassa (Spain): Universitat Politècnica de Catalunya, pp. 140

Maspons et al., these firms rather pursue imitative strategies in which R&D is mainly performed in order to adapt new technology. The third class consists of enterprises with R&D intensities below 0.4% that pursue traditional strategies with competitive advantages based on low production costs and control over the distribution system. Hence one can conclude on a general level that enterprises in the pulp and paper industry performs R&D for a range of reasons. For those enterprises there exists in fact a positive relationship between R&D expenditures and innovation performance. In this context the question arises whether high R&D intensity is particularly correlated with one of the performance indicators and with the share of products new to the industry. Correlation analysis on the pooled observations has shown that there is no significant correlation between R&D intensity and products new to the industry. However, this result could be expected because both variables refer to 1992 and it is not very likely that R&D performed in 1992 will result in significant sales of new products in the same period.

Figure 3.26: Share of R&D expenditures related to extramural services

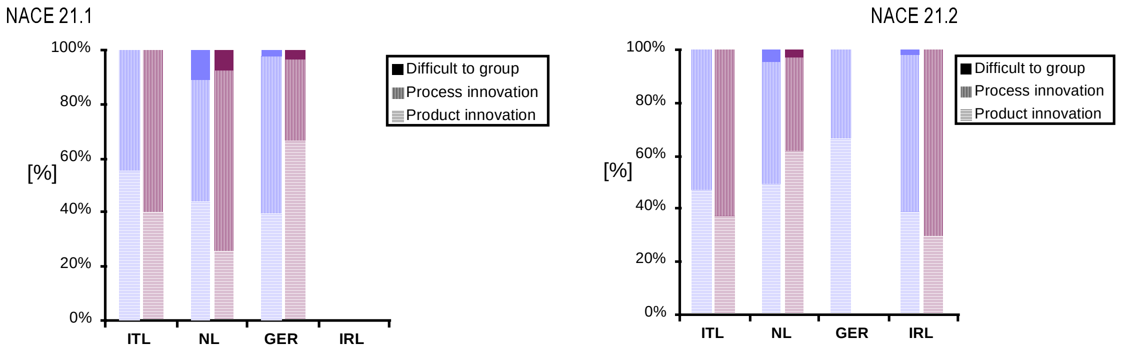


COUNTRY	**Italy**		**The Netherlands**		**Germany**		**Ireland**
NACE	*21.1*	*21.2*	*21.1*	*21.2*	*21.1*	*21.2*	*21.2*
Observations							
average performers	13 (26)	38 (116)	10 (12)	15 (29)	7 (13)	9 (16)	11 (12)
high performers	4 (9)	12 (39)	3 (4)	7 (10)	2 (4)	0 (3)	5

For similar reasons there is also just weak correlation with the share of introductory and growth products. The strongest correlation exists between R&D intensity and the intensity of innovation (INNINT). (Spearman's correlation coefficient 0.6032, significance level 99.99%). However, it must be emphasised that INNINT and the level of R&D expenditures are not unrelated because the innovation costs also contain R&D expenditures as one of the six components (see chapter 3).

Finally the relation between innovation performance and the distribution of R&D costs will be examined. Figure 3.27 shows the shares of the R&D budget that the enterprises used for R&D related to product and process innovation.

Figure 3.27: Distribution of R&D expenditures pertaining to product and process innovation



COUNTRY	Italy		The Netherlands		Germany		Ireland
NACE	*21.1*	*21.2*	*21.1*	*21.2*	*21.1*	*21.2*	*21.2*
Observations							
average performers	13 (26)	38 (116)	10 (12)	15 (29)	7 (13)	9 (16)	11 (12)
high performers	4 (9)	12 (39)	3 (4)	7 (10)	2 (4)	0 (3)	5

The distribution varies across the samples and cannot be explained through significant correlation with performance indicators. Hence one must assume that innovation performance and the distribution of R&D costs are unrelated. In summarising this section we can therefore draw the following conclusions:

⇒ **about half of the enterprises achieve high innovation performance according to the definition of this study without internal R&D activity. Other studies on technology strategy in the sector suggest that these firms are unlikely to be industry leaders and unlikely to operate in market segments characterised by sophisticated technology.**

⇒ **those enterprises that perform R&D exhibit higher R&D expenditures if they are highly innovative. Correlation analysis shows that R&D expenditures are linked with the level of expenditures related to innovation.**

⇒ **enterprises with high innovation performance spend less on extramural services, which suggests that R&D in these enterprises is of the applied, competitive type.**

3.2.8 R&D Cooperation

It would have been interesting to analyse R&D cooperation under the aspect of innovation performance. But unfortunately data is not available for Italy and the data for the remaining sample is so scarce that reasonable analysis of differences between countries or even enterprises cannot be performed. Hence this aspect has to be left out. Moreover, there are only a few enterprises in the other samples which actually had R&D cooperation.

3.2.9 Factors Hampering Innovation

Figure 3.28 displays how enterprises with low, average and high innovation performance rated the importance of selected factors as obstacles to innovation. It must be pointed out at the beginning of the discussion that most of the Dutch data must have been estimated. Dutch low performers exhibit, without exception, the value one in all variables. Dutch enterprises with average and high innovation performance also exhibit value one uniformly for the questions concerning ‘resistance to change in the enterprise’. This value raises issues concerning Eurostat’s estimation procedure for this dataset: it is assumed that respondents who did not answer a question consider it unimportant. This approach certainly has some justification but in this case must be seriously doubted that all Dutch enterprises did in fact consider the latter questions unimportant. Whatever the reasons may be, the data on the other countries strongly suggest that the Dutch data at least partially deficient.

After all the restrictions imposed by the data, what can be said about innovation performance and factors hampering innovation? Perhaps somewhat unsatisfactory is the answer that virtually no common characteristics of the analysis groups can be detected. On the other hand, this is not so surprising because the answers of the respondents are likely to depend on the national environment and a number of enterprise specific factors which are only partially covered in the CIS database. The obtained values might be understood if one understands the interplay of factors such as firm size, firm status, innovation objectives, technological content of desired innovations. Such analysis, however, goes far beyond the aim of this study to analyse the characteristics of low, average, and high performing enterprises in the CIS database.

Figure 3.28: Factors hampering innovation

COUNTRY	Italy		The Netherlands		Germany		Ireland
NACE	*21.1*	*21.2*	*21.1*	*21.2*	*21.1*	*21.2*	*21.2*
Observations *low performers* *average performers* *high performers*	 46 26 9	 260 116 39	 3 12 4	 20 29 10	 4 13 4	 15 16 3	 9 12 5
Barriers							
ECONOMIC FACTORS:							
- excessive perceived risk	■▌ ■■ ■	■▌ ■ ■	■ ■■ ■▌	(shaded) ■ ■■■ ■■	■▌ ■■■ ■■■▌	■ ■■■ ■	■■ ■■■ ■■■
- lack of appropriate sources of finance	■■■ ■■■ ■■■	■■■ ■■■ ■■■	■ ■■▌ ■■	(shaded) ■ ■■ ■■	■▌ ■■■ ■■■▌	■■ ■■■ ■	■■■ ■■ ■■■
- innovation costs too high	■■■■ ■■■ ■■■	■■■ ■■■ ■■■	■ ■■ ■	(shaded) ■ ■■ ■■	■ ■■ ■■■■	■ ■■ ■■	■■■ ■■■ ■■■■
- pay-off period of innovation is too long	■■■ ■■■ ■■■	■■■ ■■■ ■■■	■ ■■■ ■■■▌	(shaded) ■ ■■■ ■■	(shaded) ■ ■■ ■■■■	■ ■■ ■■	■■■ ■■▌ ■■■
ENTERPRISE FACTORS:							
- enterprise's innovation potential (e.g. R&D design, etc.) too small	■▌ ■■ ■	■ ■ ■	(shaded) ■ ■■ ■■■	(shaded) ■ ■■ ■■▌	missing	missing	■■■ ■■▌ ■■
- lack of skilled personnel	■ ■■ ■	■ ■ ■	■ ■■ ■■	(shaded) ■ ■■ ■■▌	■ ■■ ■■■	■■■ ■■▌ ■	■■■ ■■ ■■■■
- lack of information on technologies	(shaded) ■ ■■ ■	■ ■ ■	(shaded) ■ ■■ ■	(shaded) ■ ■■ ■■	■ ■ ■■▌	■ ■■ ■	■■ ■■ ■■
- lack of information on markets	(shaded) ■ ■■ ■	■ ■ ■■	■ ■■ ■■	(shaded) ■ ■■ ■■	■▌ ■ ■■■	■■ ■■ ■	(shaded) ■■■ ■■ ■■
- innovation costs hard to control	■▌ ■■ ■	■ ■ ■	■ ■■ ■▌	(shaded) ■ ■■ ■▌	■▌ ■■ ■■■■	■ ■■▌ ■■■	■■■ ■■ ■■
- resistance to change in the enterprise	■ ■■ ■	■ ■ ■	■ ■■ ■■	(shaded) ■ ■■ ■■	■ ■ ■■	■ ■ ■	■■ ■▌ ■■
- deficiencies in the availability of external technical services	■ ■■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■▌ ■■ ■■■	■ ■■ ■	■■■ ■■ ■
- lack of opportunities for techno-logical cooperation	■ ■▌ ■	■ ■ ■	■ ■ ■	■ ■ ■	■▌ ■ ■■■	■ ■■ ■■■■	■■■ ■■ ■
OTHER REASONS:							
- lack of technological opportunities	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■▌ ■■ ■■▌	■■ ■■■ ■	■■■ ■■ ■
- no need to innovate due to earlier innovations	(shaded) ■ ■▌ ■	■ ■ ■	■ ■ ■	■ ■ ■	missing	missing	■■ ■ ■
- innovation too easy to copy	■ ■■ ■	■ ■ ■■	■ ■ ■	■ ■ ■	■ ■■ ■■■▌	■ ■■▌ ■■■	■■ ■ ■
- legislation, norms, regulations standards, taxation	(shaded) ■ ■■ ■	■ ■ ■■	■ ■ ■	■ ■ ■	■ ■■■ ■■	■ ■■■ ■■■■	■■ ■▌ ■■■
- lack of customer responsiveness to new products and processes	■ ■■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■▌ ■ ■■■	■ ■■ ■■■	■■ ■■ ■
- uncertainty in timing of innovation	(shaded) ■ ■■■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■▌ ■ ■■■■	■ ■■ ■■■	■■ ■■ ■■■

Scale:

■	unimportant
■■	slightly important
■■■	moderately important
■■■■	very important
■■■■■	crucial

The first line of a cell shows the median that low performing firms assigned to a source of information, the second line shows the median for average performers, and the third line the values for high performers

Statistically significant differences between groups are shaded.

What can be said about innovation and the national aspects? It seems that economic factors are more important barriers in Italy and Ireland than in The Netherlands and

Germany. With respect to enterprise factors and other reasons conclusions are difficult to draw because of the above-mentioned item non-response problem. However, Italian firms rated those factors lower than German, Irish and Dutch enterprises (the latter as far as they have answered). At this point we should at least once refer to the psychological factor, which also applies to all the other ranking questions in the CIS questionnaire. It is likely that Italian, Dutch, German, and Irish respondents have a different conception of the ordinal scale, that for example Germans and Irishmen consider an identical problem more important than Italians. It may be that part of the country differences is the reflection of cross-cultural differences of perception. Concluding the discussion on data, which is to some degree deficient, it can be suggested that:

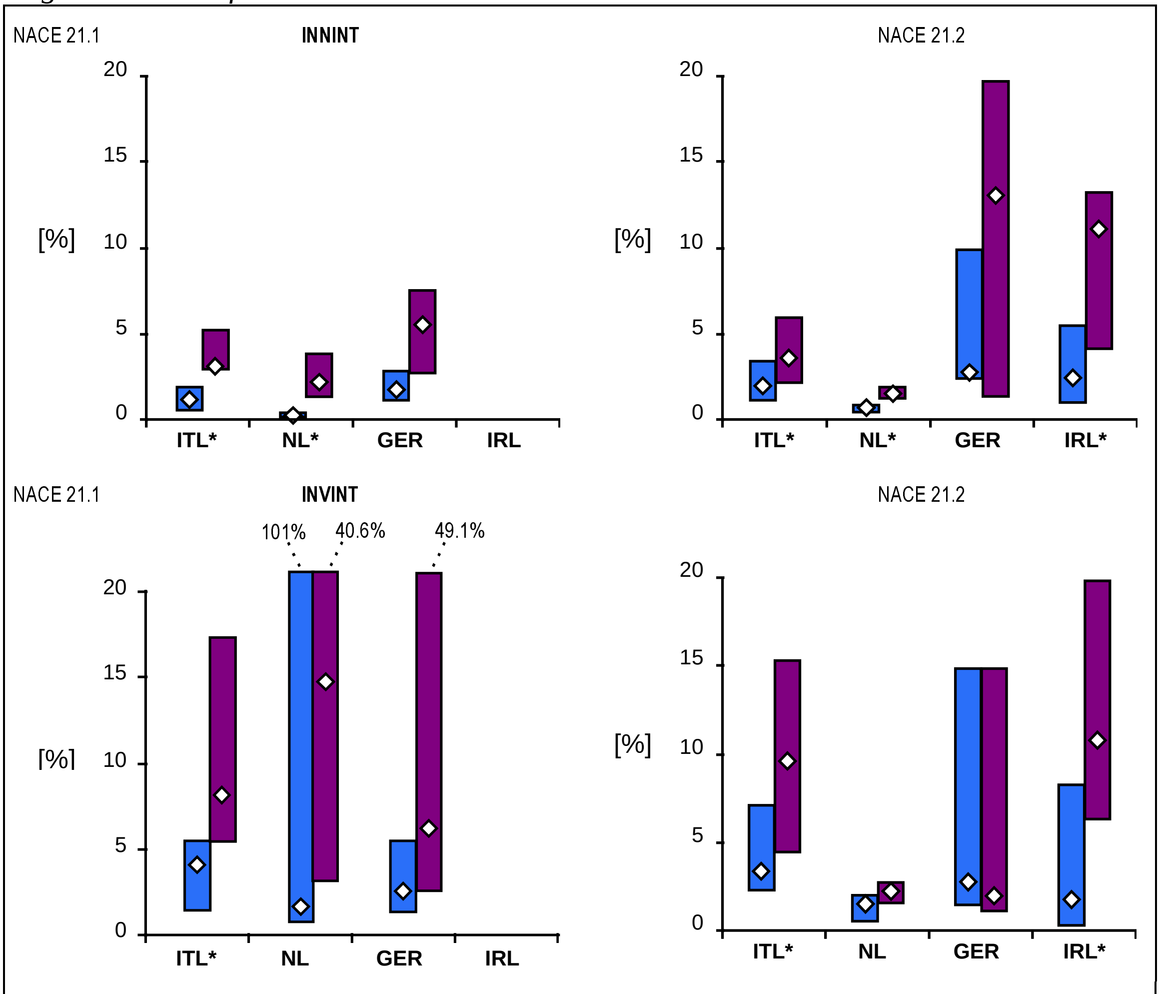
⇒ **there are no potential factors hampering innovation which seem particularly linked to innovation performance on the firm level across samples.**

⇒ **on the national level the data shows that Italian and Irish enterprises mention more distinctly than in the other countries the lack of appropriate sources of finance, excessive innovation costs and too long pay-off periods. Factors within the enterprise and other factors are considered less important as innovation hindrances in Italy than in Germany and Ireland.**

3.2.10 Costs of Innovation

The focus of this section is the relationship between innovation costs and innovation performance. The CIS database contains information on the total costs of innovation in 1992, the amount of capital investments linked to innovation projects, and the distribution of the innovation costs pertaining to characteristic activities. The former two are used as two of the four performance indicators, on which the highly innovative firms are defined as the overall top-25 per cent. Hence high performing enterprises in Figure 3.29 exhibit of course higher values than those with average innovation performance.

Figure 3.29: Performance indicators INNINT and INVINT



COUNTRY	Italy		The Netherlands		Germany		Ireland
NACE	*21.1*	*21.2*	*21.1*	*21.2*	*21.1*	*21.2*	*21.2*
Observations							
average performers	26	116	12	29	10 (13)+	9 (16)*	12
high performers	9	39	4	10	4	3	5

However on the country level one should note that the Dutch conversion sector exhibits very low values, compared to the others, whereas a considerable share of Dutch manufacturers invested heavily in innovation-related capital equipment.

+ 13 firms answered CHGPROD, INNINT, and INVINT; but only 10 firms answered PRDPORTF

* 16 firms answered CHGPROD, INNINT, and INVINT; but only 9 firms answered PRDPORTF

Figure 3.30: distribution of innovation costs according to characteristic activities - truncated boxplots

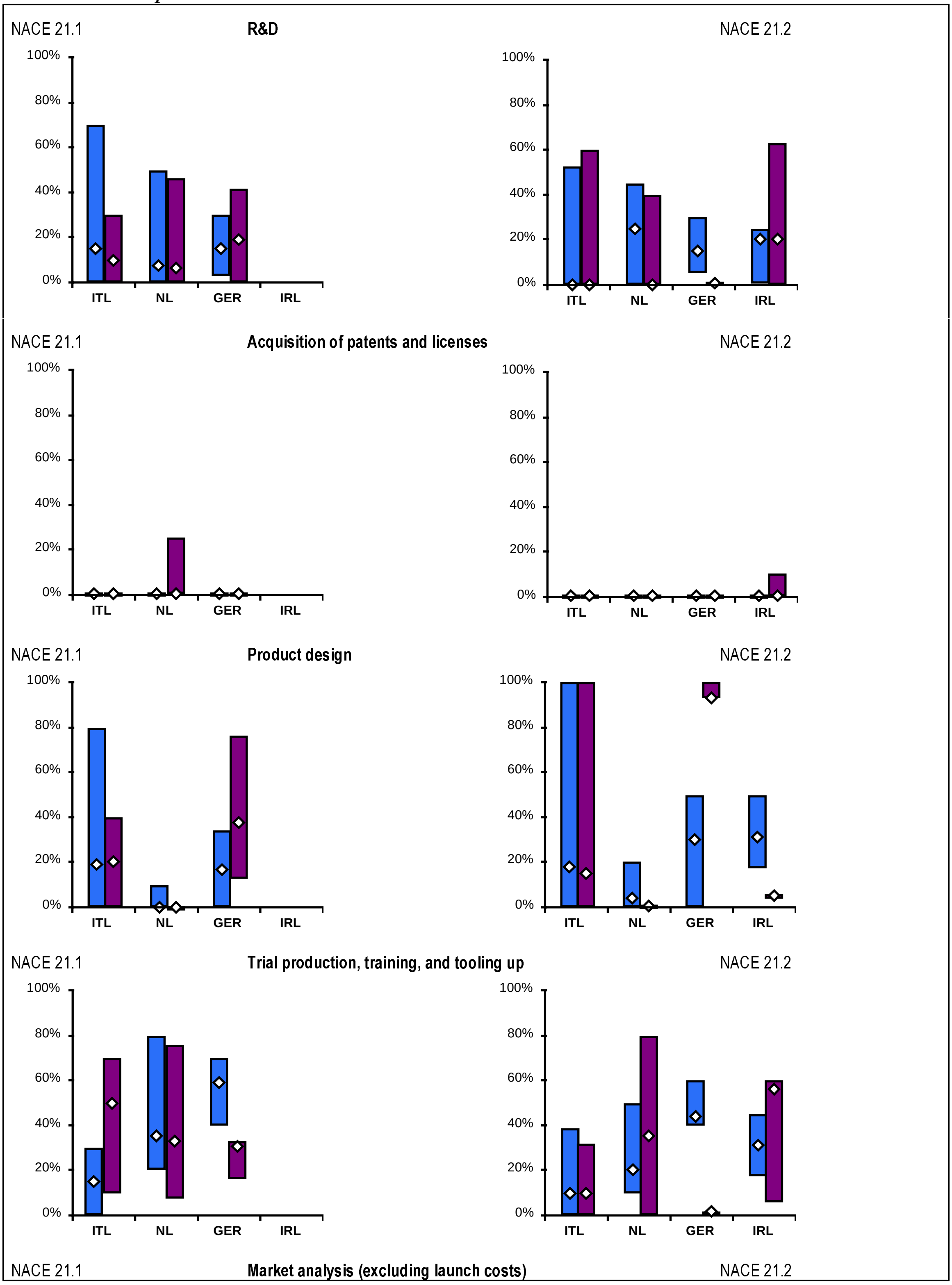
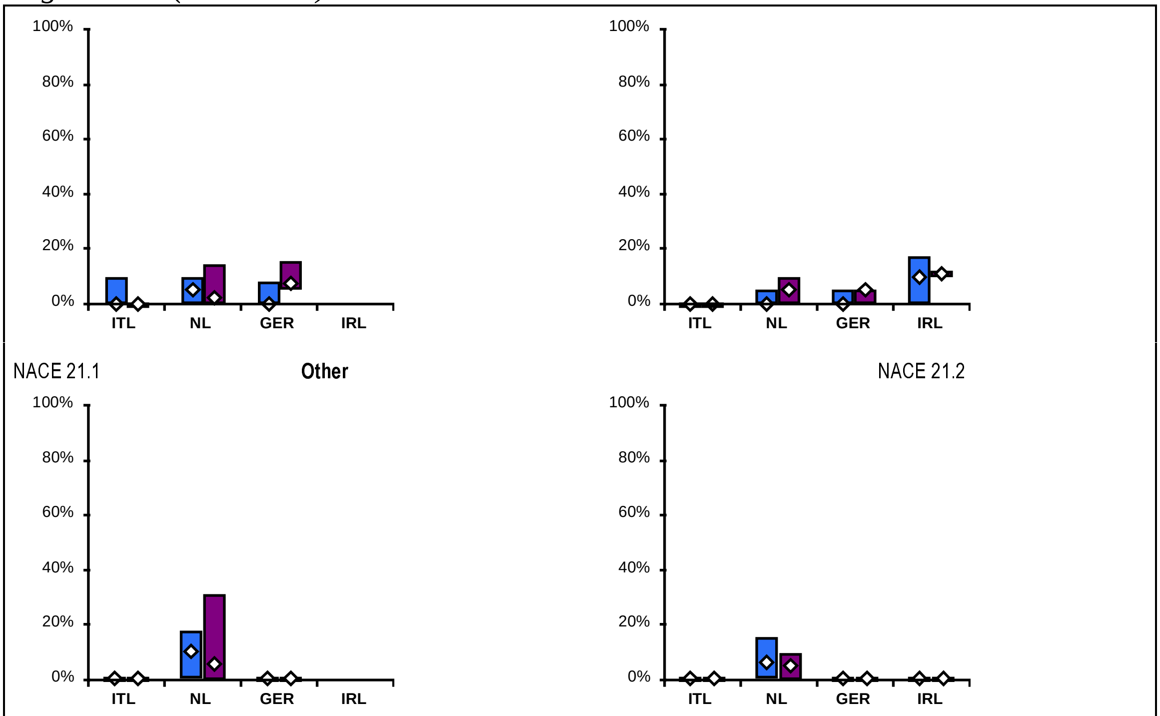


Figure 3.30 (Continued)



COUNTRY	Italy		The Netherlands		Germany		Ireland
NACE	*21.1*	*21.2*	*21.1*	*21.2*	*21.1*	*21.2*	*21.2*
Observations							
average performers	26	116	12	29	10 (13)	9 (16)	12
high performers	9	39	4	10	4	3	5

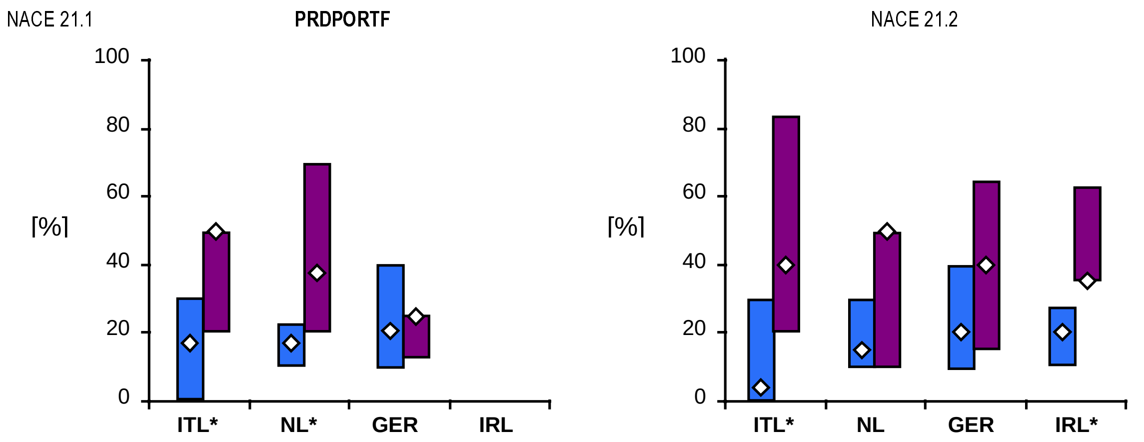
Figure 3.30 shows the distribution of the innovation costs according to characteristic activities. These innovation costs are implicitly contained in the performance indicator INNINT, which is defined as the innovation expenditures in relation to firm sales. Costs are mainly incurred with R&D, product design, and trial production and tooling up, whereas other cost factors play only marginal roles. A look at the relation between product design and trial production reveals that firms that enterprises either put the focus on product design or on trial production and tooling-up, which also make up the bulk of innovation costs. With respect to innovation performance there are no links of a kind which suggest that highly innovative enterprises spend relatively more on, for example, R&D or market analysis. Hence we can conclude:

⇒ **innovation performance is not linked to a particular distribution of innovation costs.**

3.2.11 Impact of Innovation

This chapter revolves around the impact of innovation activities, on the distribution of enterprise's sales of products in different phases of their lifecycle, on the degree of change, and on the degree of newness of products. Part of the variables have been used in performance indicators so that differences between enterprises with average and high innovation performance are involved. Figure 3.32 shows the distribution of the enterprises' sales of their products at different stages in their lifecycle. The sum of first two variables, the share of sales derived from products in the introductory phase and growth phase, constitutes the innovation indicator 'product portfolio' (PRDPORTF) which is presented extra in Figure 3.31. On the sectoral and national level it shows that the Italian paper manufacturers with high innovation performance have the highest share of introductory products, whereas average performing paper manufacturers in all three countries have almost 20% of their sales originating from those products. Together with Dutch high performing converters Italian high performing score the highest in this sector. On the other side, half of the average performing enterprises in the Italian conversion sector have virtually no sales generated with products in the introductory or growth phase.

