EUROPEAN INNOVATION MONITORING SYSTEM (EIMS)

EIMS PUBLICATION N° 39

STRATEGIES FOR THE FUTURE:

INNOVATION IN THE EUROPEAN TELECOM EQUIPMENT INDUSTRY

BY

Anthony Arundel
Ed Steinmueller
Richard Hawkins

MERIT, Maastricht, NL

EUROPEAN COMMISSION

DIRECTORATE GENERAL XIII

The Innovation Programme

EIMS Project N° 94/108

STRATEGIES FOR THE FUTURE:

INNOVATION IN THE EUROPEAN TELECOM EQUIPMENT INDUSTRY

BY

Anthony Arundel
Ed Steinmueller
Richard Hawkins

MERIT, Maastricht, NL

THIS STUDY WAS COMMISSIONED BY THE EUROPEAN COMMISSION, DIRECTORATE-GENERAL "TELECOMMUNICATIONS, INFORMATION MARKET AND EXPLOITATION OF RESEARCH", UNDER THE INNOVATION PROGRAMME

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

TABLE OF CONTENTS

EXECUTIVE SUMMARY AND CONCLUSION

This report evaluates the innovative activities and strategies of the European telecom equipment sector, which includes line telephony, radio communication, and TV and radio broadcasting equipment. Part One examines publicly available data on production, trade, patents and technological trends, while Part Two presents the results of analyses of the 1993 Community Innovation Survey (CIS). The CIS provides data on the innovative strategies in 1992 of up to 210 European telecom equipment manufacturers in Norway and in six EU countries, France, Germany, Italy, Ireland, the Netherlands, and Belgium, that were responsible for 80% of total telecom equipment production in the EU in 1992. The timing of the CIS survey provides a snapshot of conditions in the European telecom equipment sector before the liberalisation and privatisation of telecom services in most European countries.

The purpose of this Executive Summary and Conclusion is to integrate and highlight the main results of Part One and Two that are of particular interest to European innovation policy.

European firms have a substantial position of strength in global telecom equipment. In 1994 four EU firms, Alcatel, Siemens, Ericsson, and Nokia ranked among the world's top ten telecom equipment manufacturers, while European firms, as a whole, had approximately 42% of the world market in 1990.

Other than a recession year of 1993, total European production of telecom equipment has been growing steadily between 1989 and 1995, though employment has been falling because of increasing productivity. However, rising production is largely due to a rapid increase in radio and broadcast equipment, including mobile telephone systems, while production in the traditional areas of line telephony and public networks has declined slightly since the peak year of 1991. These production figures are also reflected in sales data for Europe. The percentage of all European telecom equipment sales from radio and broadcasting equipment, over half of which are from mobile telephone systems, increased from 36.0% in 1989 to 41.0% in 1994, while the share of switching equipment fell from 31.5% to 25.0%. High market growth in mobile systems, a main area of European strength, is expected to continue.

Imports of telecom equipment world-wide increased from 55.4 billion US in 1990 to 71.2 billion in 1993, giving an indication of growth rate and size of the world market. The EU-12 consistently ran an extra-EU trade surplus in line telephony equipment between 1984 and 1993, though there was a trade deficit for all telecom equipment in 1989, which moved into surplus by 1991. The advent of Finland and Sweden to the EU after 1995 should increase the extra-EU trade surplus because of mobile communication sales by both Ericsson and Nokia to American and Asian markets.

Patent application rates at the EPO for telecom equipment increased 319% between 1980 and 1991, partly because of a rapid increase in patenting by American and Japanese firms seeking to protect their innovations in the European market and an increase in patenting by Finnish firms. The increase in application rates for Germany and France were below average, at 97.8% and 99.3% respectively. These rates compare favourably, however, with an increase in patent applications of 78% by American firms in their home market of the US and do not, by themselves, suggest that French and German firms are technically lagging behind their competitors.

The success of the European telecom equipment sector is built upon technologically competitive products in a high R&D intensity industry. The high cost of product development in telecom equipment requires large markets and high sales to be able to recover R&D investments. The European single market, the successful GSM standard for mobile communications, and the procurement policies of national telecom service operators to favour national equipment manufacturers, have helped to ensure that these investments were economically feasible. National operators also invested heavily in upgrading public networks, thereby guiding the innovation agenda towards large public, switched systems.