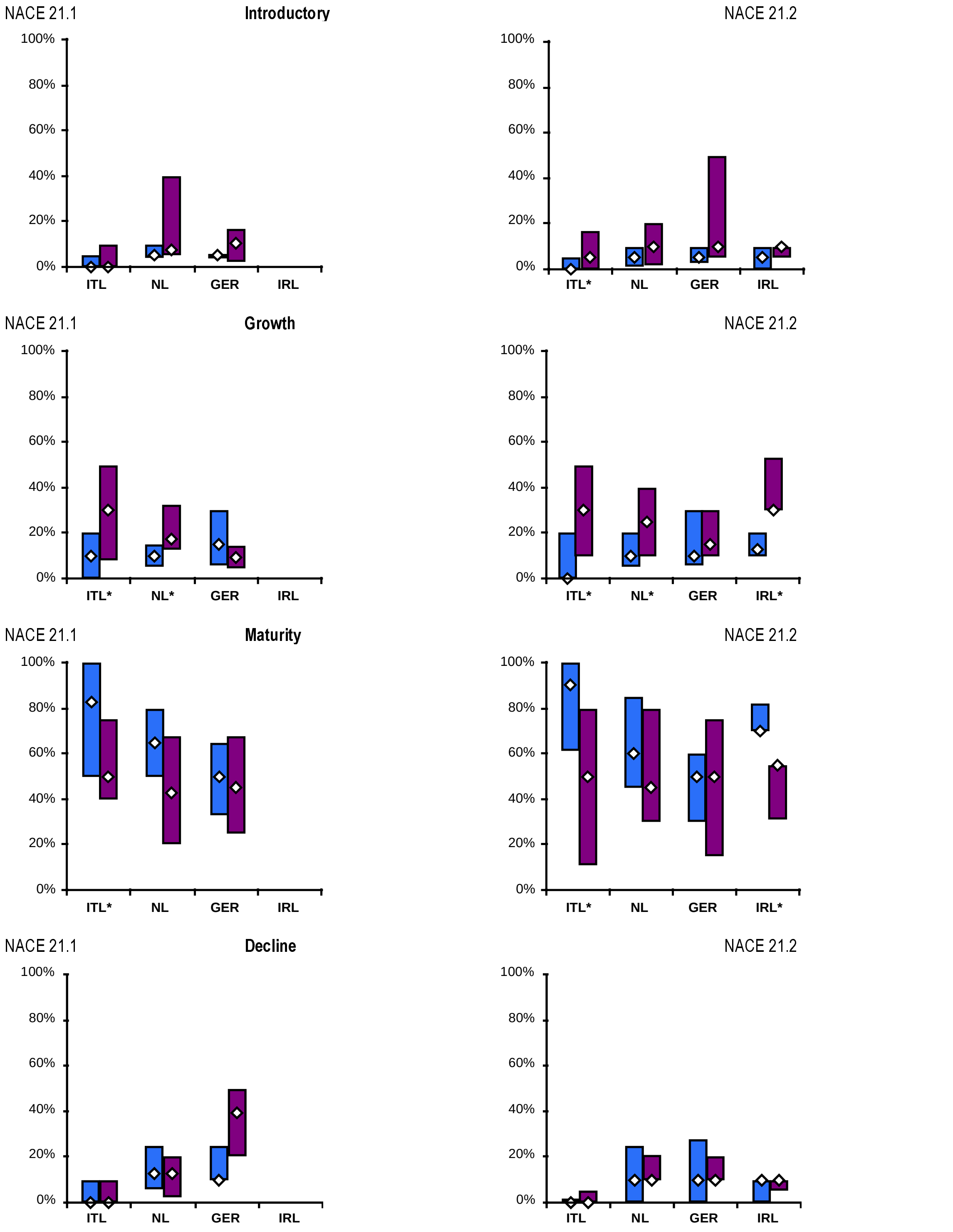
Figure 3.31: indicator sales of products in the introductory or growth phase in their lifecycle.



COUNTRY	**Italy**		**The Netherlands**		**Germany**		**Ireland**
NACE	*21.1*	*21.2*	*21.1*	*21.2*	*21.1*	*21.2*	*21.2*
Observations							
average performers	26	116	12	29	10 (13)	9 (16)	12
high performers	9	39	4	10	4	3	5

But, as Figure 3.32 indicates, those Italian enterprises also have no decline products in their portfolio whereas Dutch and particularly German enterprises have a significant share thereof.

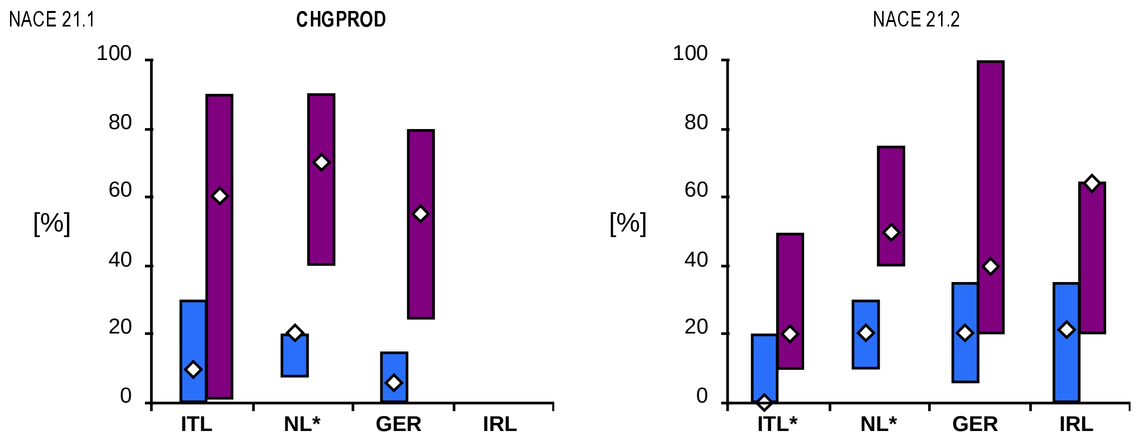
Figure 3.32: Distribution of the enterprise's sales of its products at the different stages of the product lifecycle in 1992



COUNTRY	Italy		The Netherlands		Germany		Ireland
NACE	*21.1*	*21.2*	*21.1*	*21.2*	*21.1*	*21.2*	*21.2*
Observations							
average performers	26	116	12	29	10 (13)	9 (16)	12
high performers	9	39	4	10	4	3	5

Figure 3.34 and Figure 3.35 display the enterprises’ sales of products according to the degree of change, both related to the total sales and to the export sales in 1992. The sum of the variables referring to ‘incremental change’ and ‘radical change’ in Figure 3.34 was used as performance indicator ‘changed products’ CHGPROD.

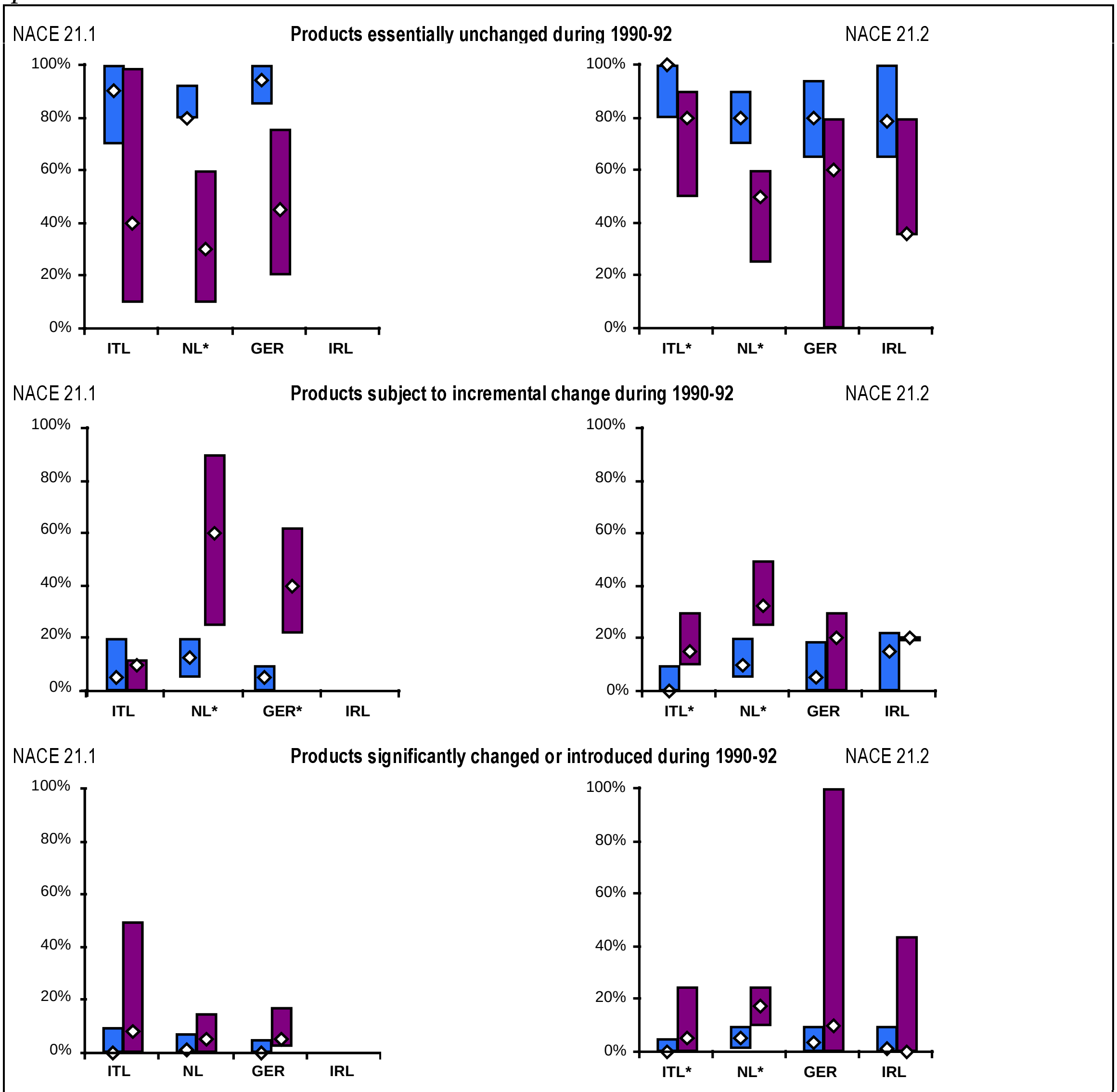
Figure 3.33: performance indicator changed products



COUNTRY	**Italy**		**The Netherlands**		**Germany**		**Ireland**
NACE	*21.1*	*21.2*	*21.1*	*21.2*	*21.1*	*21.2*	*21.2*
Observations							
average performers	26	116	12	29	13	16	12
high performers	9	39	4	10	4	3	5

Figure 3.33 shows that Dutch German, and Irish converters with average innovation performance have some 20 per cent of changed products in their sales. Although this percentage resembles very much the threshold found for indicator PRDPORTF there is no strong correlation between those two indicators except for Irish converters (Spearman’s correlation coefficient 0.7712, significance 99.99%). It also shows that the differences between high performing paper manufacturers and average performers in this sector is more marked than in the conversion sector, a fact which might be explained by lower product variety in the paper manufacturing sector. Figure 3.34 shows that the bulk of innovation aims at incremental improvements. Italian high performing manufacturers, Dutch and German high performing converters, however, show also significant shares of radically changed or newly introduced products.

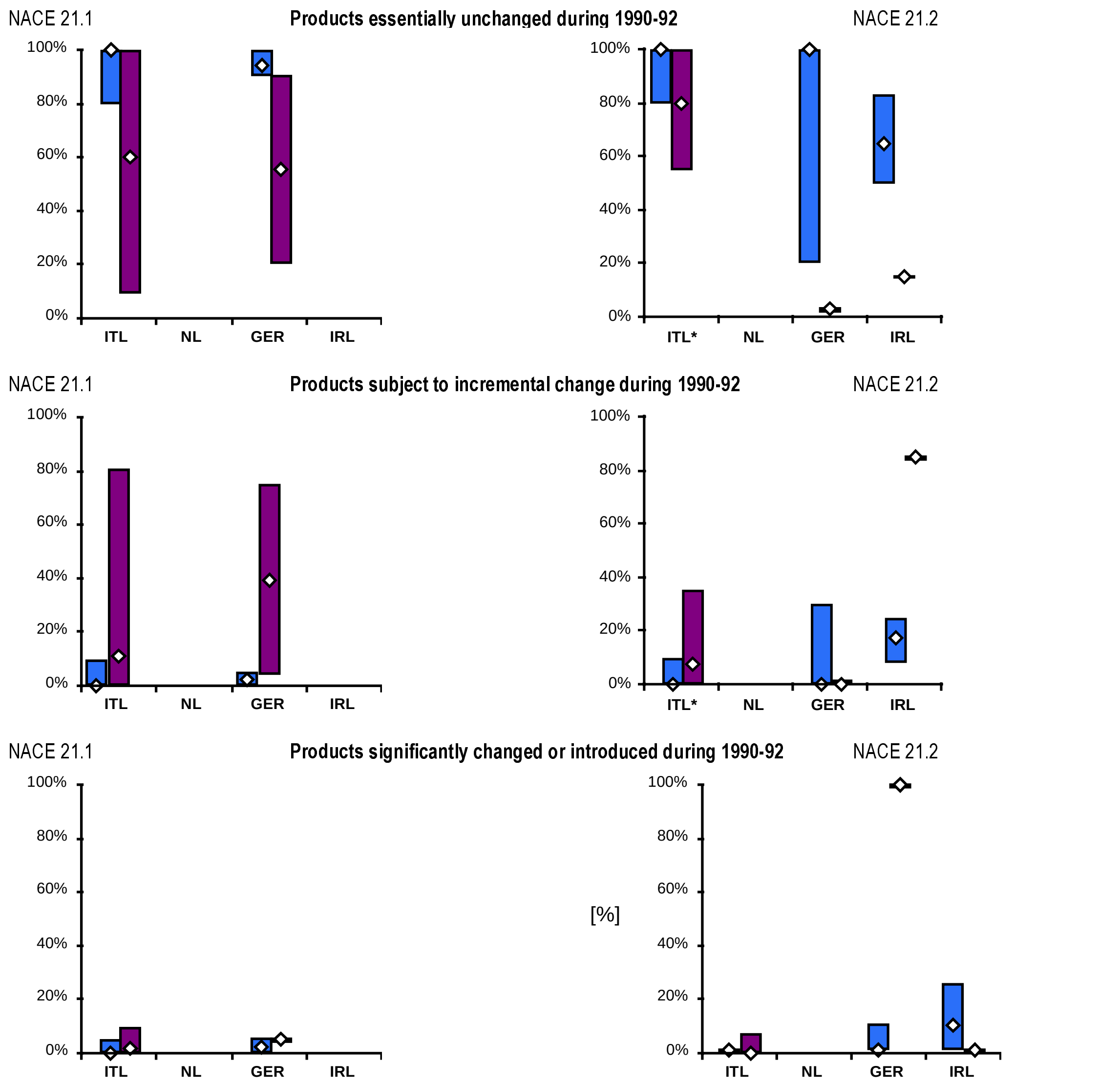
Figure 3.34: Distribution of the enterprise's total sales across different types of products



COUNTRY	Italy		The Netherlands		Germany		Ireland
NACE	*21.1*	*21.2*	*21.1*	*21.2*	*21.1*	*21.2*	*21.2*
Observations							
average performers	26	116	12	29	10 (13)	16	12
high performers	9	39	4	10	4	3	5

The shape of the truncated boxplots in Figure 3.35 indicates that the distribution of export sales resembles very much that of the total sales. Correlation analysis confirms this hypothesis, for all samples at least medium correlation that could be computed.

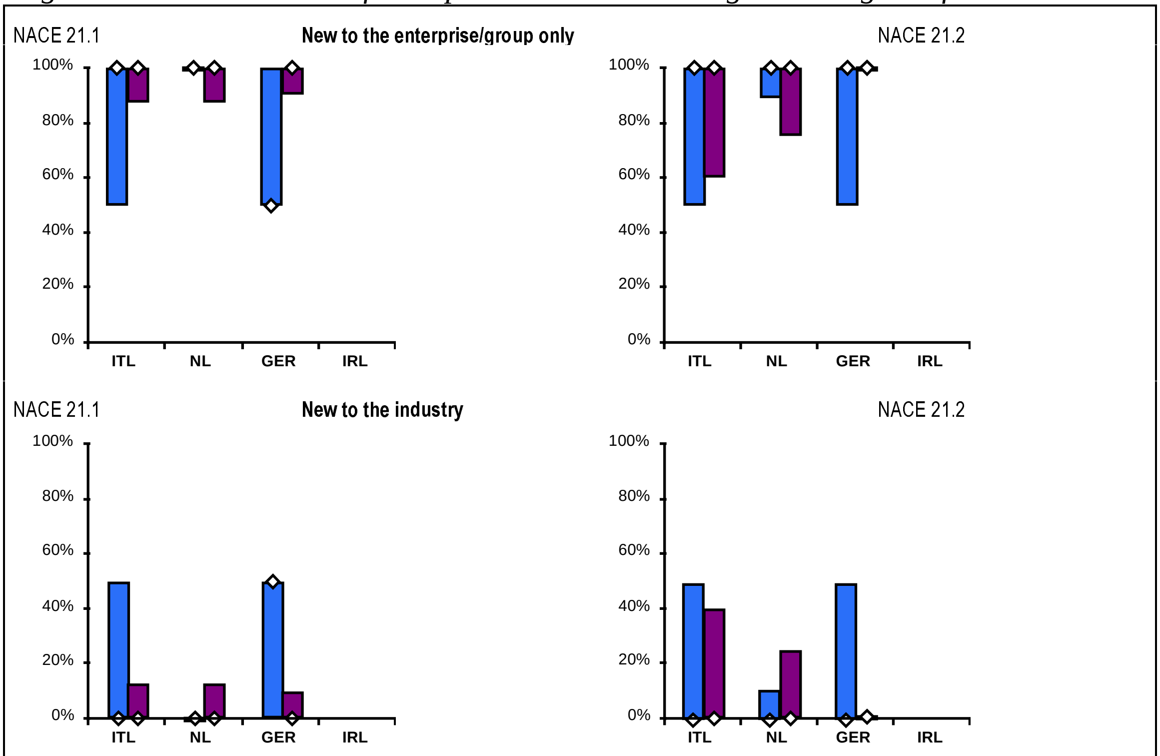
Figure 3.35: Distribution of enterprise's export sales across different types of products



COUNTRY	Italy		The Netherlands		Germany		Ireland
NACE	*21.1*	*21.2*	*21.1*	*21.2*	*21.1*	*21.2*	*21.2*
Observations							
average performers	21 (26)	91 (116)	0 (12)	0 (29)	10 (13)	7 (16)	6 (12)
high performers	6 (9)	28 (39)	0 (4)	0 (10)	2 (4)	1 (3)	1 (5)

Last but not least Figure 3.36 gives a hint at the relation between invention, innovation and innovation performance. Data for Ireland is not available so that this country is missing. The data shows clearly that, apart from Dutch high performers, highly innovative enterprises are not the inventors in the industry. On the other hand, both Dutch sectors have less changed products than Italy and Germany.

Figure 3.36: Distribution of enterprise's sales according to the degree of newness.



COUNTRY	Italy		The Netherlands		Germany		Ireland
NACE	*21.1*	*21.2*	*21.1*	*21.2*	*21.1*	*21.2*	*21.2*
Observations							
average performers	26	116	12	29	10 (13)	9 (16)	12
high performers	9	39	4	10	4	3	5

In summary of the discussion in this chapter we can state the following:

- ⇒ **the majority of enterprises in the pulp and paper sector make some 20 per cent of sales with products in the introductory or growth phase of their lifecycle.**
- ⇒ **innovation in the pulp and paper industry is largely incremental.**
- ⇒ **enterprises with high innovation performance according to the heuristic approach of this study are not the inventors in the pulp and paper industry.**

3.3 Summary

In this study the innovation performance of enterprises in the CIS database were analysed. Enterprises that ranked among the top 25% on the average of four innovation indicators were considered highly innovative, enterprises with no innovation activity during 1990-1992 as uninnovative, and the remainder as enterprises with average innovation performance. The four indicators were ”share of changed products”, ”intensity of innovation expenditures”, ”intensity of innovative investment”, and ”share of products in the introductory and growth phase of their lifecycle”. Due to structural differences between countries and between the manufacture of pulp, paper and board and conversion of paper and board, innovation performance was determined separately for each industry sub-class and country. Moreover the analysis had to be confined to data from Italy, The Netherlands, Germany, and Ireland. Other potential samples could not be analysed because of high item non-response, insufficient sample size or missing distinctions between the sub-classes. The chosen approach revealed the following differences between enterprises with high and average innovation performance:

- both small and larger enterprises in the pulp and paper industry can be very innovative according to the definition used in this study but smaller enterprises are not so likely to pursue innovation projects with high technological complexity.
- large enterprises are more frequently innovative than smaller ones.
- innovation performance and firm status are, generally speaking, not linked with each other. The ownership status is rather determined by factors resting with the country and by firm size.
- the CIS-database does not provide evidence that enterprises with owners from particular countries are more or less innovative than others.
- highly innovative firms tend to yield lower sales per employee which might, in some cases, be caused by production halts due to machine set-ups and trial production.
- on the firm level there is no evidence that high innovation performance is linked with high growth rates in a two years period. However one should expect that innovation performance and growth are positively related on the longer run.
- innovation performance and export activity are unrelated on the enterprise level. Export activity rather depends on the country, firm size and firm status.
- high performing enterprises in four out of seven samples tended to rank the following sources of information for innovation higher: internal sources within the group of enterprises, suppliers of equipment, and competitive

intelligence. Fairs and exhibitions, on the other hand, were ranked lower by high performing enterprises in four out of seven samples.