Some of these past conditions for the success of the European telecom sector are changing, creating new hazards and market turbulence. The dominance of public network providers as the major purchasers of telecom equipment, and consequently as the driving force behind the innovation agenda, is declining, as the technology lead shifts to consumer premise equipment and private networks. A greater proportion of output is being sold to either business users, for example for Private Branch Exchange (PBX) and Computer Telephony Integration (CTI) systems, or to individuals, as with mobile phones and fax machines. The dominance of networks is also declining because of a global move towards the privatisation of telecom services and greater competition. This has often broken close relationships between telecom equipment manufacturers and the telecom service sector, opening up previously closed procurement markets to new competitors. This could have serious repercussions for less competitive European firms. The liberalization of telecom services in the US in 1982 and in the UK in 1984 is believed to be partly responsible for both countries moving from a trade surplus between 1978 and 1982 to a trade deficit in telecommunications equipment between 1983 and 1987 (OECD, 1991).

There are five key emerging technologies in telecom systems: 1) switching, transmission and network management, 2) the Intelligent Network, 3) mobile communications, 4) customer premise equipment and private networks, and 5) integrating fixed and mobile networks.

The success of some of these emerging technologies depends on their ability to overcome substantial public network and user commitment to existing legacy systems for switching, line and other equipment. The problem is often one of migration paths, or how to move from existing telecom systems to the "Information Society", based on high bandwidth systems capable of transmitting voice, data, and video. Other emerging technologies provide intermediate methods to upgrade existing systems, thereby extending their useful life, but delaying the introduction of more advanced technologies.

Many of the most advanced new systems take advantage of the computer power available at user terminals. One example is Asynchronous Transfer Mode (ATM), a technology for public networks. ATM can replace the use of central nodes for many switching and routing functions with the 'intelligence' of user terminals. A similar example is the Intelligent Network, which decentralises some network control tasks from centralised switching facilities to computer-operated nodes.

The diffusion of ATM is inhibited by five problem areas, some of which also affect the diffusion of other telecom technologies. These problem areas are: how to migrate to the new technology from existing systems, unsolved technical difficulties, delays in developing standards, conflicts between standards, for example for consumer premise equipment versus public networks or between countries, and price discrepancies between European networks.

Two major problems confront European telecom firms in the face of changing market structures and technological trends.

First, the technical capabilities of European telecom equipment firms are dangerously concentrated in the telecommunication side of network-based markets with major weaknesses in integrating telecom with computers and software. This is a serious problem because a common feature of many of the new technologies is the importance of increasing and decentralising system intelligence, which require greater processing capabilities and software. Furthermore, the European lead in telecommunication technology, though supported by EU programmes such as RACE and ESPRIT, is narrowing, while the European lag with its American and Asian competitors in the complementary computing and software technologies is *not* narrowing. European firms appear to strongly depend on joint ventures with non-European, mostly American firms, for these complementary technologies. Reliance upon non-European firms for the provision of the 'intelligence' to shape new network capabilities and service concepts will likely remain a structural feature of the European telecom industry for some time to come.

Second, the ability of European telecom equipment firms to control the content and pace of development of standards has historically been a major support mechanism for their product development strategies. This is breaking down because of the growing importance of computer and software firms to the development of standards and the concomitant decentralisation of standards development.

At the same time as these changing conditions are creating new hazards for the telecom equipment sector, new opportunities are opening up. Upgrading of the European telecommunication network to permit higher bandwidths, the blossoming of new markets in Eastern Europe, Latin America and Asia, and growing world-wide demand for mobile systems, all point toward market expansion and the potential for strengthening the competitive position of European firms. Maintaining this competitive position requires an aggressive innovation strategy to develop the equipment necessary to succeed in high-growth markets. Exploiting the opportunities in emerging markets could also require a different blend of capabilities, in which reducing manufacturing costs could equal the importance of product innovation.

The analyses of the CIS data focus on six areas that are of interest to innovation policy and the response by telecom firms to the challenges raised by technological trends. The six areas include the factors that determine whether or not a firm innovates and innovative success, the types of innovation that a firm undertakes, the importance of external sources of knowledge, particularly publicly funded research and technology acquisition from outside of Europe, the importance of an aggressive innovation strategy, the effect of regulation and other barriers to innovation, and the factors that influence the export rate. The analyses use the firm as the unit of analysis. Component firms and a group of other high technology firms, drawn from electronic equipment, office equipment and instruments, are used as comparison groups.

Firm size, measured by the number of employees, has a major influence on innovation by telecom firms. There is a strong, positive relationship between firm size and the probability of innovating, measures of innovative success, and between firm size and the proportion of innovative products in total firm sales. However, there is no relationship between firm size and export performance, or the percentage of exports in total sales. The lack of a relationship between firm size and exports could reflect dynamic, innovative activity among small and medium sized (SME) telecom firms, but a more plausible explanation is probably due to relatively *low* export rates by some large firms which sell a substantial proportion of their output to domestic telecom service firms or PTTs.

A higher proportion of the total innovation expenses of telecom firms is spent on R&D than for component and other hitech firms, but relatively more of this R&D component is focused on process instead of product innovation. This could have a beneficial effect on lowering costs. Both the R&D share and the focus of product innovation increase with the absolute level of R&D expenditures in the telecom sector, indicating that new product development is more common among larger telecom firms. The more successful innovative telecom firms spend a lower proportion of their R&D budget outside of the firm, indicating that success depends on the ability of firms to develop their own, internal innovative strengths.

European subsidies for public research appear to have had few positive impacts on the telecom sector. Public research is not rated as an important source of information by telecom firms, both in comparison with component and other hitech firms and in comparison with other information sources. This low rating overall disguises important differences by the type of public research. The most valuable public research source for telecom firms is government laboratories, while the type of research conducted at universities and technical institutes is considerably less important to telecom firms than, for example, for component firms.

Telecom firms that find public research to be an important source of information are more likely to be successful innovators, which is encouraging, given public subsidies for public research. However, the positive benefits of public research do not appear to be due to programmes to encourage cooperative R&D. Large, export-oriented telecom firms are most likely to participate in cooperative R&D programmes, but telecom firms with a high percentage of innovative products in their total sales are *less* likely to participate. Therefore, the positive value of public research on innovative success is probably due to informal or other means of acquiring knowledge from public research institutions rather than through cooperative R&D. A further, worrisome result is that firms that find public research of importance are less likely to pursue aggressive innovation strategies to create new markets outside of Europe and to develop new products. It is possible that public research is more oriented to the needs of firms that are pursuing defensive strategies than the needs of firms that are more likely to maintain European competitiveness in telecom equipment.

Telecom firms obtain new technologies from sources outside of Europe more frequently than component firms. This could reflect the acquisition of components and software technology from outside Europe, but unfortunately there is no information on the types of technologies that are acquired. Equipment purchases and communication with foreign firms are the most important means by which telecom firms acquire new technologies from outside of Europe. Both are linked to success, with a positive relationship between exports and communication with non-European firms and between innovative product share and equipment purchases from outside of Europe. The fact that telecom firms are acquiring needed technologies from outside of Europe suggests that the single market is not forming a barrier to sourcing material from other countries.

The ability to obtain new technologies from foreign sources, and the importance of these sources, are both strongly linked to the size of the firm. SMEs may benefit from programmes to assist them in acquiring expertise held by foreign, particularly American firms.

Telecom firms are less likely than component and other high tech firms to find aggressive innovative strategies to be important. However, the probability that firms will find several goals that are related to future export success - lowering costs, developing new products in the main product field, and creating foreign markets, increases with the share of the firm's sales from exports. These results, though admittedly sparse and exploratory, further suggest that the European telecom sector is relying too much on defensive innovation strategies, while export success is related to an aggressive strategy.

The relative failure of telecom firms to adopt aggressive innovative strategies, compared to component firms, could have been caused by protected national markets for telecom firms, rather than a displacement effect of the single market, whereby firms expend most of their effort on expanding their European market while neglecting foreign ones.

A more aggressive approach is particularly important for telecom firms with their main strengths in line telephony equipment. The loss of protected markets due to the liberalisation of telecom services, and stagnant markets in Europe, North America and Japan mean, that these firms must both move into new technologies that integrate telecom, computing and software, and aggressively pursue new markets in Asia.

The question on legislation and standards is not formulated in a way that is particularly useful for this sector. It is not possible to determine if the low importance attached to this factor by telecom compared to component and other hitech firms is due to the respondents perceiving legislation as basically advantageous, or if they are simply less likely to view legislation as a negative factor.