- in four of the seven samples high performing enterprises exhibit higher median values for the creation of new national markets than average performers.

- the improvement of production flexibility is considered more important among high performing enterprises from The Netherlands, Ireland, and Germany whereas Italian enterprises and German converters consider this objective unanimously as very important.

- high performing enterprises mentioned more frequently that they used R&D contracted out and consultants to acquire technology.

- high performing enterprises in the conversion sector mentioned more frequently that they acquired technology through the purchase of equipment.

- high performing enterprises transfer more technology through ”hardware” than enterprises with average innovation performance.

- innovation performance is not linked to particular preferences for certain methods used to protect the competitive advantage of product or process innovation.

- about half of the enterprises achieved high innovation performance according to the definition of this study without internal R&D activity. Other studies on technology strategy in the sector suggest that these firms are unlikely to be industry leaders and unlikely to operate in market segments characterised by sophisticated technology.

- those enterprises that perform R&D exhibit higher R&D expenditures if they are highly innovative. Correlation analysis shows that R&D expenditures are linked with the level of expenditures related to innovation.

- enterprises with high innovation performance spend less on extramural services, which suggests that R&D in these enterprises is of the applied, competitive type.

- there are no potential factors hampering innovation which seem particularly linked to innovation performance on the firm level across samples.

- innovation performance is not linked to a particular distribution of innovation costs

Those findings seem compatible with existing knowledge on innovation in the pulp and paper industry. However, the majority of the above differences are not statistically significant and hence have to be treated with care . The basis for the analysis was quite narrow: The Dutch and the German sample of manufacturers of pulp and paper were very small as were the German and Irish sample of converters of paper and board. On the other hand, the big samples from France and Spain had be left out because indicators and, in the Spanish case additionally NACE three-digit classifications were missing. Moreover the question should be raised whether the four innovation indicators are not too crude to identify innovation performance. In particular it would have been valuable to include the growth of sales as a further indicator, but such data was not available for all countries. In order to avoid impediments of the analysis due to item non response in future studies, Eurostat should consider how the quality of the data can be improved with respect to homogeneity (that all questions are asked in all countries) and properly filled out questionnaires. With respect to data on the enterprise’s sales it must also be pointed out that a two years period is too short term in the pulp and paper industry to determine whether a trend is characteristic or just an exception caused by particular circumstances. From the analytical viewpoint it would definitely be more valuable if future surveys could ask for the development of the enterprise's sales over longer periods of time, e.g. four figures covering a time span of six years.

The analysis of innovation performance has also shown that the groups of enterprises with high, average, and low innovation performance exhibit a high degree of variation. The underlying reason for this must be sought in the internal diversity of the industry, reflecting different market characteristics of segments, firm strategies, resources, and on a broader level, factors rooted in the national innovation system. Innovation performance might explain fairly little of this variation; as we suggested above, factors such as firm size or firm status may have a primary role in explaining the variation in the data. However, within the goals and the scope of this study it is not possible to explore systematically how much of the variation can be explained through independent variables such as firm size, firm status, country, sector, and export activity and R&D. Nevertheless it could be put on the agenda for future research. Ideally one could thus create a taxonomy of firms within this and other industries so that groups of enterprises with rather homogenous characteristics can be identified. Such knowledge would certainly make a significant contribution to providing an adequate basis for effective industrial policy in this sector.

Innovation performance of enterprises also depends on the national environment in which they are embedded. Within the scope of this study such factors could not be analysed in depth. Nevertheless the analysis showed some interesting differences between nations that are related to the performance of the national systems of innovation. Eurostat time series on the development of the aggregated sectoral sales of EU countries between 1985 and 1992 shows that the Dutch paper manufacturing sector and the Italian conversion sector generated high growth rates in EU Europe from the mid 1980s whereas the Italian paper manufacturing sector exhibits the slowest growth rate between 1985 and 1992. Moreover the same source confirms apparent differences in the CIS database between countries with respect to labour productivity. German converters of paper and board exhibit significantly lower labour productivity than one could expect. Since Germany is a high wage country and, in the light of its overall economic performance, assumed to be among the leading countries this result is surprising. The reasons remain unclear and would need follow-up research. A look at the ownership structure of the Dutch enterprises in the CIS database suggests that the Netherlands exercises a particular attractiveness for foreign investments in the pulp and paper sector. The CIS database also revealed interesting differences with respect to the use of sources of information for information: Firstly, Italian enterprises are the most inward oriented, measured by the weight that they give to categories of sources of information. Secondly, Dutch and Irish enterprises rank educational resources higher than in other countries. This raises the question whether Italian enterprises operate in fact in an environment that is less supporting for the industry than in other countries. In this context it is worthwhile noting that German enterprises, which are located in the most industrialised European country, use the most channels for the acquisition of technology. On the other hand one could expect that potential disadvantages of supporting factors would be reflected in answers concerning obstacles to innovation. But this is not the case. Together with Irish enterprises, Italian enterprises report more than German or Dutch enterprises that they suffer from a lack of appropriate sources of finance, excessive innovation costs and too long pay-off periods. It seems interesting from the policy point of view to investigate such national aspects more in depth. Future research on the pulp and paper industry should definitely put more emphasis on these national aspects.

We believe that the analytical work undertaken here with the CIS Pilot Data has been worthwhile. In spite of some shortcomings, the analysis of innovation based on comprehensive empirical data has a high potential for enhancing significantly our understanding of innovation in industries, a prerequisite for maintaining and enhancing Europe’s ability to withstand intensifying competition from other regions of the world. The value of this study must rather be viewed as the collection of first experiences with such empirical data, pointing not only to specific results but to the scope for future improvements.

4 Conclusions and Policy Issues

4.1 Main Findings

The principal finding of this study is the industry's extensive focus on external knowledge sources in the innovative process. This is indicated via a number of the indicators studied in this report.

Firstly, pulp, paper and paper products have a higher investment intensity (gross fixed capital formation as a percentage of value added) than other industries. This finding is quite robust and it is reflected in the OECD STAN database time series from 1985, 1987, 1989 and 1991.

Secondly, in accordance with the above finding, the pulp, paper and paper products firms rank 'suppliers of materials' and 'suppliers of equipment' as one of their most important information sources in their innovation process. Moreover, high performing enterprises tended to rank 'suppliers of equipment' higher than low performing enterprises. Furthermore, pulp, paper and paper product firms in general rank these information sources as more important than other industries.

Thirdly, when it comes to co-operation in R&D, suppliers are ranked as the most important partner. The CIS data shows that more than 30% of the R&D co-operations in pulp, paper and paper products are undertaken together with suppliers. It was found that high performing enterprises utilised, more extensively than low performing firms, R&D contracted out. We should note that it was not only suppliers participating in this co-operative process: specialised consultants also play an important role - pulp, paper and paper products plants are highly systemic and multi technological in character, and consulting firms and consultants may be the only actors who have a thorough understanding of the system as a whole. Furthermore, on the downstream end of the product scale we see that clients and customers are ranked as very important sources of information and indeed do spur innovation. About 40% of the pulp, paper and paper products firms reported clients and customers to be very important information sources with respect to innovation and new products

The data gives clear indications that knowledge found in the external environment of the firm, for instance via suppliers of materials, and knowledge within the pulp, paper and paper products firms themselves, are complementary: High-performing enterprises rank suppliers as more important than low performing enterprises and at the same time, high performers rank internal R&D as more important than low performing enterprises. This indicates that enterprises which invest more in internal competence building also are more capable of absorbing knowledge external to the firm. This supports the general view, expressed by various analysts of innovation and technical change, that 'R&D efforts and internal competence building not only generate new information and new knowledge, also it enhances the firms ability to assimilate and exploit existing information'.[137]

Taken together these indicators show that the pulp, paper and paper products firms acquire new products and processes on the basis of close co-operation with external agents, the most essential being suppliers of equipment and materials. This is however not a costless acquisition of new technology deriving purely from the knowledge of suppliers; rather new technologies are acquired in a cumulative process where the user and the producer work in close-knit interactions within an interactive learning environment.

4.2 Policy Issues

The above findings indicate extensive user-producer interactions in the pulp, paper and paper products sector. By implication, a large part of innovation, learning and competence building takes place in the interface between the firm and its external environment. Although this trend is particularly explicit within pulp, paper and paper products, several authors of technical change and innovation underline this point as one of the most important characteristics of modern economies:

> In an economy characterised by vertical division of labour and by ubiquitous innovative activities, a substantial part of all innovative activities will be addressed towards users, outside the innovating units. In such an economy successful innovations must be based upon knowledge about the needs of potential users, and this knowledge is as important as knowledge about new technical opportunities.[138]

There are several policy issues stemming from the approach and results developed above. A key issue is that attention should be drawn to the importance not only of knowledge production in the traditional sense, but perhaps more importantly, to mechanisms and institutions for knowledge distribution. After all, the universe of knowledge external to the firm is always larger than that found within a single firm.

Firstly, to develop and improve knowledge distribution capabilities it is necessary to establish effective information channels within the enterprise, with a focus on the links between different elements of the organisation participating in the innovation process. But at the same time it is necessary to establish channels of knowledge flow from within the enterprise to the outside world. Public policy might have an important role in this respect, in setting up and/or supporting an infrastructure favourable to communication and information sharing. This might occur for example by sponsoring conferences, fairs, exhibitions, marketing activities, R&D co-operations etc. Public policy may also play a role in facilitating consultancy to firms, by supporting organisations and mechanisms promoting higher rates of knowledge distribution.

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[137] See also Wesley M. Cohen and Daniel A. Levithal, 1989, Innovation and learning: The two faces of R&D, *The Economic Journal*, September 1989

[138] C. Freeman, 1982, The *Economics of industrial innovation*, London, Frances Printer

Secondly, coming from the user-producer approach, there is the importance of competence among users and producers. [139] Lack of technological or economic competence in either part of the interactive links will hamper innovation capability. Public policy is therefore essential in the process of stimulating both competent supply and competent demand. In fact, a large part of the firms in CIS mention this point: ‘Lack of customer responsiveness’ is ranked as an important obstacle to innovation.

Public policy, via regulation, standards setting and knowledge creation, is widely recognised as a central component of environmental issues at the present time. These are particularly important in this sector, and policy has a major role to play in the development of environmentally sustainable technologies.

Finally, in periods of radical innovations and shifts in technological paradigms, there is a need for transformation of the existing network of user-producer relationships.[140] The existing networks might be closely tied to existing interest groups, existing methods and technologies, and might be particularly difficult and costly to alter. Public policy in this context is likely to play an important role within the transformation process by playing a ‘catalytic’ role in the renewal of interactive relationships and the establishment of new relationships. Environmental technologies are such an area of radical change at the present time.

[139] B. Å. Lundvall: Innovation as an interactive process: from user-producer interaction to the national system of innovation, in G. Dosi (editor), 1988, *Technical Change and Economic Theory*, Pinter Publishers

[140] ibid.

Appendix A : Innovation objectives

This section explores which factors are primary or important objectives for the innovating firm. The firms were asked to rank 18 factors on a scale from 1(insignificant) to 5 (crucial). In the following we have transformed these numbers to a binary scale. Objectives that were rated from 1 - 3 were given the value '0' (unimportant), and objectives that were rated 4 or 5 were given the value '1' (important). Hence we were able to calculate the share of firms within a certain group, that ranked a certain objective as important. In additions we have performed statistical tests, testing whether differences between groups are statistically significant. Due to few observations and skewed distributions, we have utilised a distribution free test, the Wilcoxon test. This test is described in more detail in Sec.(2.1.1).

The data shows that 'improving product quality' is the main objective of firms in innovation. About 80% of the *pulp, paper and paper products* firms rank this objective as very important. This objective is consistently ranked higher in this industry than in other industries. 'Increasing and maintaining market share' is also recorded as an important objective of innovation. The firms rank the national market as the most important and the EU market as the second most important. Creating new markets in USA, Japan and other countries is considered important by only about 5% of the firms. Furthermore it is seen that 'decreasing environmental damage' is recorded consistently more important in *pulp, paper and paper products* than in other industries. The path dependency of firms is also quite clearly seen from the data: 'Extending product range outside main field' is seen as considerably less important than 'extending product range within main field'. The importance paid to the last objective is about half of that paid to the first.

Figures A.5-A.15 give an overview of the country specific data. We seek to show differences between the pulp and paper industry, and other industries as a whole. In these figures we have calculated i) a weighted average for the pulp and paper industry as a whole, ii) a simple average for the pulp and paper industry as a whole iii) and a simple average for the each country. The weighted average is calculated at a cross national level utilising the simple average for each country weighted by the total number of firms in that country. We did not have access to the population of firms *by firm size*, hence we did not discriminate on firm size in the following analysis.

Figure A.1: Innovation objectives by industrial category

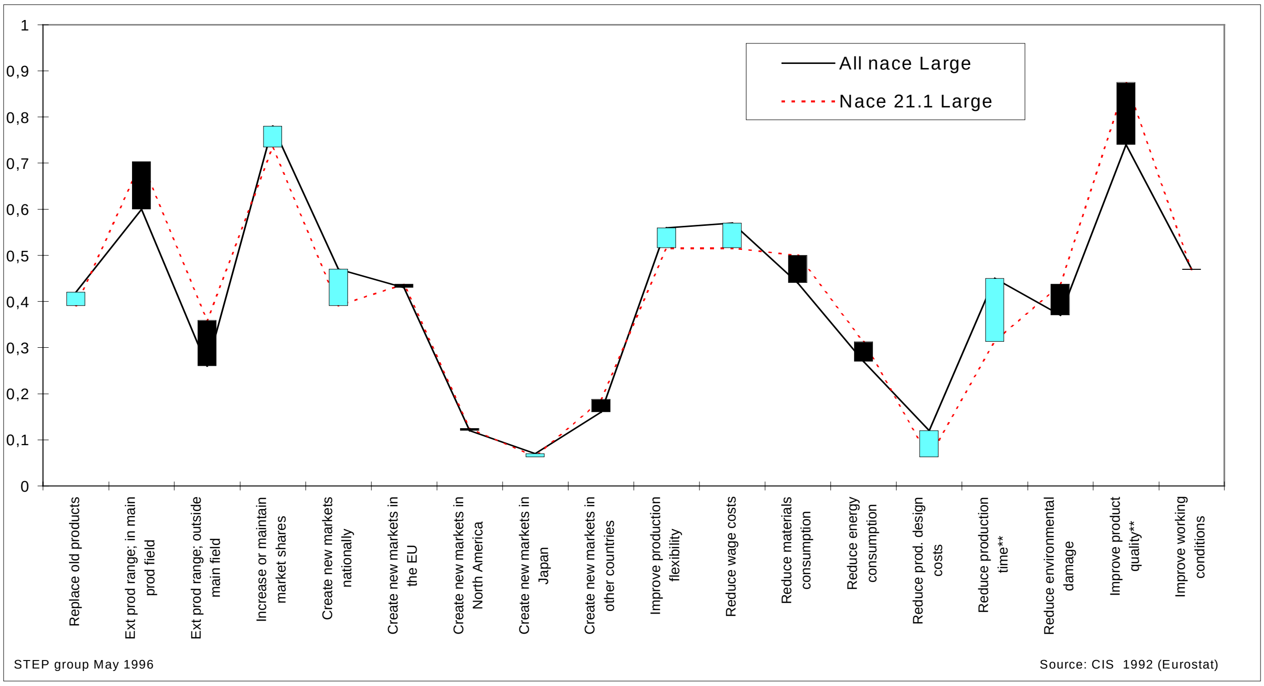


Figure A.2: Innovation objectives by and industrial category

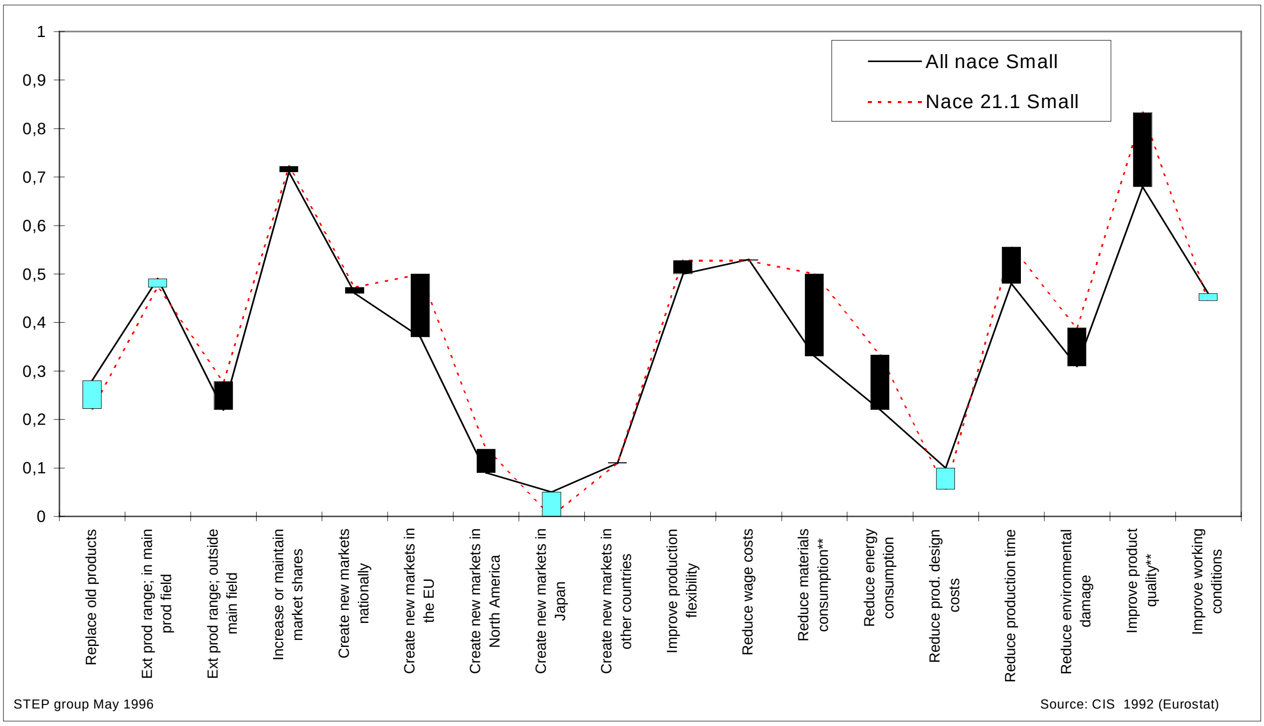


Figure A.3: Innovation objectives by and industrial category

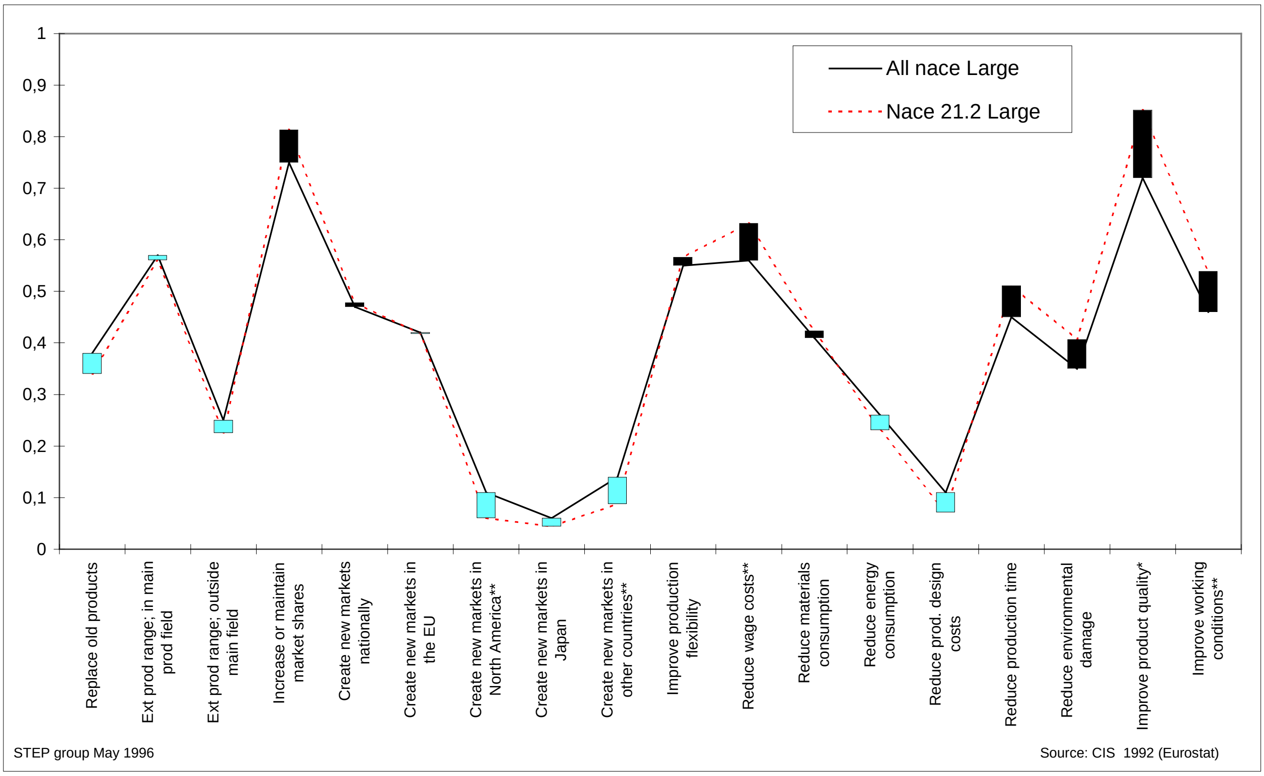
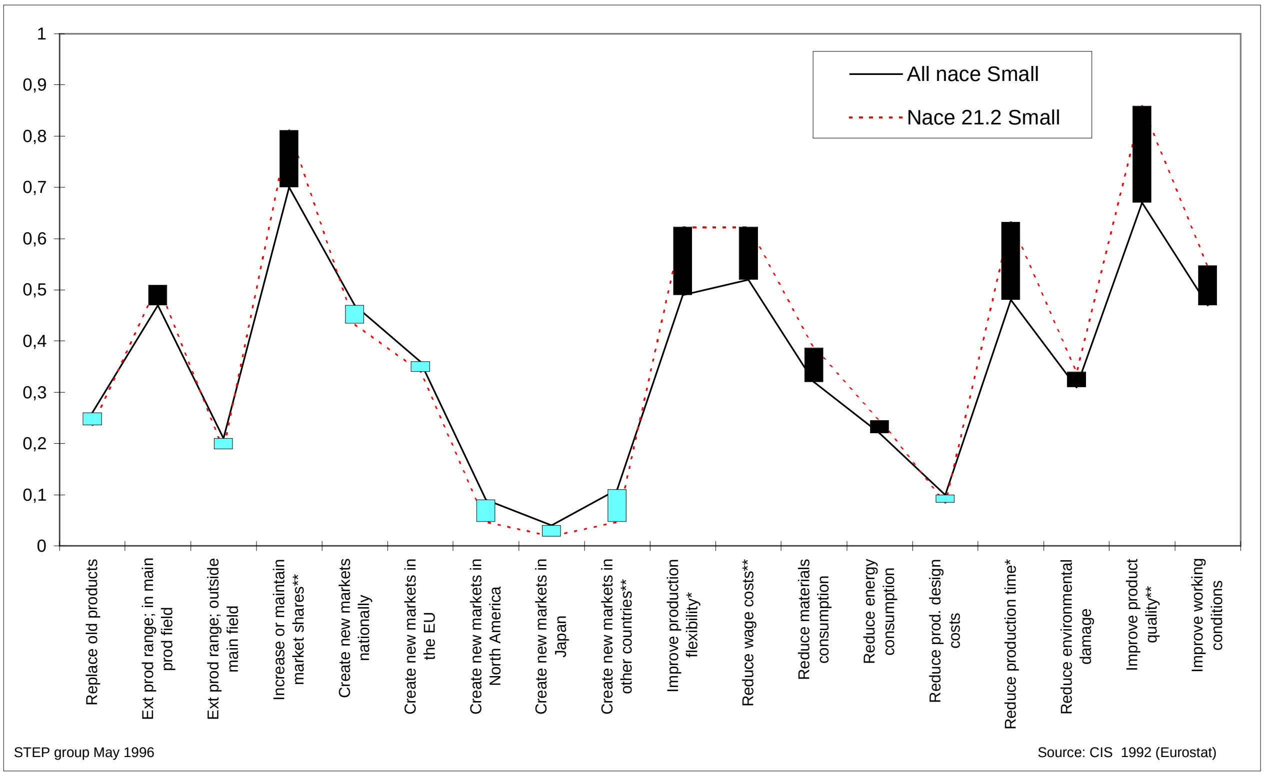


Figure A.4: Innovation objectives by and industrial category



NACE 21.1

Figure A.5: Innovation objectives by country and industrial category

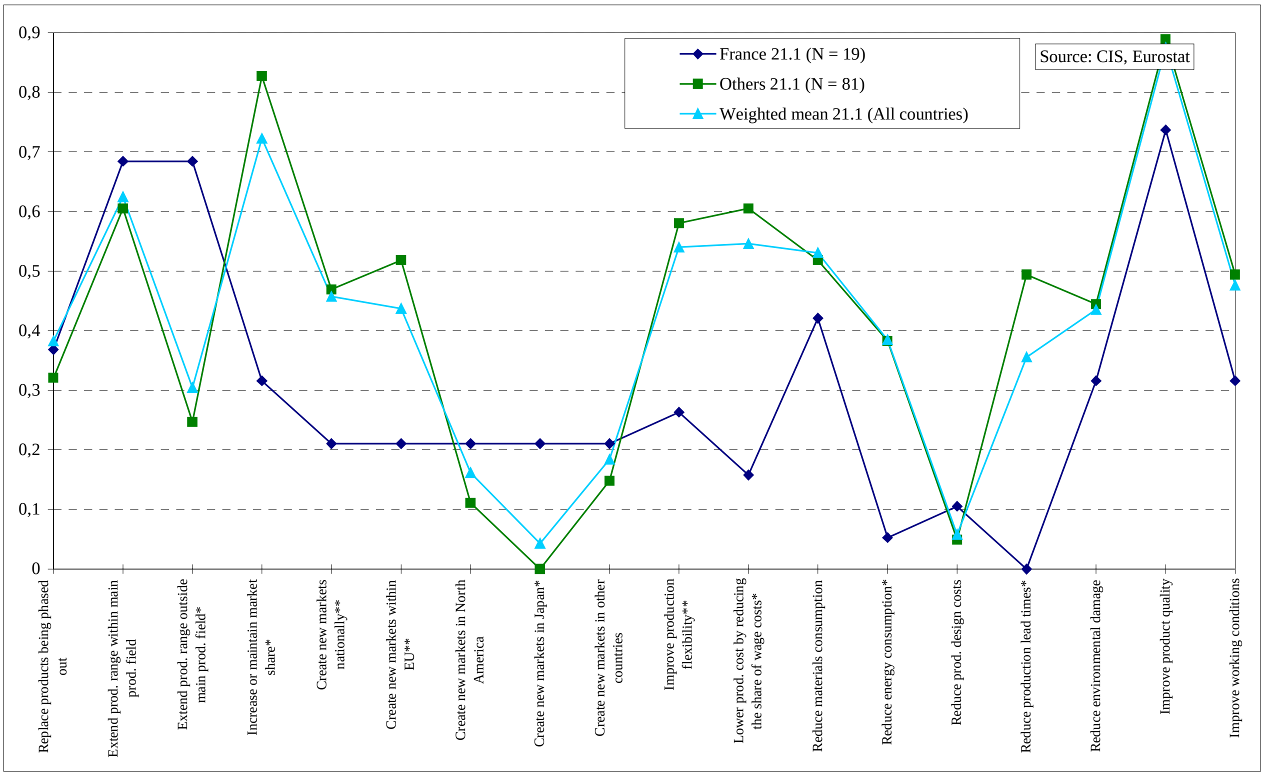


Figure A.6: Innovation objectives by country and industrial category

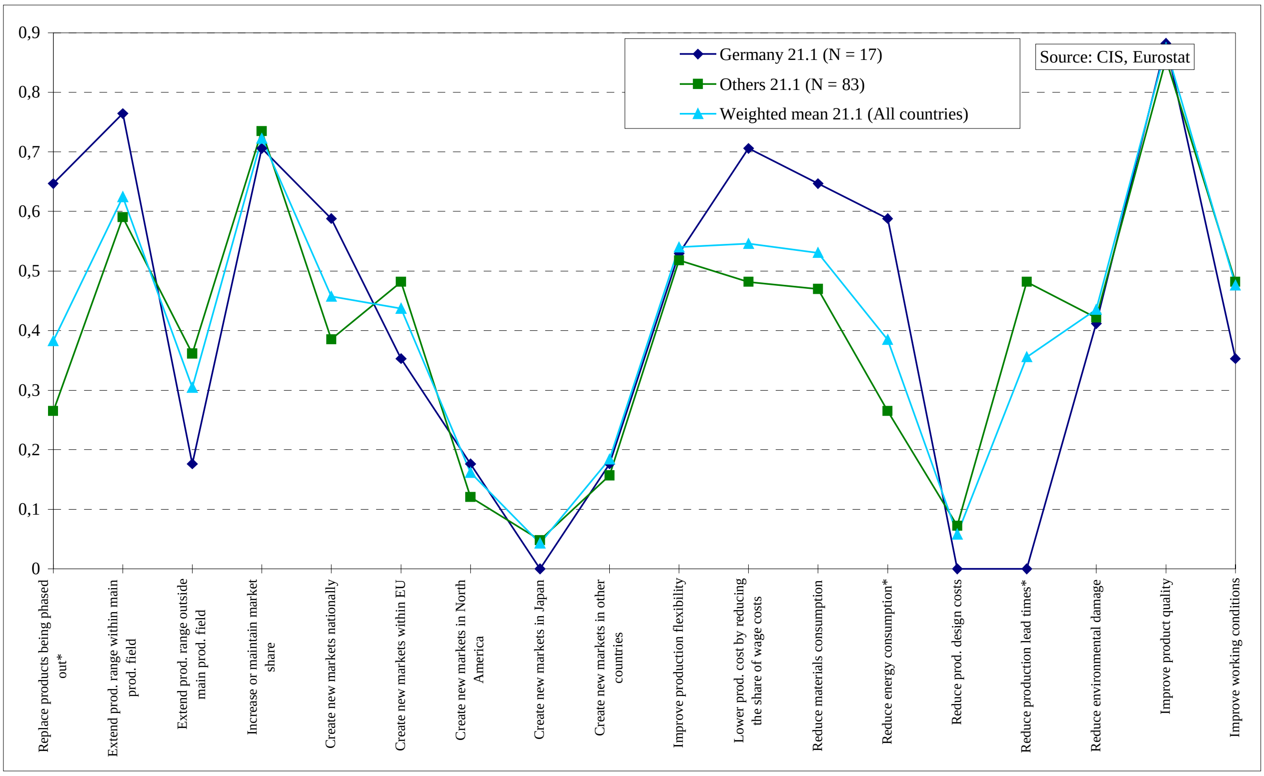


Figure A.7: Innovation objectives by country and industrial category

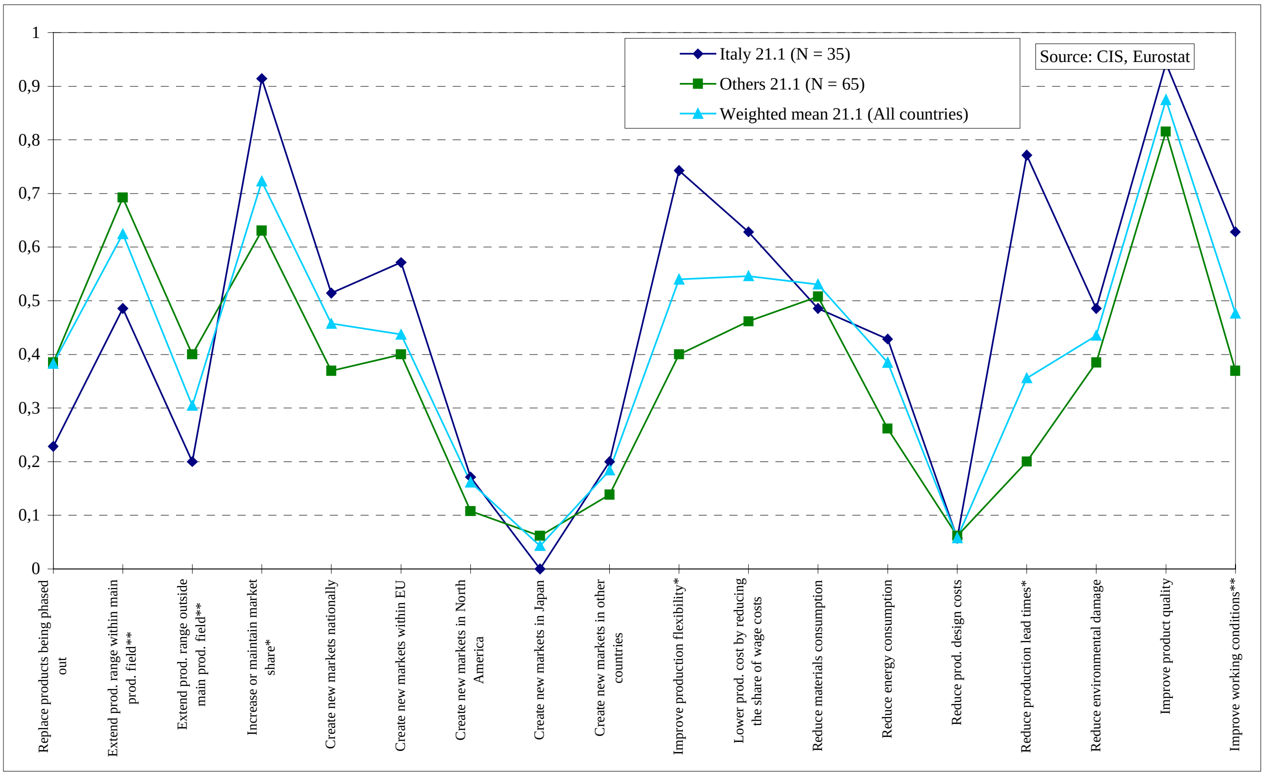


Figure A.8: Innovation objectives by country and industrial category

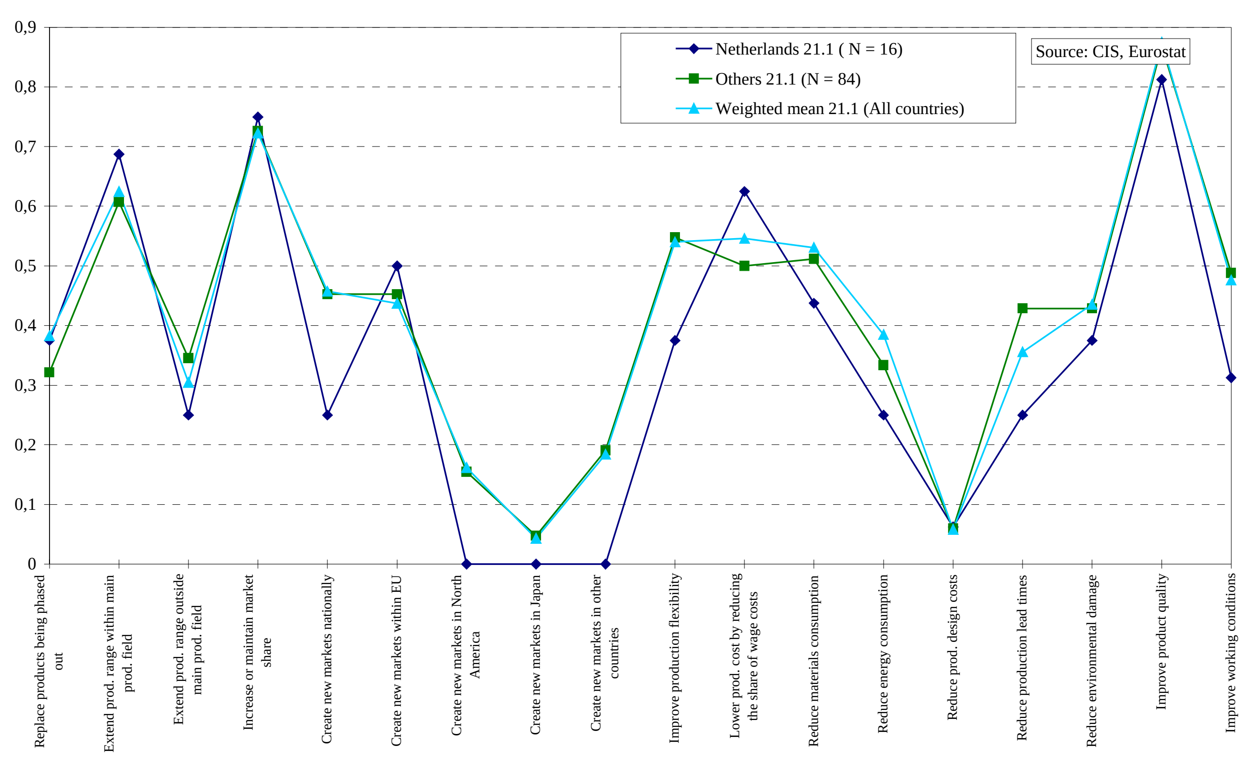
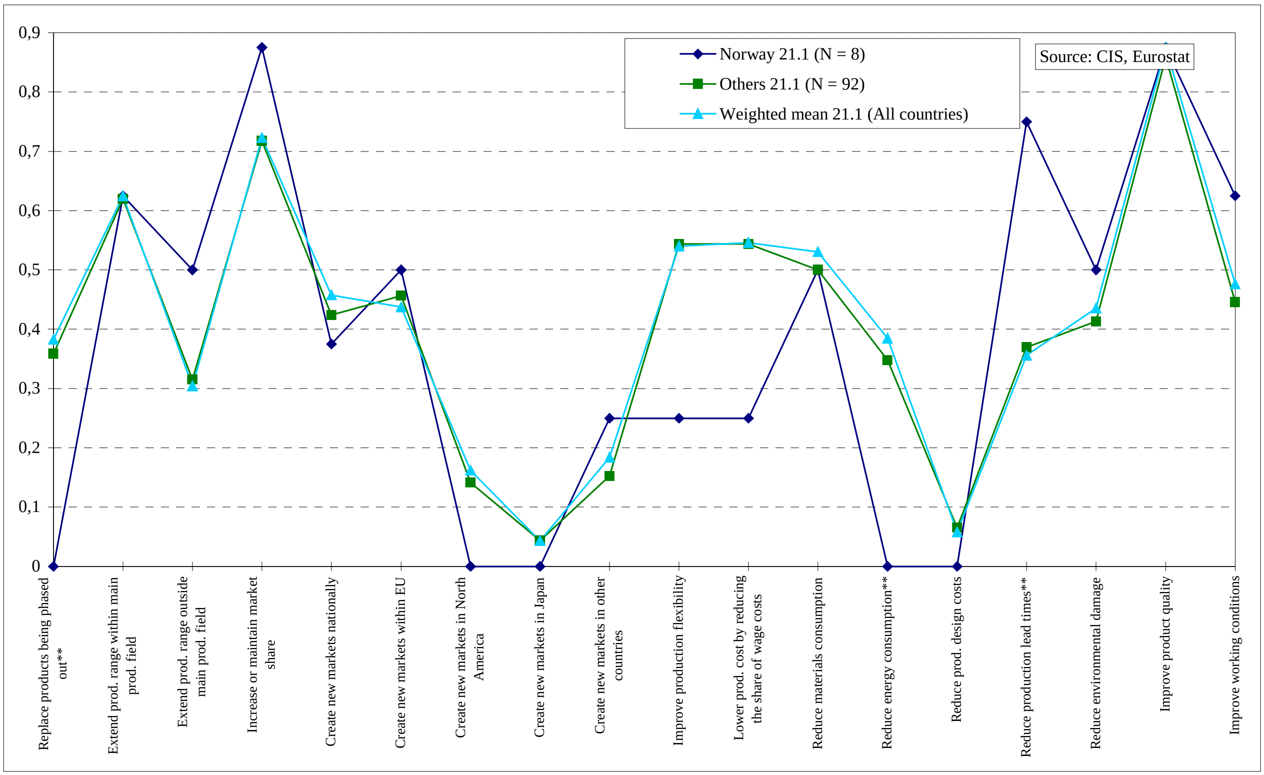