The importance of barriers to innovation is usually unrelated to the size of telecom firms. Of interest, firms with a high export share and a goal to create new foreign markets are more concerned about their internal capabilities to innovate and market uncertainty. This could reflect intense technological competition in export markets. This suggests that telecom firms that are export oriented and seeking to move into foreign markets, perhaps the most important firms for European competitiveness, could be confronting barriers in their ability to acquire skilled personnel and technical and market information. There are probably few short-term policy options to solve a lack of skilled personnel. Making it easier to hire staff from outside the EC does not appear to be a potential solution, since firms that hire staff from abroad are less innovative than firms that do not. We assume that these firms are using this strategy to catch-up technically, but that this is not a widespread solution. Conversely, close attention to the role of standards in reducing uncertainty could be of benefit.

INTRODUCTION

This report provides an overview of the innovative activities and strategies of the European telecom equipment sector in the early 1990s, using both publicly available data, for example on patents and technological trends, and analyses of the data gathered by the Community Innovation (CIS) survey. Though the focus of this study is innovation, additional results on production, trade, markets and employment are given in order to provide a full description of conditions in this sector. In addition, production and trade data can serve as proxy indictors of the technological competitiveness of an industry.

The European telecom equipment sector faces profound change, partly as a result of the privatisation of telecom services in many countries, and partly because of the development of a range of technological options for providing existing and future services. Privatisation occurred in the UK in 1984, and is either underway or planned in other EU member states in the late 1990s. These changes in the status of telecom services directly affects the European telecom equipment manufacturing sector because of the traditionally close commercial links between national service providers and major equipment vendors. Examples include the long-standing ties between Telecom France and Alcatel and between Deutsche Telekom and Siemens. Privatisation and open tendering for new equipment, as part of the EU competition policy, are likely to reduce these close commercial links between telecom equipment manufacturers and service providers and to expose the European telecom equipment sector to greater competition.

The CIS survey, mailed in 1993, provides a wealth of data on the innovative strategies of European telecom equipment manufacturers in Norway and in six EU countries: France, Germany, Italy, Ireland, the Netherlands, and Belgium[1]. The survey obtained subjective data on innovative strategies over the three year period between 1990 and 1992 and quantitative information on employment, sales, and R&D expenditures for 1992. This time period predates planned privatisation in these seven countries. Therefore, the results largely reflect innovative strategies in the telecom equipment sector *before* the major push to privatise services, though respondents would have been aware of the impact of future changes from following the effects of privatisation in the UK or the liberalisation of telecom markets in the US in 1982, and presumably would have begun preparing for privatisation. The timing of the CIS survey is also

[1] Though the CIS was also implemented in the remaining six EU countries of the UK, Denmark, Luxembourg, Spain, Greece, and Portugal, data limitations preclude using respondents from these countries, as explained in full in Part Two.

significant for one other reason - it was mailed during the worst economic conditions in the telecom sector for over a decade. After years of steadily growing production, the output of the EU telecom sector fell by 11.6% between the peak production year of 1992 and 1993.

The timing of the CIS questionnaire creates both a liability and an opportunity for research on the telecom sector. The liability is that the results for this sector may soon be outdated by the changes initiated by privatisation. Furthermore, some of the subjective questions, for example on barriers to innovation, could have been influenced by the 1993 recession in this sector, leading respondents to give relatively pessimistic responses. The opportunity is that the results provide a snapshot of conditions before the privatisation of telecom services that can be used as a baseline for future surveys of the telecom equipment sector after privatisation is completed.

The report that follows is divided into two main parts. Part One provides a general overview of current conditions in the sector, based on publicly available data. This review examines the current structure of the sector, including the main players, markets, export and import trends; patenting activity, and major technological trends, including the main factors such as standards and legacy technologies that influence the potential market success of new technologies. Part Two presents the results of the analyses of the CIS survey on the innovative activities of European firms. Many of these analyses focus on some of the main issues raised in Part One. The Conclusion is given as the Executive Summary and integrates the results of Part One and Part Two and discusses their policy significance. Additional information is provided in several appendices. Appendix A discusses several methodological problems that are raised by the CIS survey, including a comparison between estimates for production and exports based on CIS results and actual figures, and makes recommendations for the design of future innovation surveys of this sector. Appendix B provides additional background information for the general review of Part One and the CIS analyses of Part Two.