Figure A.9: Innovation objectives by country and industrial category



NACE 21.2

Figure A.10: Innovation objectives by country and industrial category

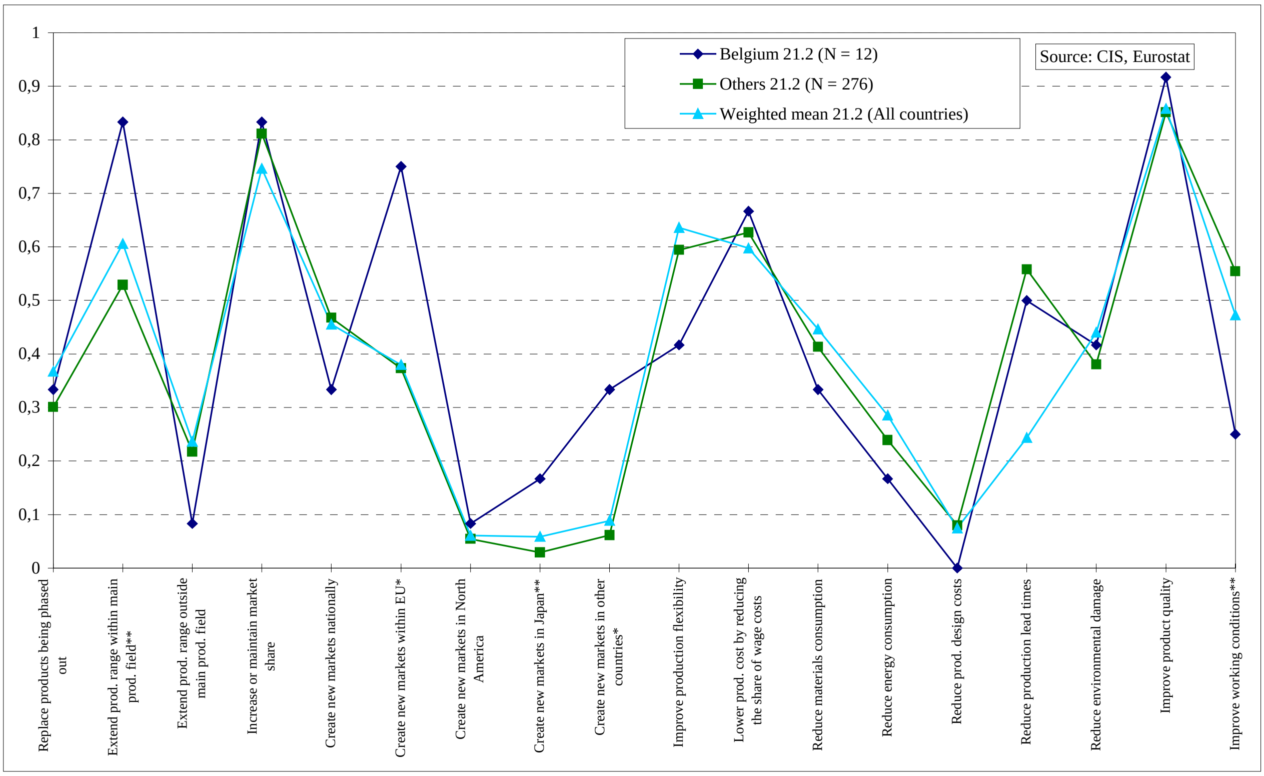


Figure A.11: Innovation objectives by country and industrial category

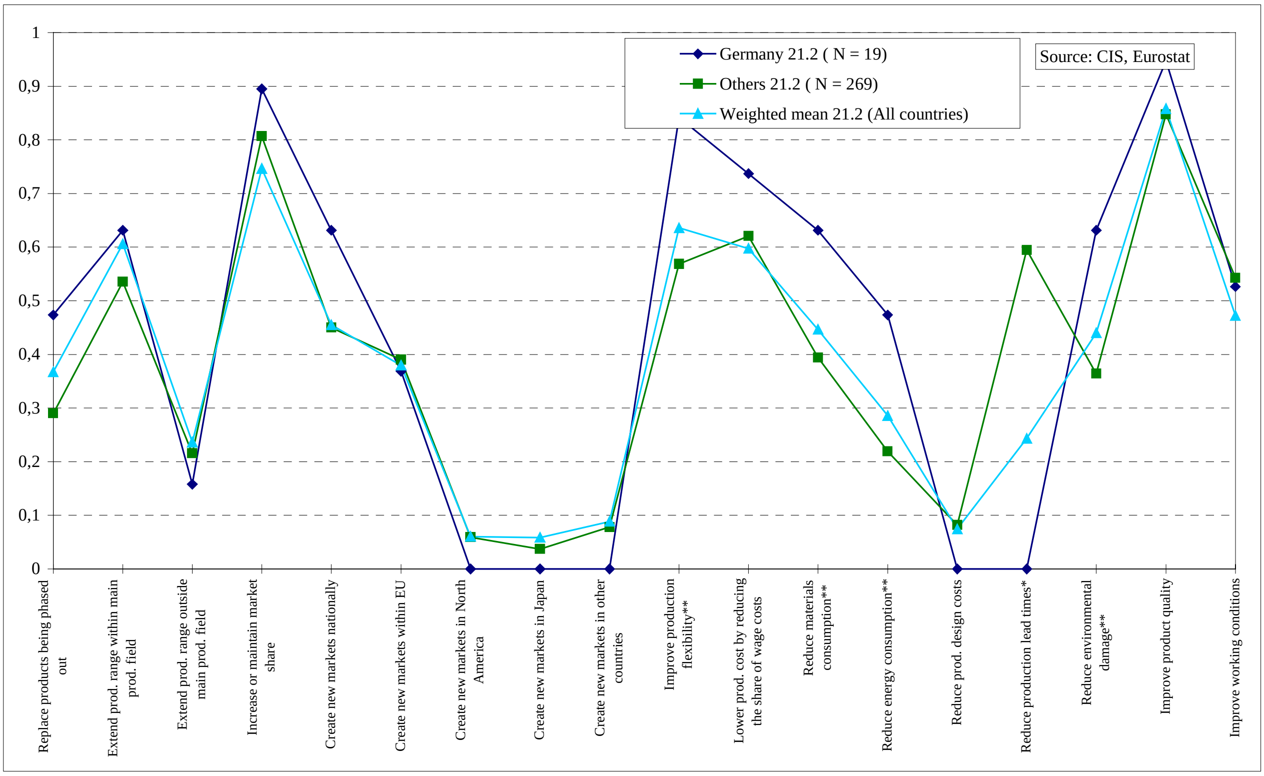


Figure A.12: Innovation objectives by country and industrial category

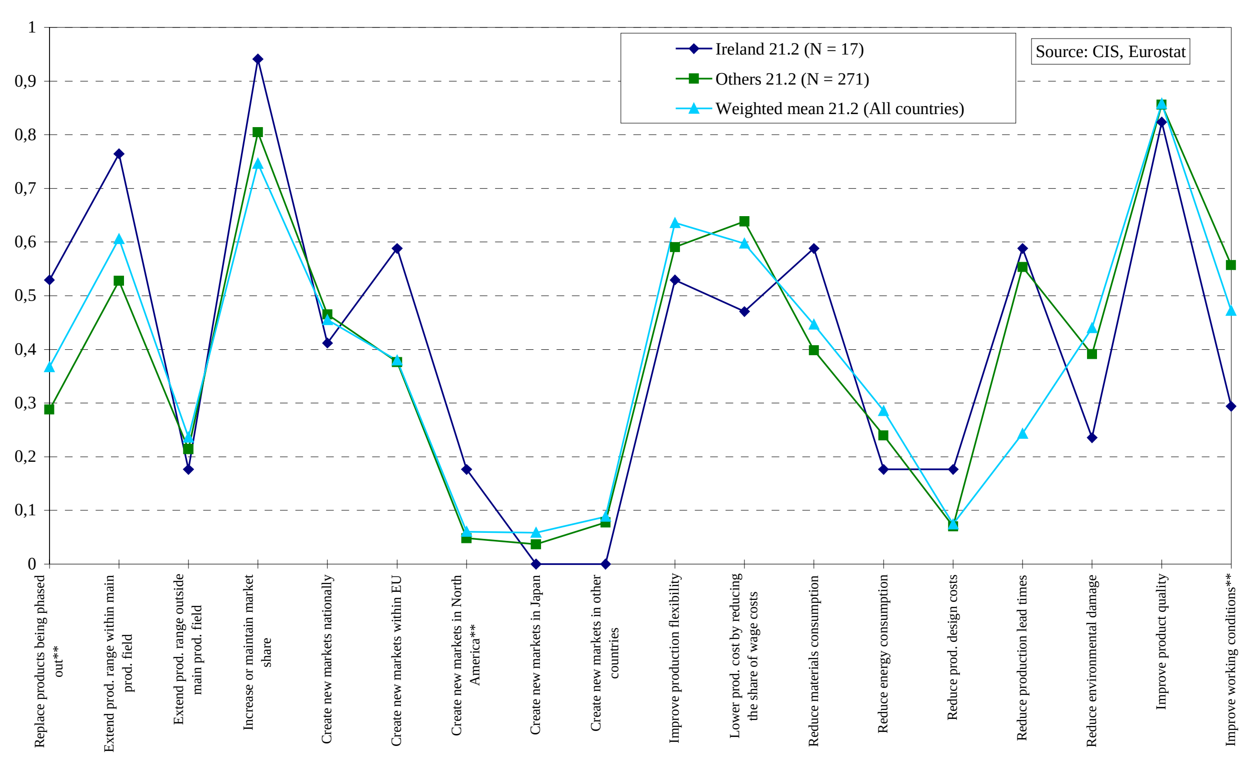


Figure A.13: Innovation objectives by country and industrial category

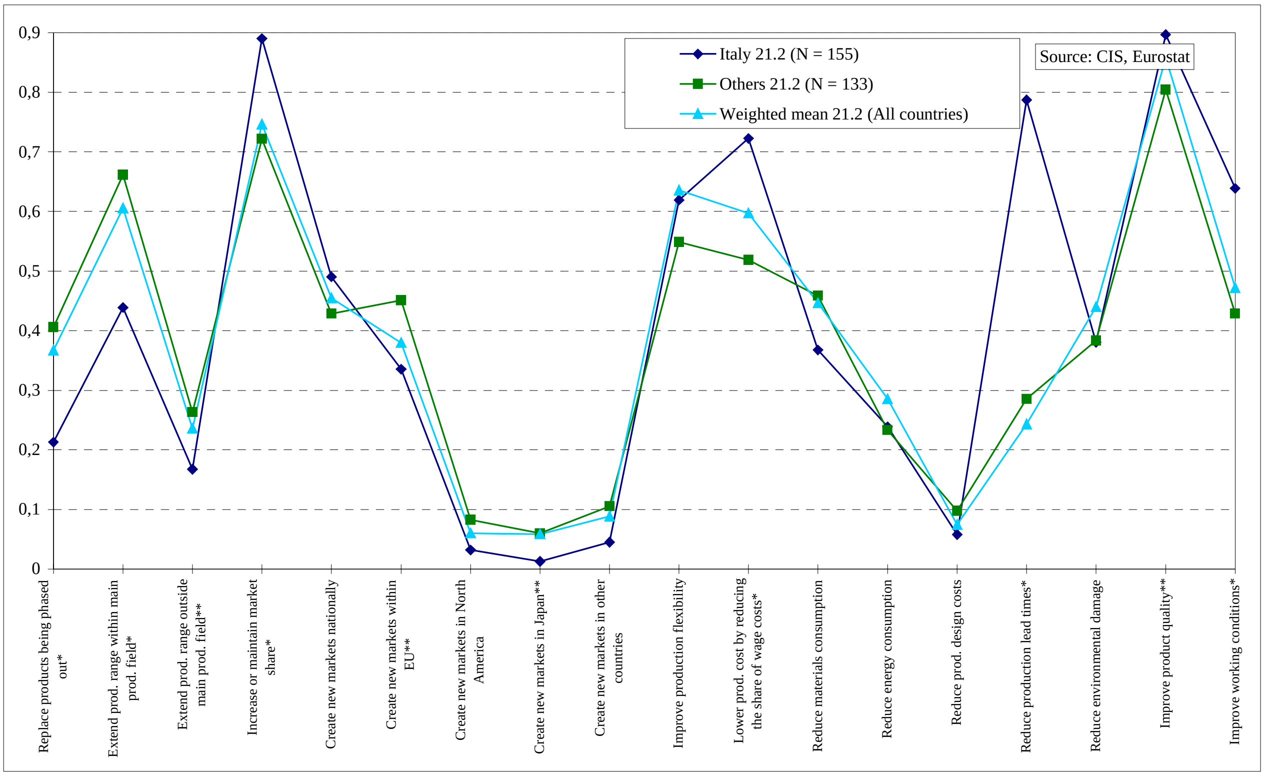


Figure A.14: Innovation objectives by country and industrial category

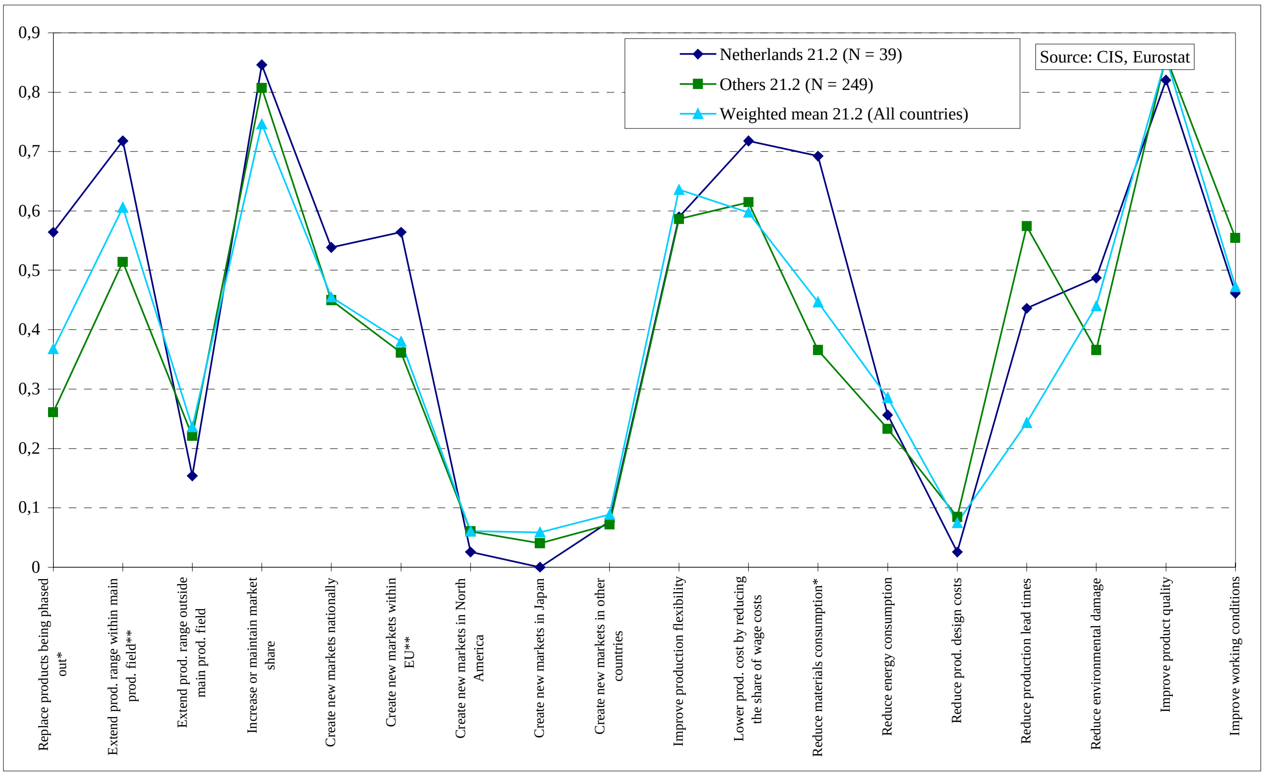
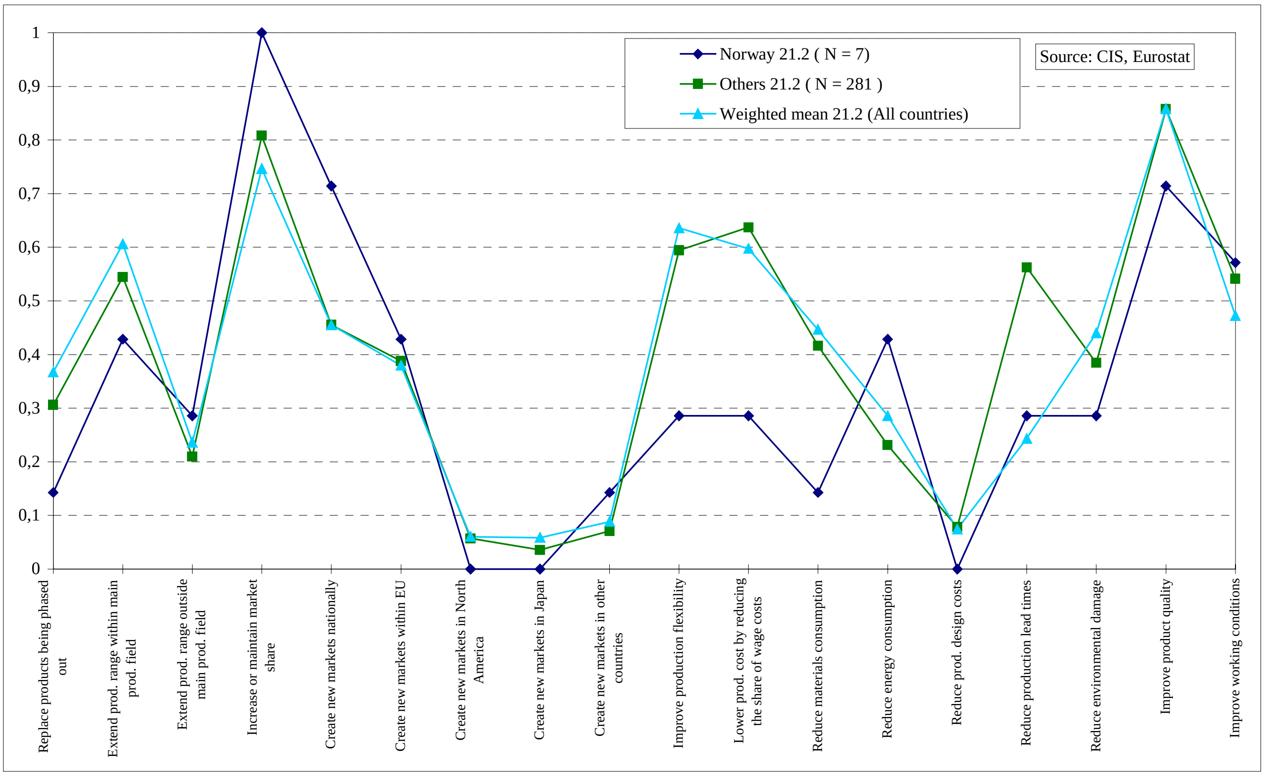


Figure A.15: Innovation objectives by country and industrial category



Appendix B: Factors hampering innovation

In their innovative activities and in search for new products, firms may experience various obstacles that block or hamper the innovation process. This section deals with factors that constitute barriers to innovative success, by either slowing down or stopping an innovative project altogether.

The firms were asked to evaluate 18 factors on a scale from 1(insignificant) to 5 (crucial). As in Appendix A we have transformed these numbers to a binary scale. Obstacles that were rated from 1 - 3 were given the value '0' (unimportant), and obstacles that were rated 4 or 5 were given the value '1' (important). Hence we were able to calculate the share of firms within a certain group, that ranked a certain obstacle as important. As earlier we have utilised a distribution free test, the Wilcoxon test.

Essentially, economic factors are ranked as the most important obstacle to innovation. 'Innovation costs too high' is ranked as the most important obstacle; second in importance we find 'lack of financial resources' and 'pay off period too long'. Hence the firms in general, see lack of finance of innovation as an essential problem; this point is also made of course in the European *Commission's Green paper on Innovation:*

'Financing is the obstacle to innovation most often quoted by firms, whatever their size, in all member states of the European Union and virtually all sectors'.

The CIS data reveals that this is an even bigger problem in *pulp, paper and paper products* than in other sectors.[141] We find also that other external factors such as 'legislation, norms, regulations, standards, taxation', 'lack of customer responsiveness' and 'uncertainty in timing of innovation' are ranked quite high by firms. Among factors internal to the enterprise we find that 'lack of skilled personnel' is an important obstacle for innovation in most firms. This might point to a lack of integration between the needs of the industry and the university system. The Green paper on innovation also emphasise this point and argues that the educational system is not well adapted to a changing world were innovation and innovative capabilities are important for firm survival. The CIS gives some support to this point.

In sum, the firms rank external obstacles as more important than internal (enterprise) obstacles to innovation[142].

Figures B.5-B.14 give an overview of the country specific data. Again, as in Appendix A, we have calculated i) a weighted average for the pulp and paper

[141] One possible implication of these findings is that the establishment of venture capital institutions would enhance innovation significantly.

[142] We see very few differences across NACE classes and firm size. This lack of firm heterogeneity holds for nearly all the 18 factors included in the survey. Out of 72 tests, we found that only 6 were significantly different (on the 5% level)).

industry as a whole, ii) a simple average for the pulp and paper industry as a whole iii) and a simple average for the each country. The weighted average is calculated at a cross national level utilising the simple average for each country weighted by the total number of firms in that country. We did not have access to the population of firms *by firm size*, hence we did not discriminate on firm size in the following analysis.

Figure B.1: Factors hampering innovation by industrial category

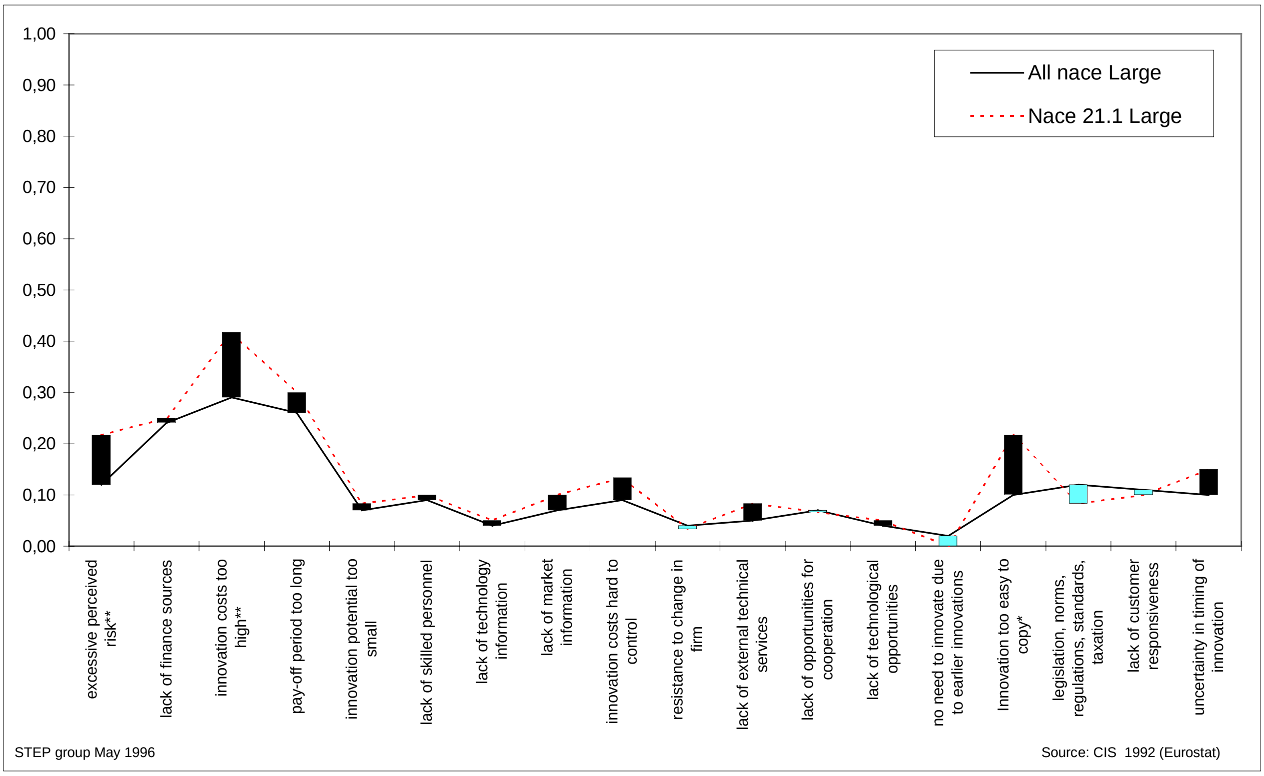


Figure B.2: Factors hampering innovation by industrial category

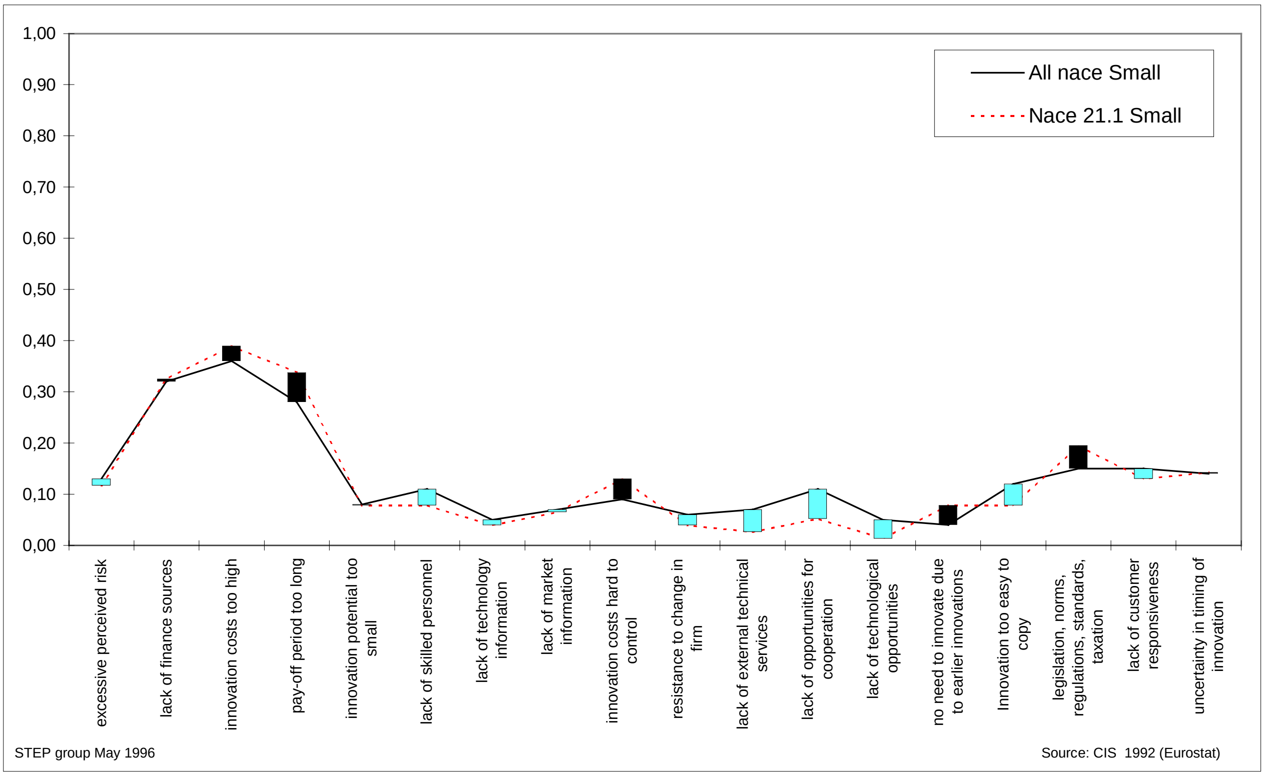


Figure B.3: Factors hampering innovation by industrial category

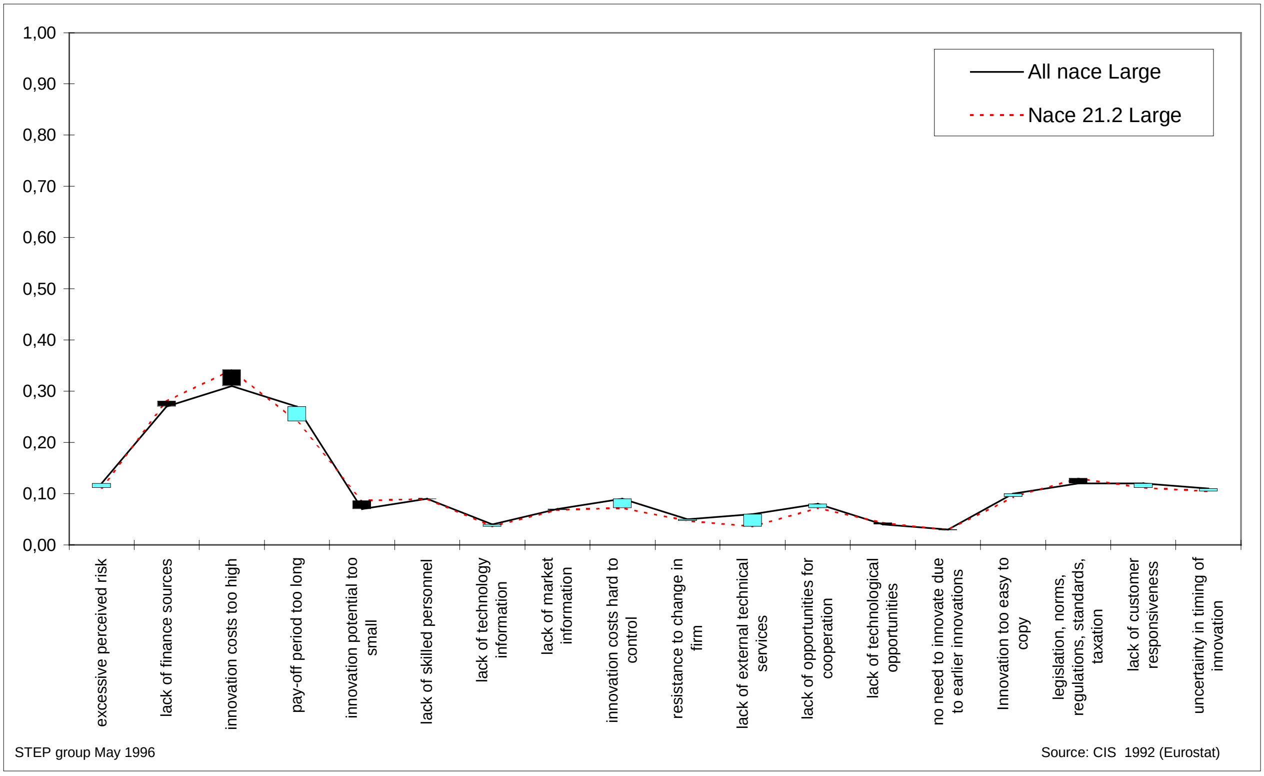


Figure B.4: Factors hampering innovation by industrial category

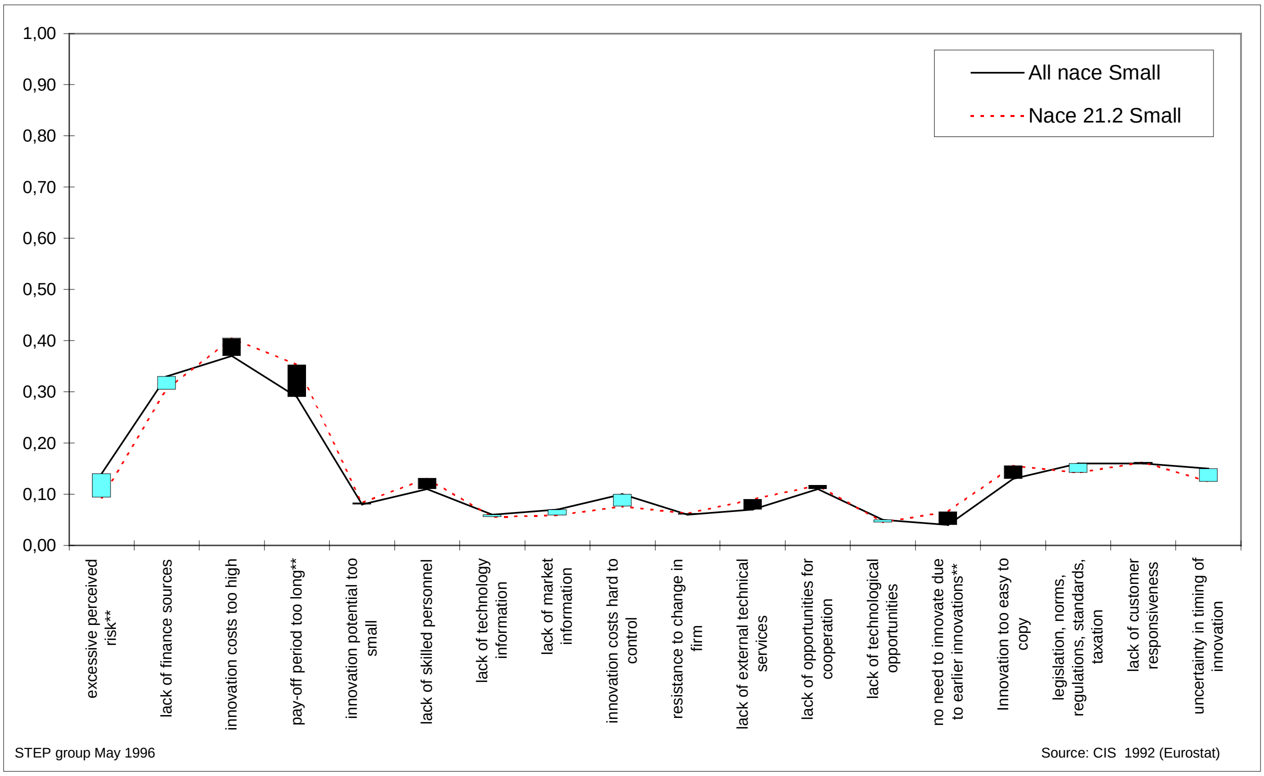


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Figure B.5: Factors hampering innovation by country and industrial category

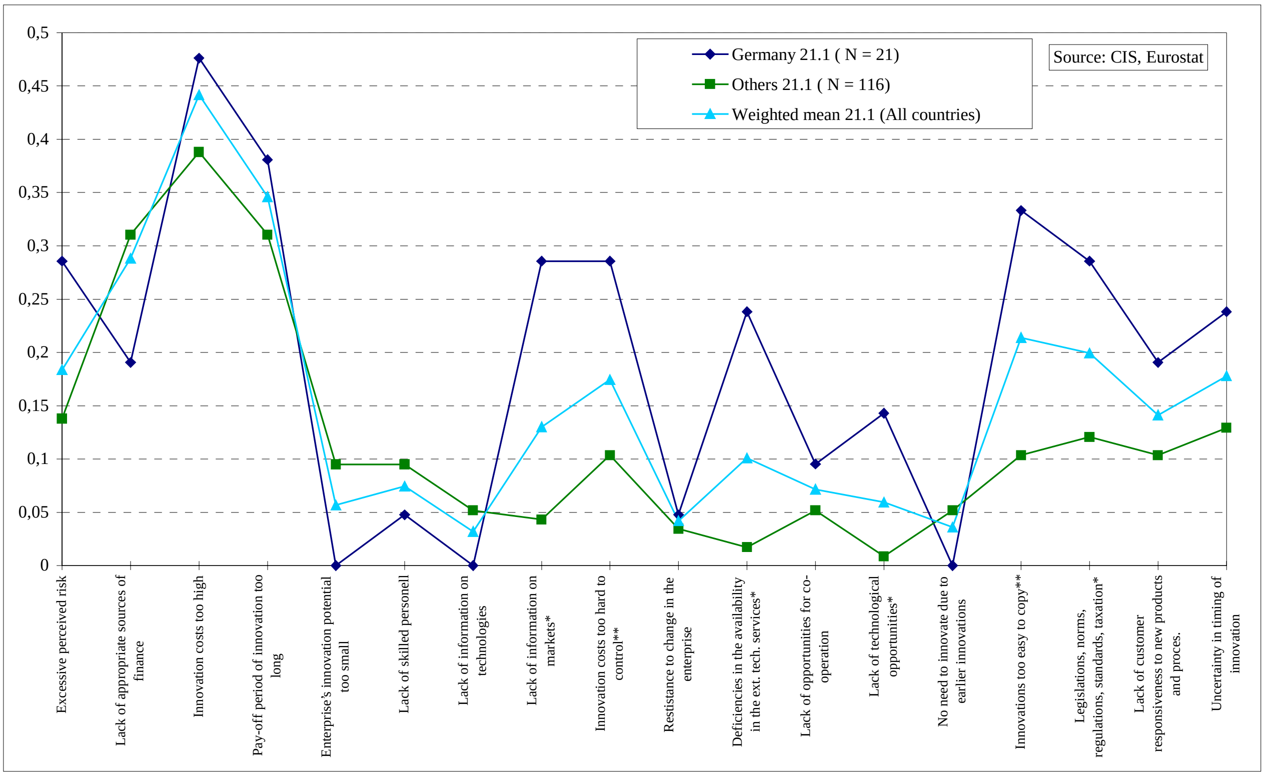


Figure B.6: Factors hampering innovation by country and industrial category

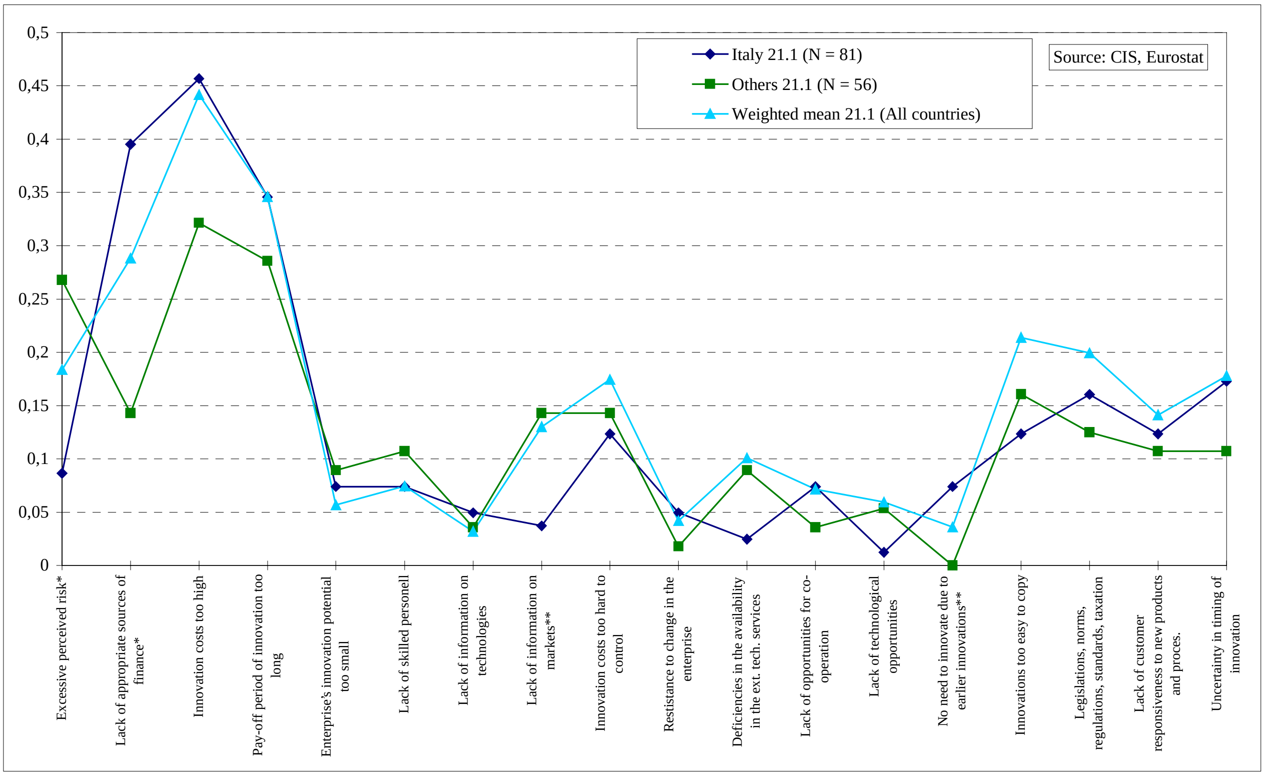


Figure B.7: Factors hampering innovation by country and industrial category

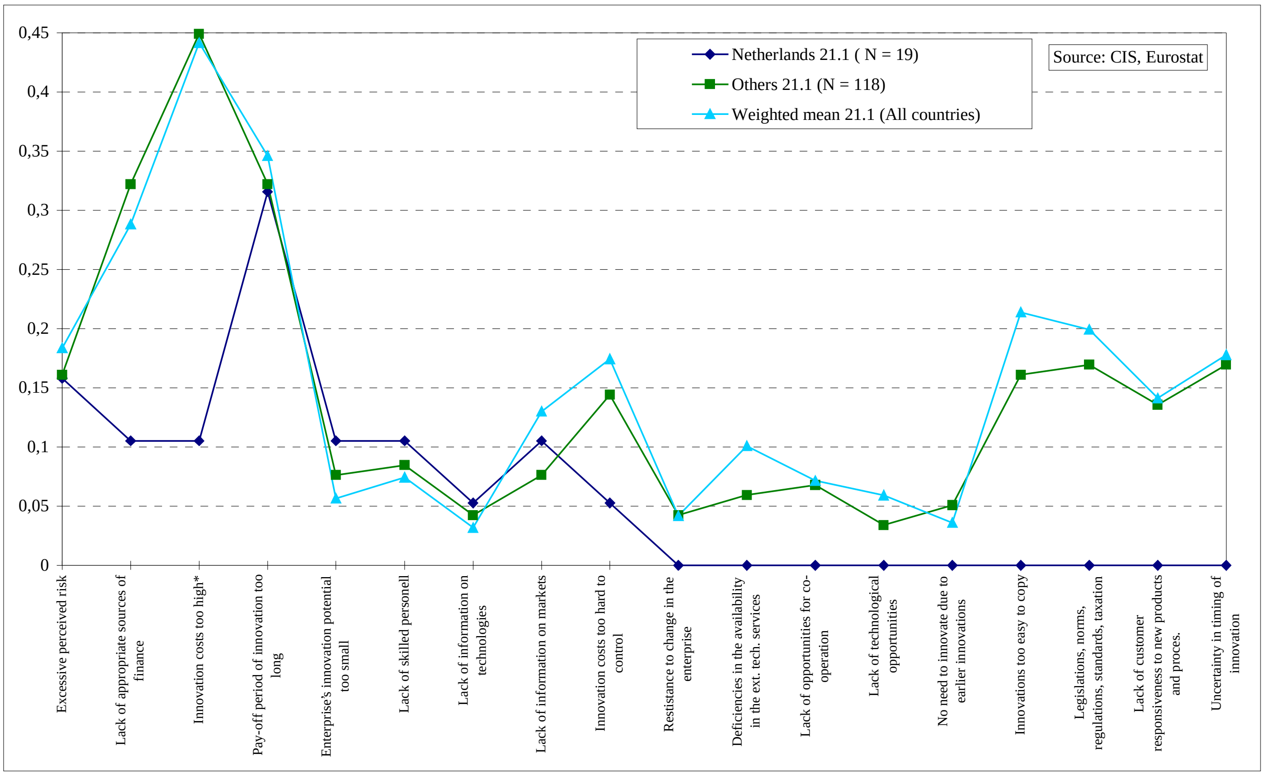
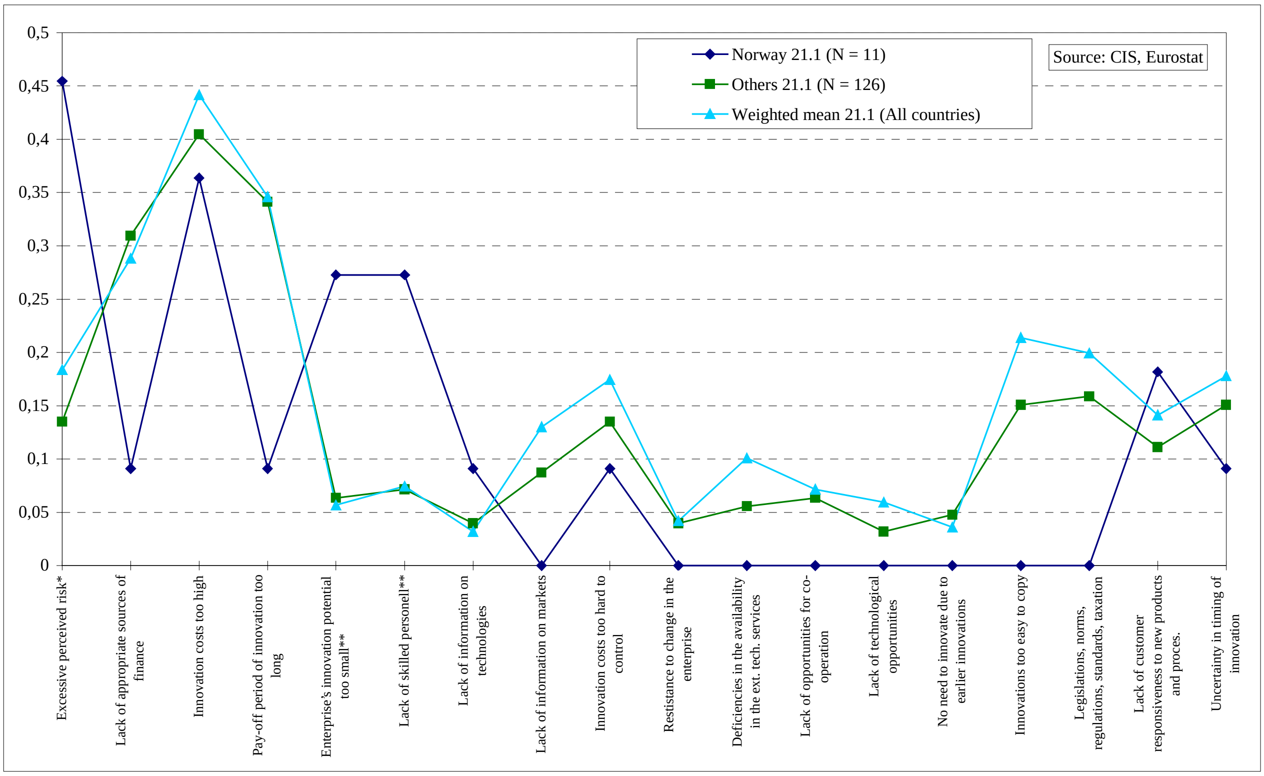


Figure B.8: Factors hampering innovation by country and industrial category



NACE 21.2

Figure B.9: Factors hampering innovation by country and industrial category

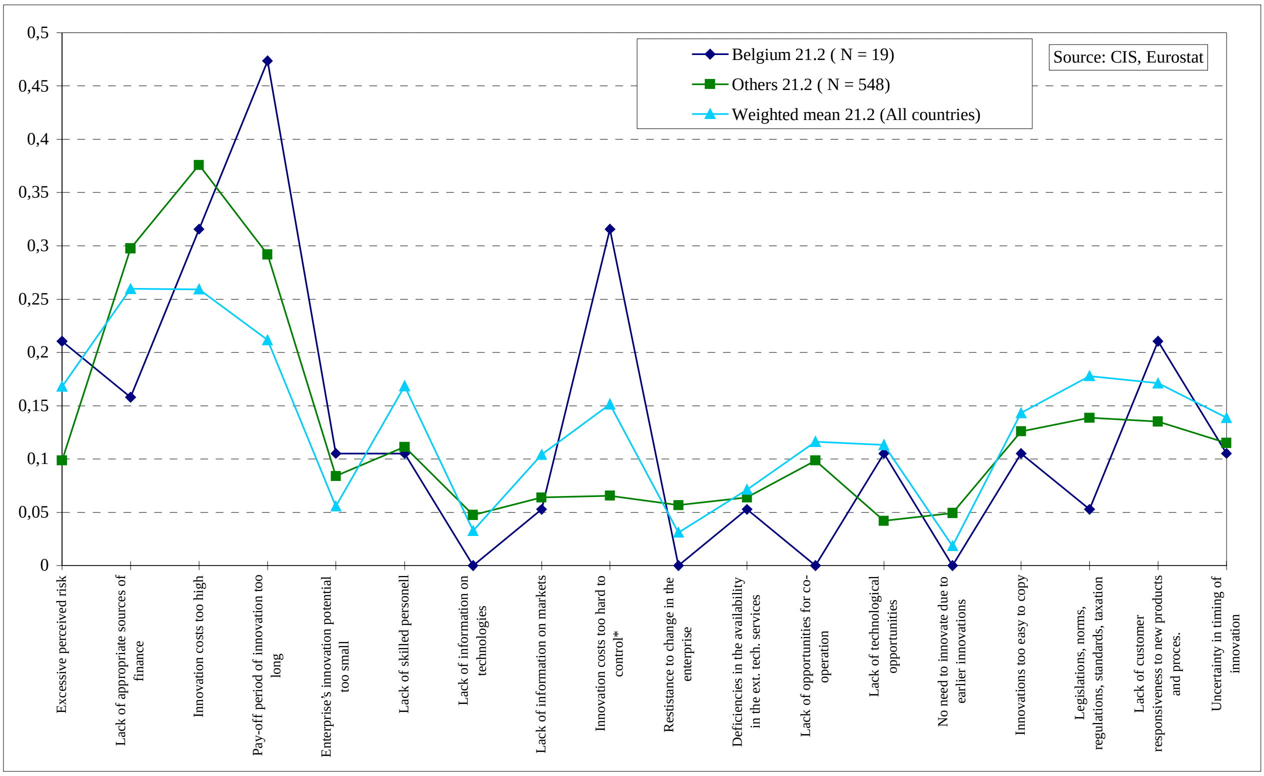


Figure B.10: Factors hampering innovation by country and industrial category

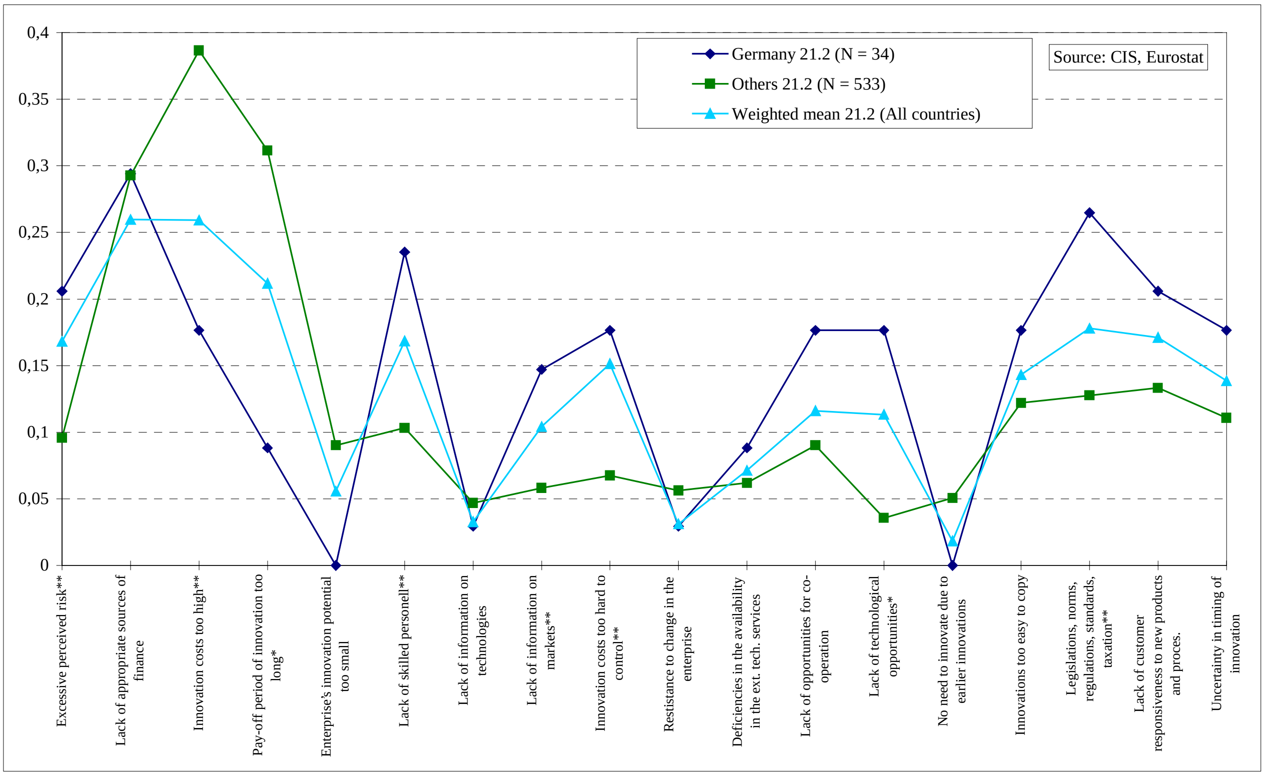


Figure B.11: Factors hampering innovation by country and industrial category

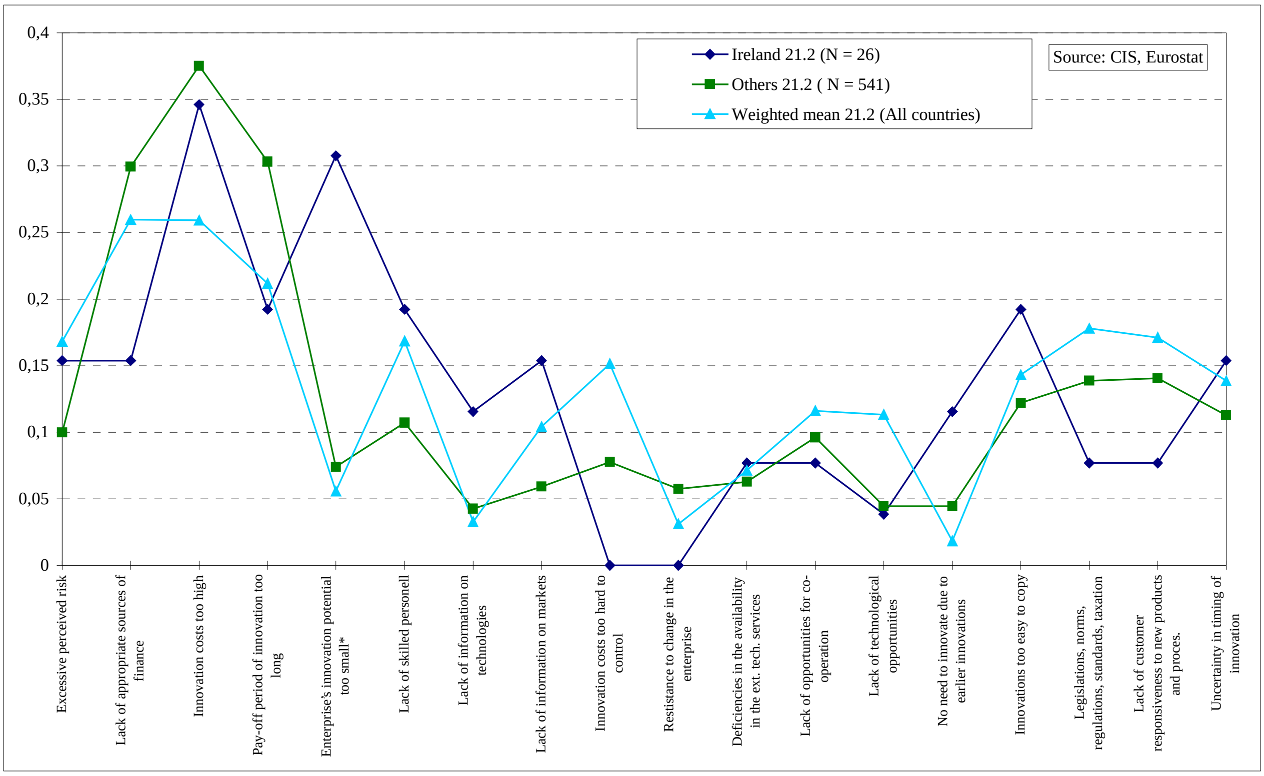


Figure B.12: Factors hampering innovation by country and industrial category

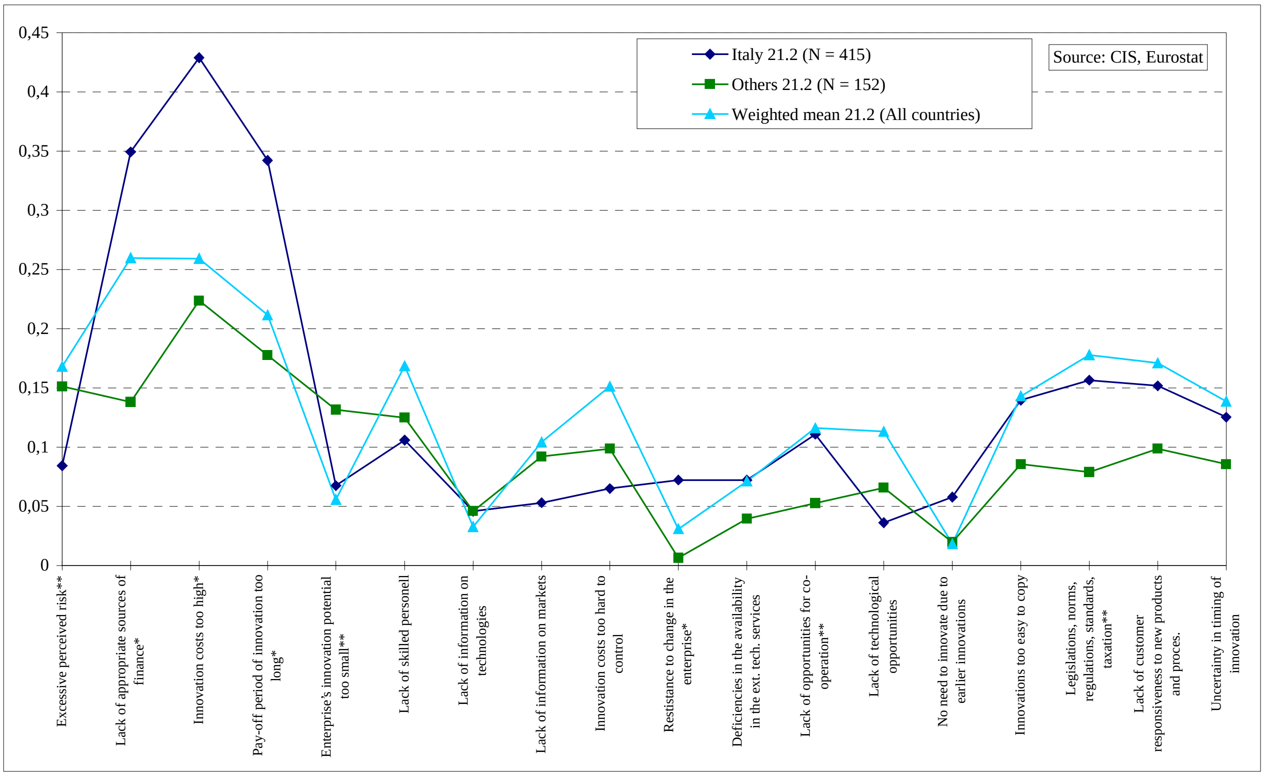


Figure B.13: Factors hampering innovation by country and industrial category

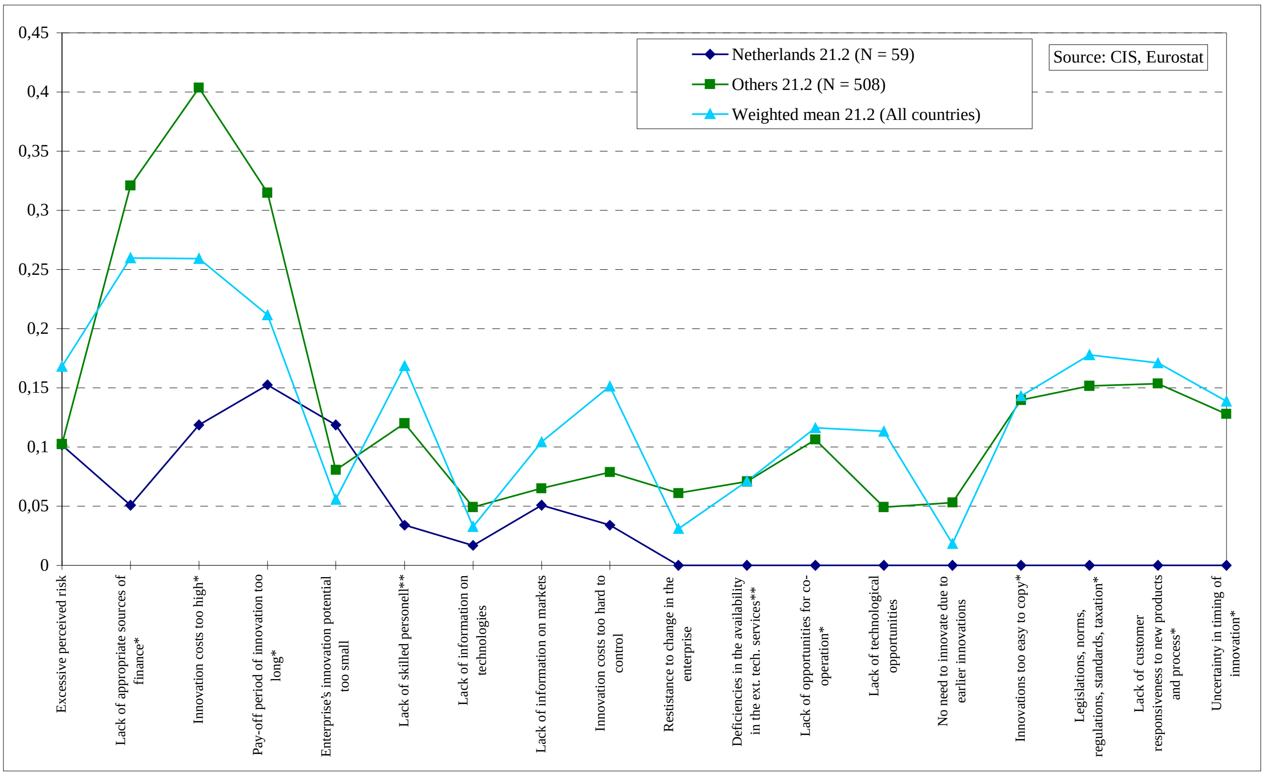
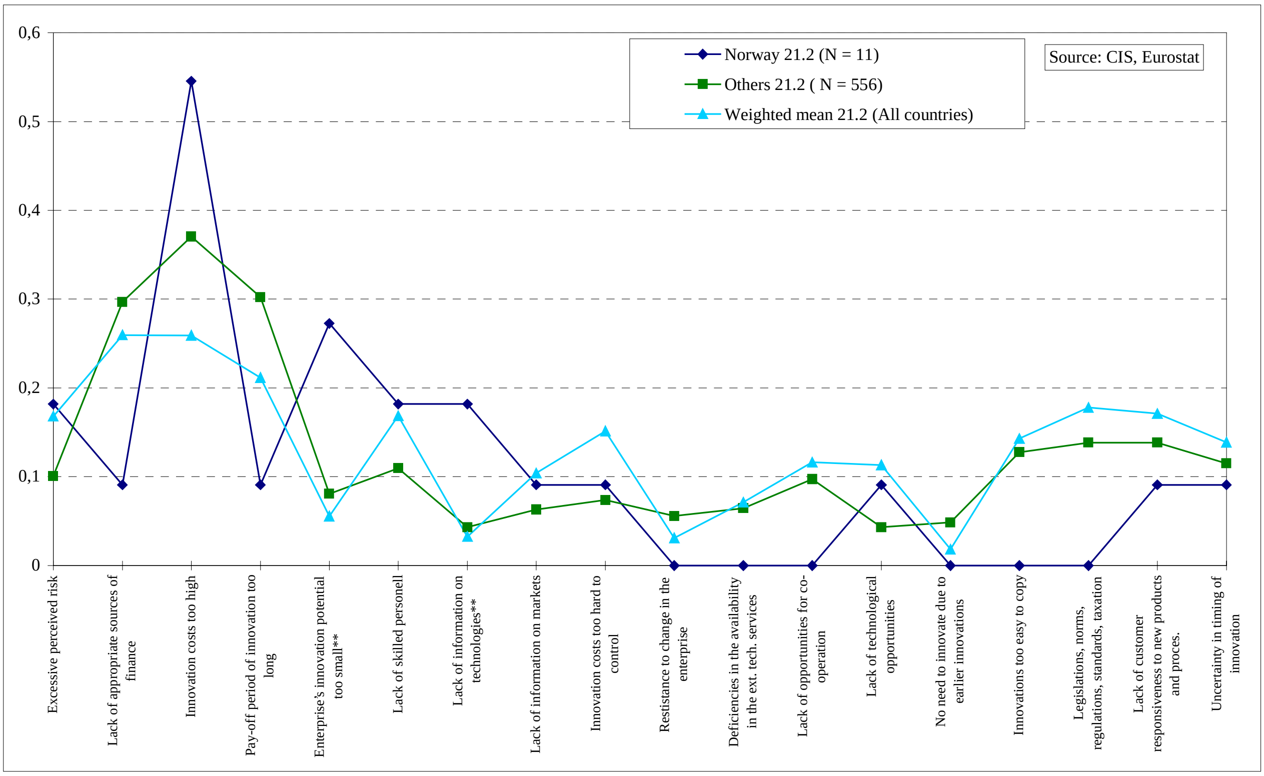


Figure B.14: Factors hampering innovation by country and industrial category



Appendix C: Sources of information for innovation

In their innovative process firms gather information from several sources. This section explores which kind of information sources that firms utilise. The figures are commented upon in Section 2 above.

The firms were asked to evaluate 13 factors on a scale from 1(insignificant) to 5 (crucial). In the following we have transformed these numbers to a binary scale. Obstacles that were rated from 1 - 3 were given the value ‘0’ (unimportant), and obstacles that were rated 4 or 5 were given the value ‘1’ (important). Hence we were able to calculate the share of firms within a certain group, that ranked a certain obstacle as important. The statistical method follows the previous appendices.

As in the previous appendices, in the following we have calculated i) a weighted average for the pulp and paper industry as a whole, ii) a simple average for the pulp and paper industry as a whole iii) and a simple average for the each country. The weighted average is calculated at a cross national level utilising the simple average for each country weighted by the total number of firms in that country. We did not have access to the population of firms *by firm size*, hence we did not discriminate on firm size in the following analysis.

NACE 21.1

Figure C.1: Sources of information for innovation by country and industrial category

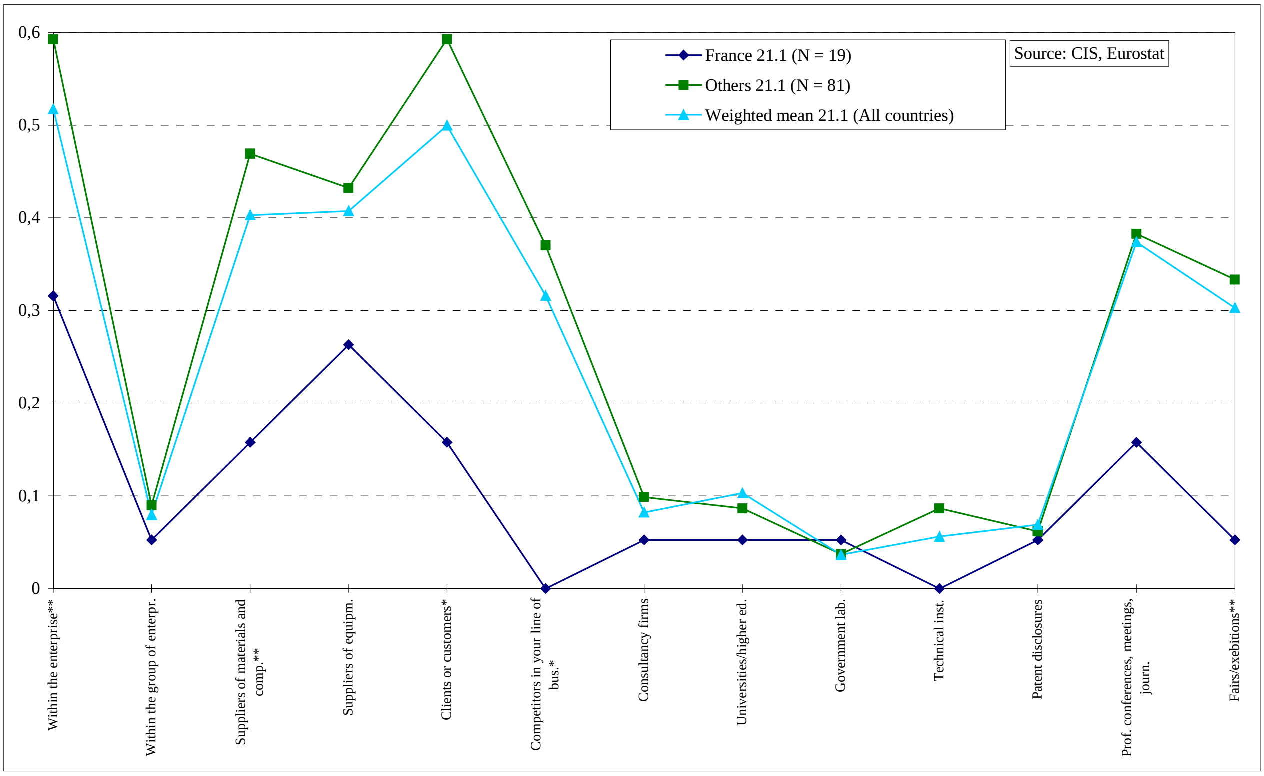


Figure C.2: Sources of information for innovation by country and industrial category

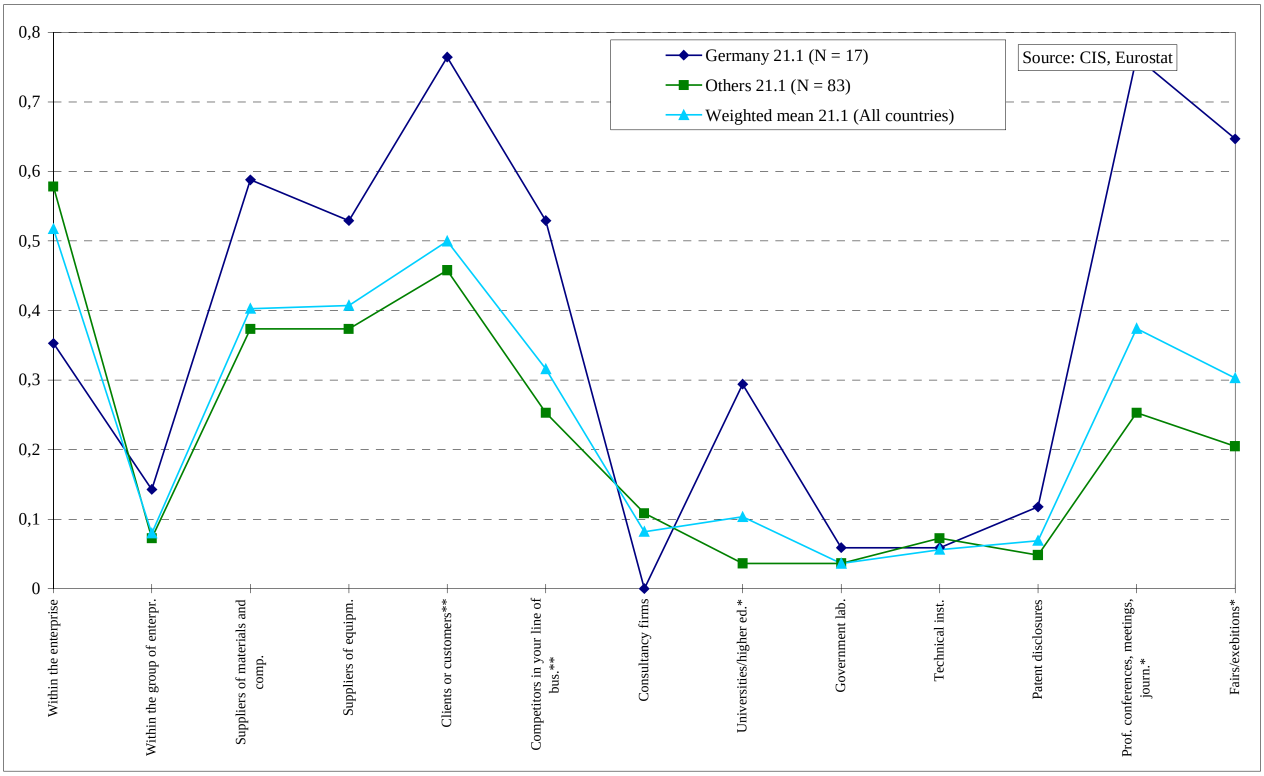


Figure C.3: Sources of information for innovation by country and industrial category

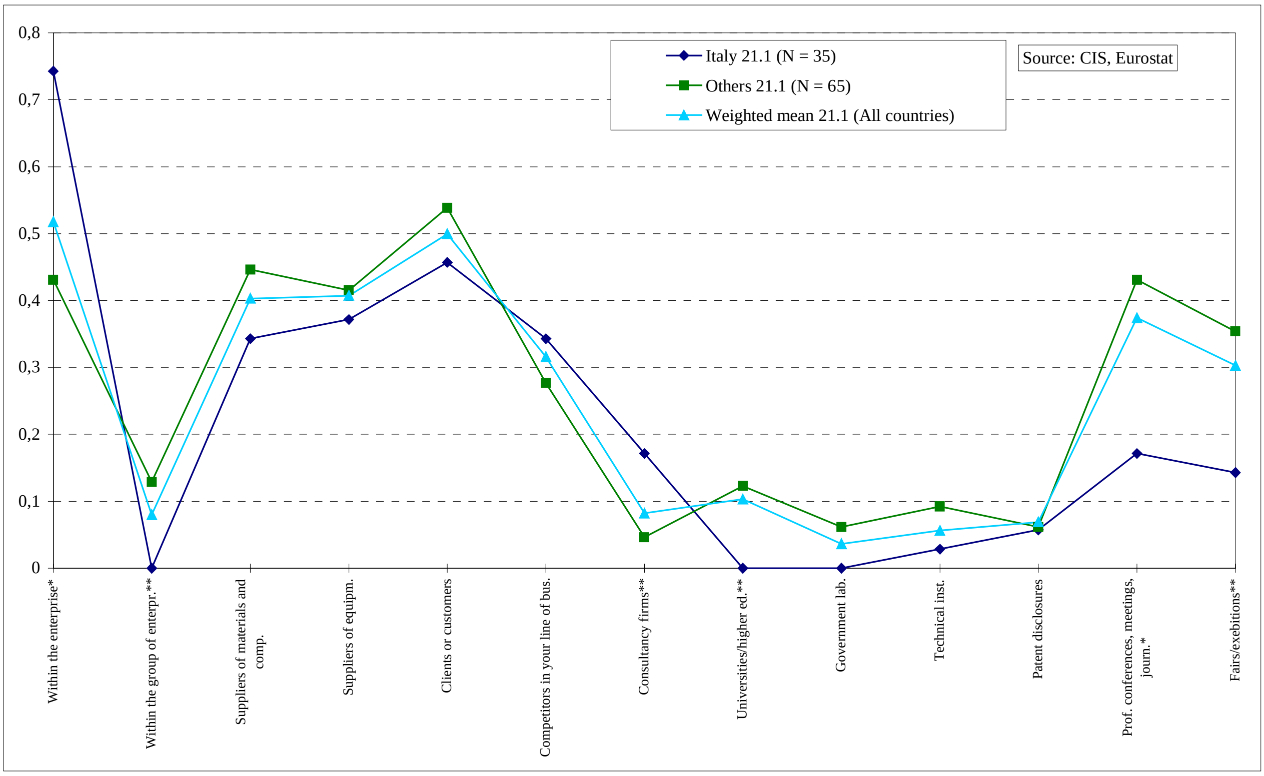


Figure C.4: Sources of information for innovation by country and industrial category

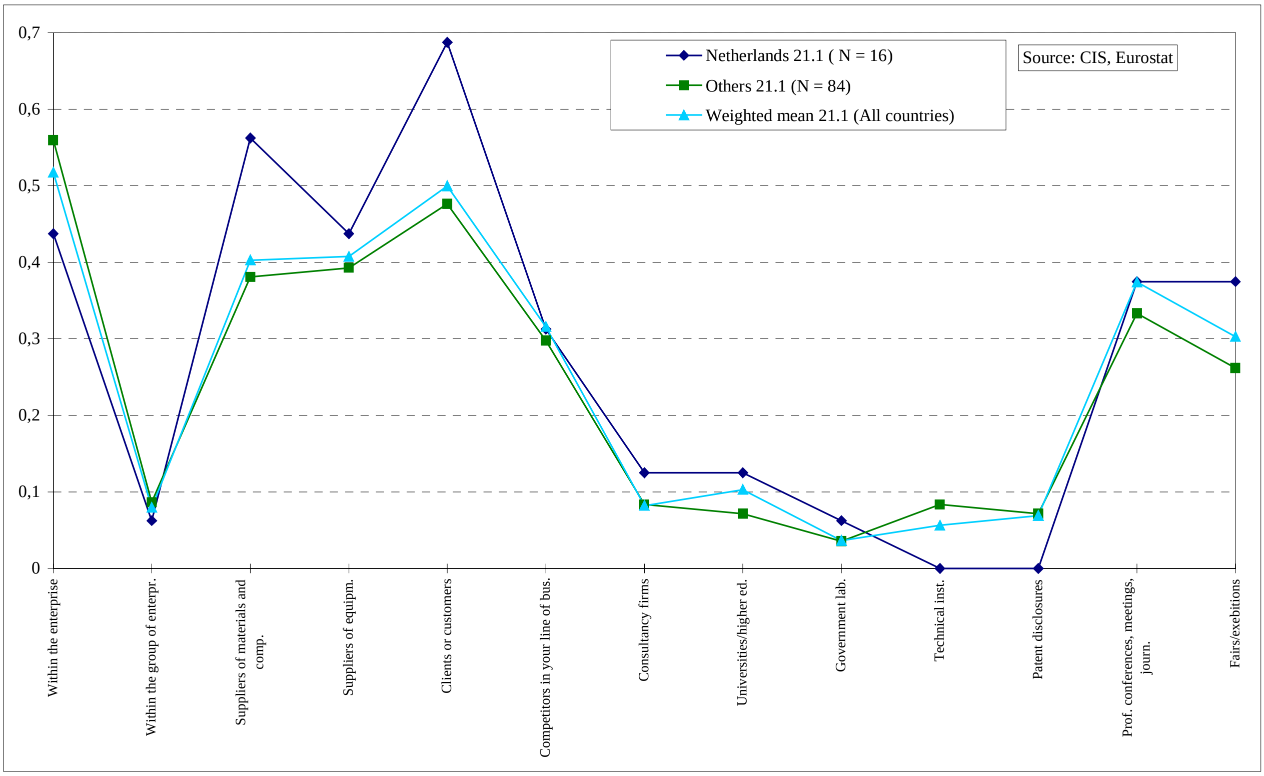
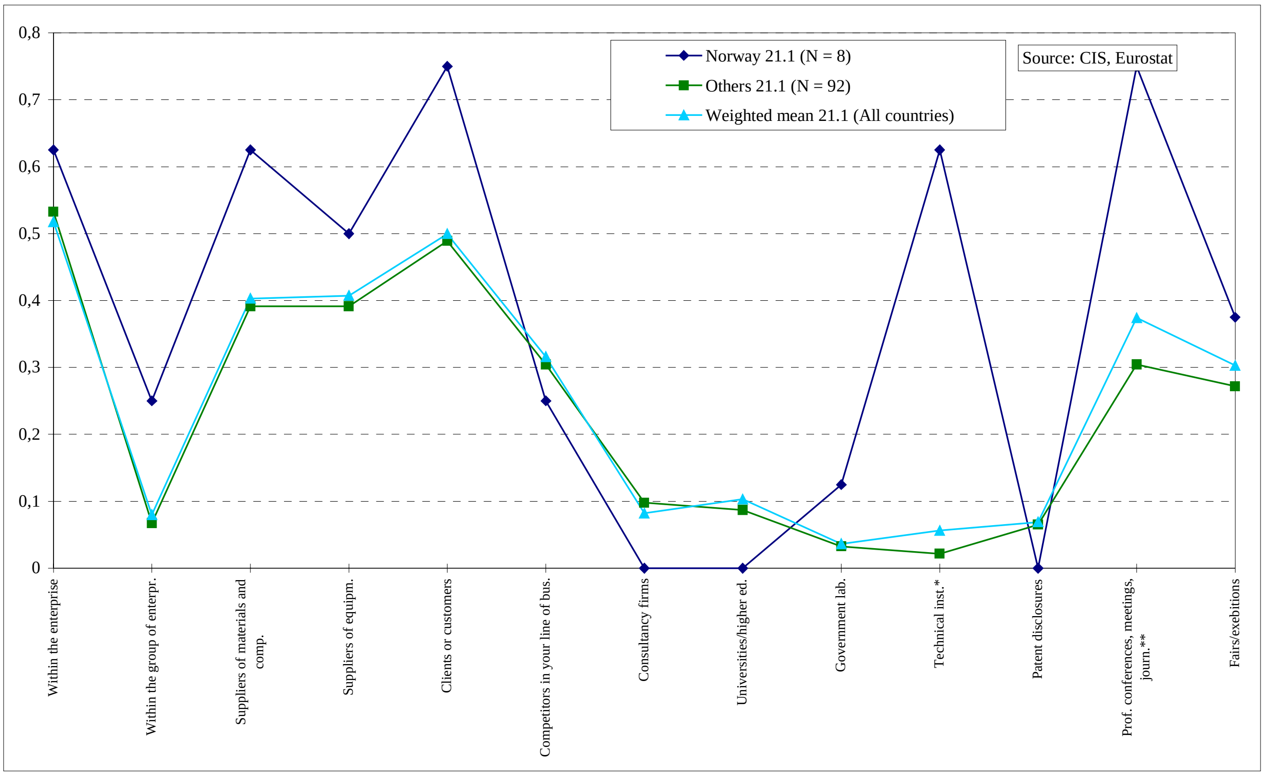


Figure C.5: Sources of information for innovation by country and industrial category



NACE 21.2

Figure C.6: Sources of information for innovation by country and industrial category

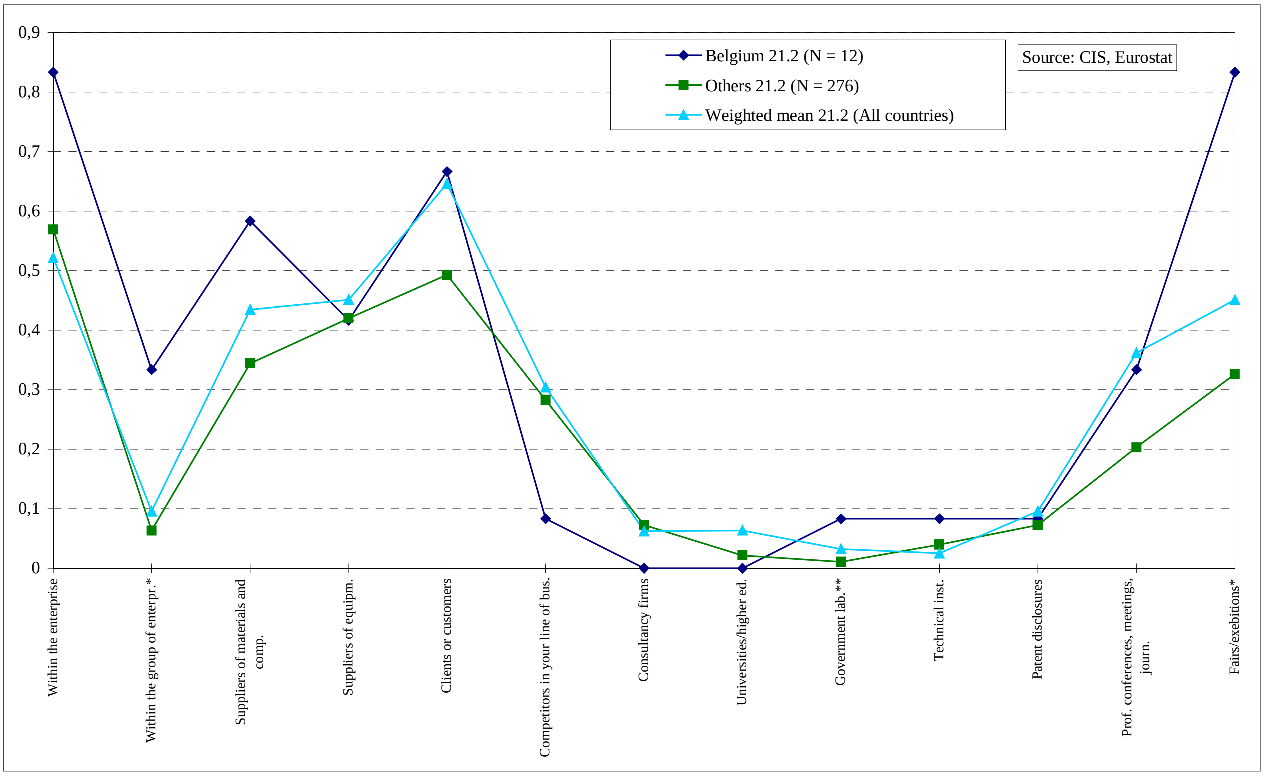


Figure C.7: Sources of information for innovation by country and industrial category

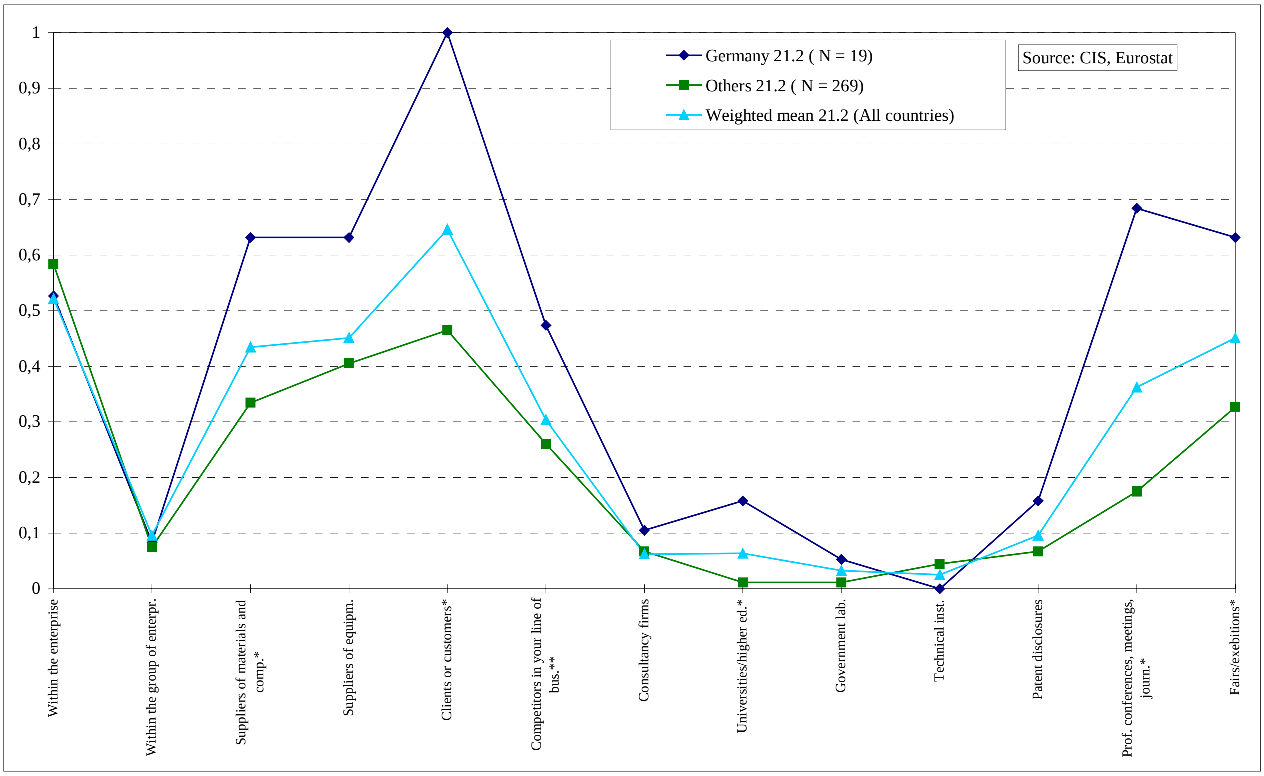


Figure C.8: Sources of information for innovation by country and industrial category

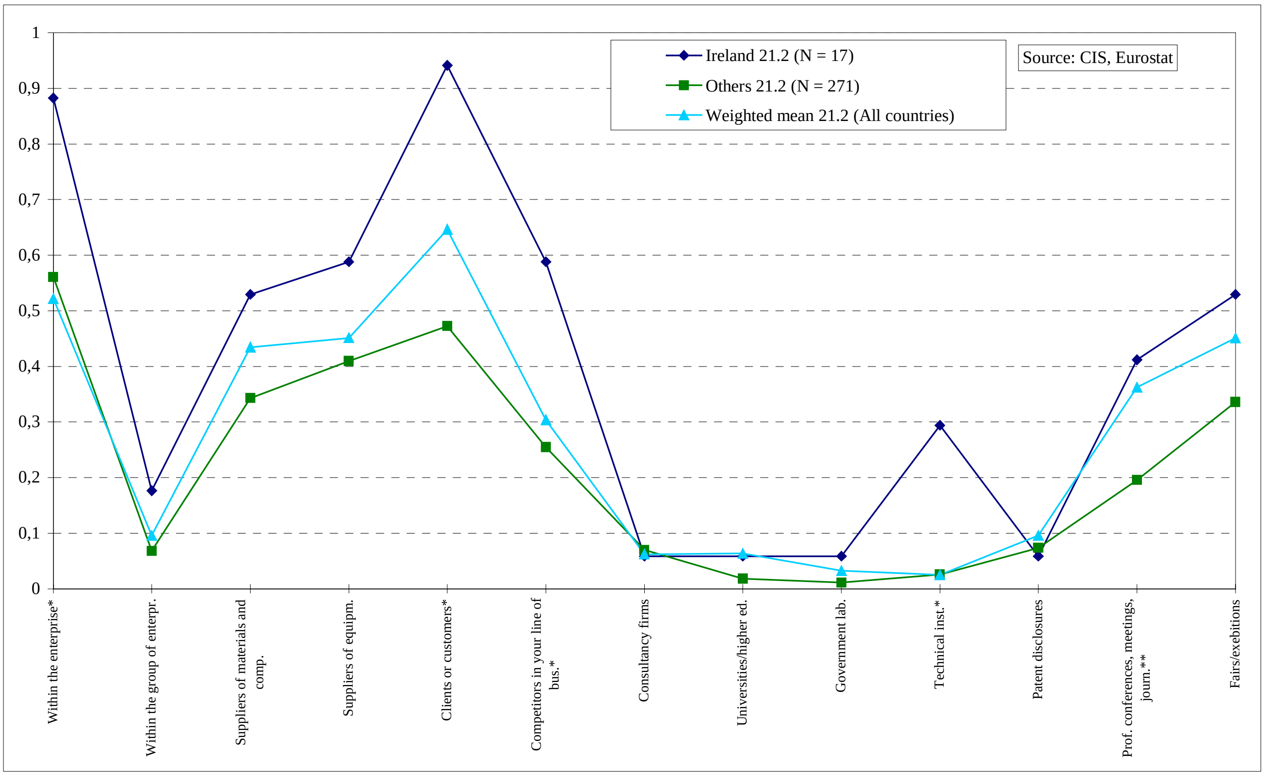


Figure C.9: Sources of information for innovation by country and industrial category

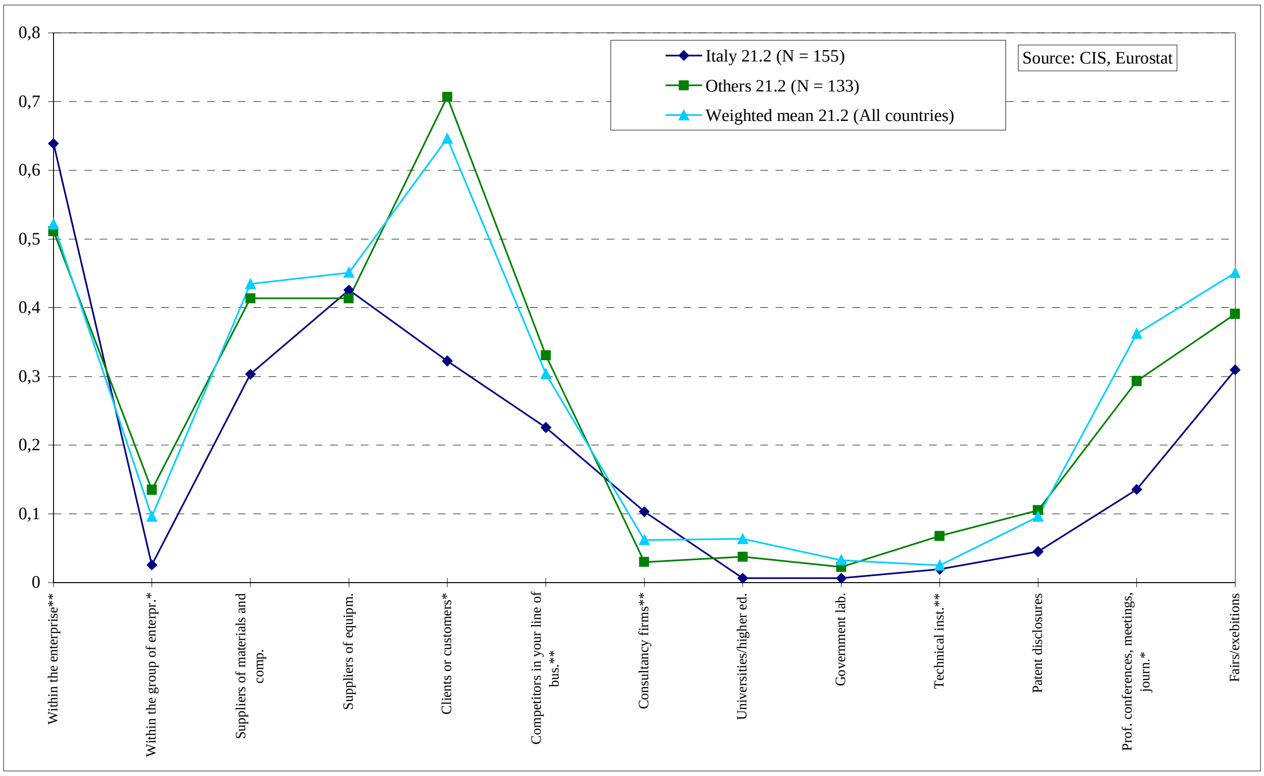


Figure C.10: Sources of information for innovation by country and industrial category

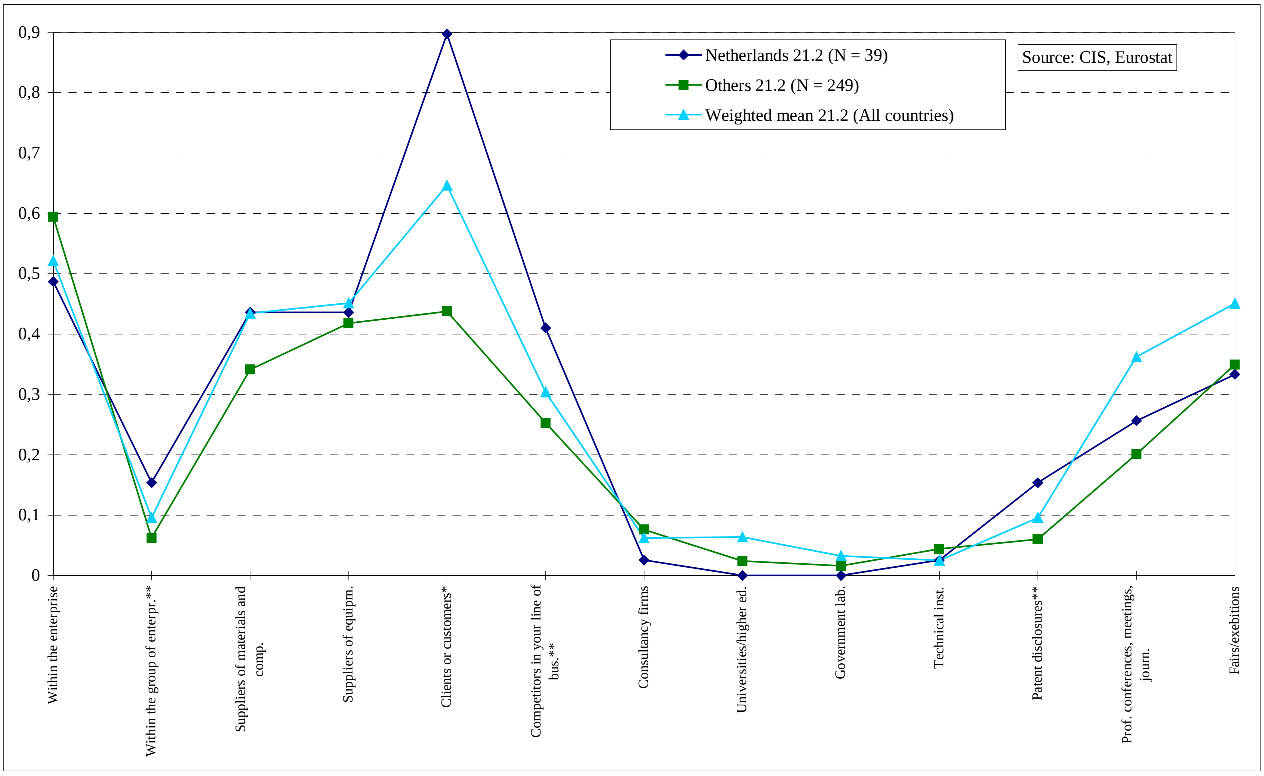
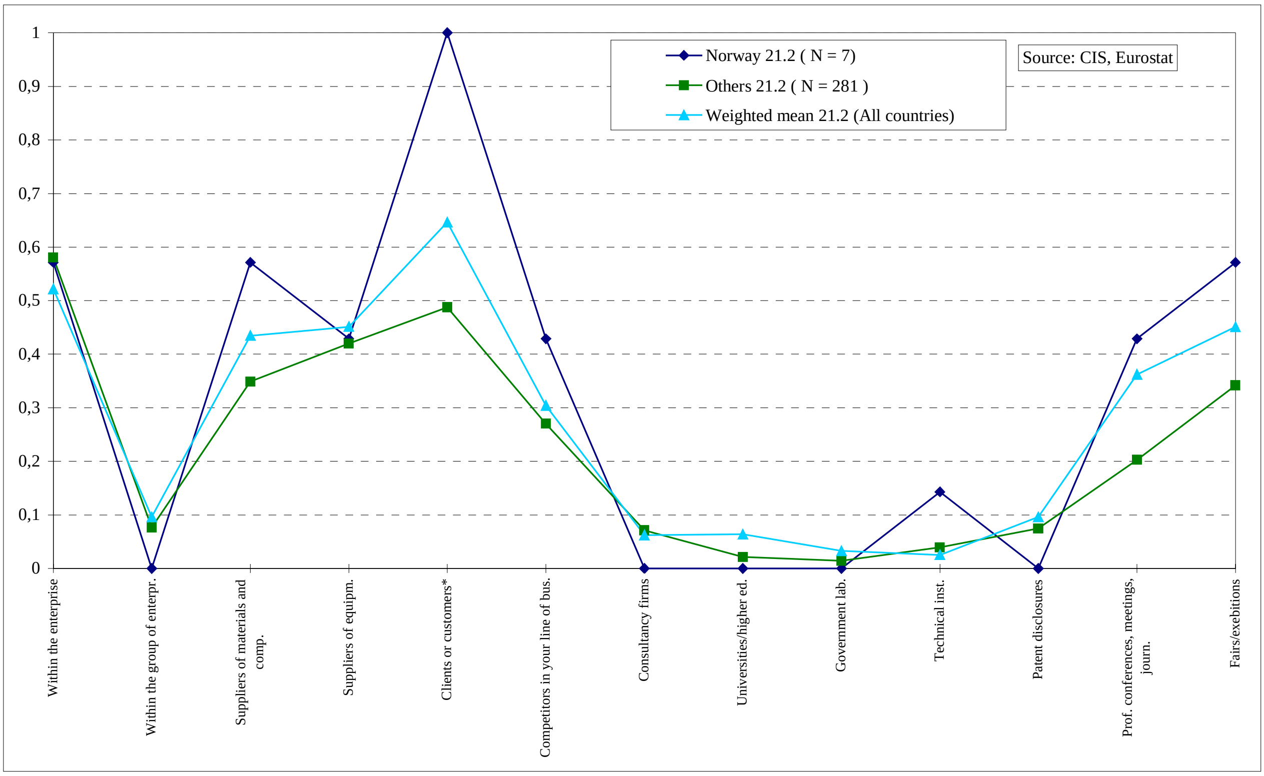


Figure C.11: Sources of information for innovation by country and industrial category



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STEP-gruppen ble etablert i 1991 for å forsyne beslutningstakere med forskning knyttet til alle sider ved innovasjon og teknologisk endring, med særlig vekt på forholdet mellom innovasjon, økonomisk vekst og de samfunnsmessige omgivelser. Basis for gruppens arbeid er erkjennelsen av at utviklingen innen vitenskap og teknologi er fundamental for økonomisk vekst. Det gjenstår likevel mange uløste problemer omkring hvordan prosessen med vitenskapelig og teknologisk endring forløper, og hvordan denne prosessen får samfunnsmessige og økonomiske konsekvenser. Forståelse av denne prosessen er av stor betydning for utformingen og iverksettelsen av forsknings-, teknologi- og innovasjonspolitikken. Forskningen i STEP-gruppen er derfor sentrert omkring historiske, økonomiske, sosiologiske og organisatoriske spørsmål som er relevante for de brede feltene innovasjonspolitikk og økonomisk vekst.

The STEP-group was established in 1991 to support policy-makers with research on all aspects of innovation and technological change, with particular emphasis on the relationships between innovation, economic growth and the social context. The basis of the group's work is the recognition that science, technology and innovation are fundamental to economic growth; yet there remain many unresolved problems about how the processes of scientific and technological change actually occur, and about how they have social and economic impacts. Resolving such problems is central to the formation and implementation of science, technology and innovation policy. The research of the STEP group centres on historical, economic, social and organisational issues relevant for broad fields of innovation policy and economic growth.