PART ONE

REVIEW OF THE TELECOM EQUIPMENT SECTOR

1 CURRENT STRUCTURE OF THE TELECOM EQUIPMENT SECTOR

There is no single definition of the telecom equipment sector that is used for all basic statistics on production, trade, and market size - the definition varies between different organisations and publications. A narrow definition is limited to a core group of line telephony equipment, consisting of switching and transmission equipment, telephones, and other terminal equipment such as fax machines and teletype units. A wider definition that forms the basis of major industrial classification systems such as NACE, ISIC, and SITC includes all line telephony equipment plus radio communications, mobile systems, and TV and radio broadcasting equipment, though they can also include some other products. An extended definition, used by some industry publications, recognizes the increasing importance of related software. The least satisfactory definition includes products that are only distantly related to communications equipment. This definition is often used in research where data is only available at the 2-digit level for NACE or ISIC classification systems (see Appendix B, Table B-1 for a summary of each definition).

Not surprisingly, how the telecom equipment sector is defined has a considerable impact on basic statistics for production, sales and exports. For example, the 1995 Panorama Report, using the narrow definition of the telecom sector, estimates that total production of telecom equipment in the four major European countries of France, Germany, Italy, and the UK was 14,566 million ECUs in 1993. An estimate based on the wide definition of telecom equipment is 53.8% higher, at 22,400 million ECUs (YWED, 1996). Wherever possible, this report uses the wide definition of the telecom equipment sector because it is also used to define telecom firms in the analyses of the CIS survey results. Furthermore, this definition includes radio communications equipment, which is one of the fastest growing telecom markets.

1.1 Major Telecom Equipment Firms

Table 1.1 lists the world's ten largest telecom equipment manufacturers, by 1994 sales using the extended definition of the telecom equipment sector, and their main products. Four firms are from EU countries: Alcatel, Siemens, Ericsson, and Nokia. Table 1.2 lists the 14 largest European telecom equipment firms, using 1992 sales data in order to provide direct comparison to CIS results, and the percentage of each firm's total sales from telecom equipment. Nine firms are from countries covered by the CIS survey. As shown in Table 1.2, there is a wide variation in the percentage of

Table 1.1	World's Ten Largest Telecom Equipment Manufacturers in 1994, based on sales (million US) of Telecom Equipment[1]			
	Firm	**Country**	**1994 Sales**	**Main Telecom Products**
1	AT&T	US	14279	Public & private network systems
2	Alcatel	France	14245	Public & private network systems
3	Motorola	US	14236	Mobile, data communication
4	Siemens	Germany	12156	Public & private network systems
5	Ericsson	Sweden	10485	Public, mobile network systems
6	NEC	Japan	10049	Public & private network systems
7	Nortel	Canada	8253	Public & private network systems
8	IBM	US	6200	Computer network systems & hardware
9	Fujitsu	Japan	4894	Public & private network systems
10	Nokia	Finland	3697	Mobile, public network products & systems

[1]:Source: Communications Week International, 7 November, 1995; 14 November 1994. Shaded lines identify European firms.

Table 1.2	Largest European Telecom Equipment Firms by Sales Revenues for 1992 - 1994 (Million US dollars) and the Percent of Total 1992 Sales from Telecom Equipment[1]				
Firm	**Country**	**1992**	**1993**	**1994**	**% Total 1992 sales from Telecom Equipment**
Alcatel	France	14856	14544	14245	52.7
Siemens	Germany	11223	11986	12156	24.3
Ericsson	Sweden	5749	7703	10485	84.8
Bosch	Germany	2543	2655	3071	13.5
GEC	UK	2255	1917	2221	11.6
Philips	Netherlands	2081	1831	1588	5.8
Sagem	France	1999	2049	1315	89.0
Italtel	Italy	1751	1558	1525	93.3
Matra Hachette	France	1508	1508	1679	15.8
Nokia	Finland	1431	2161	3697	48.9
BICC	UK	826	826	885	14.0
DeTeWe	Germany	761	721		83.4
Pirelli	Italy	746	768	749	13.1
Racal	UK	673	667	749	50.1

[1]:Source: Communications Week International, 7 November, 1995; 14 November 1994. Shaded lines identify countries included in the CIS analyses.

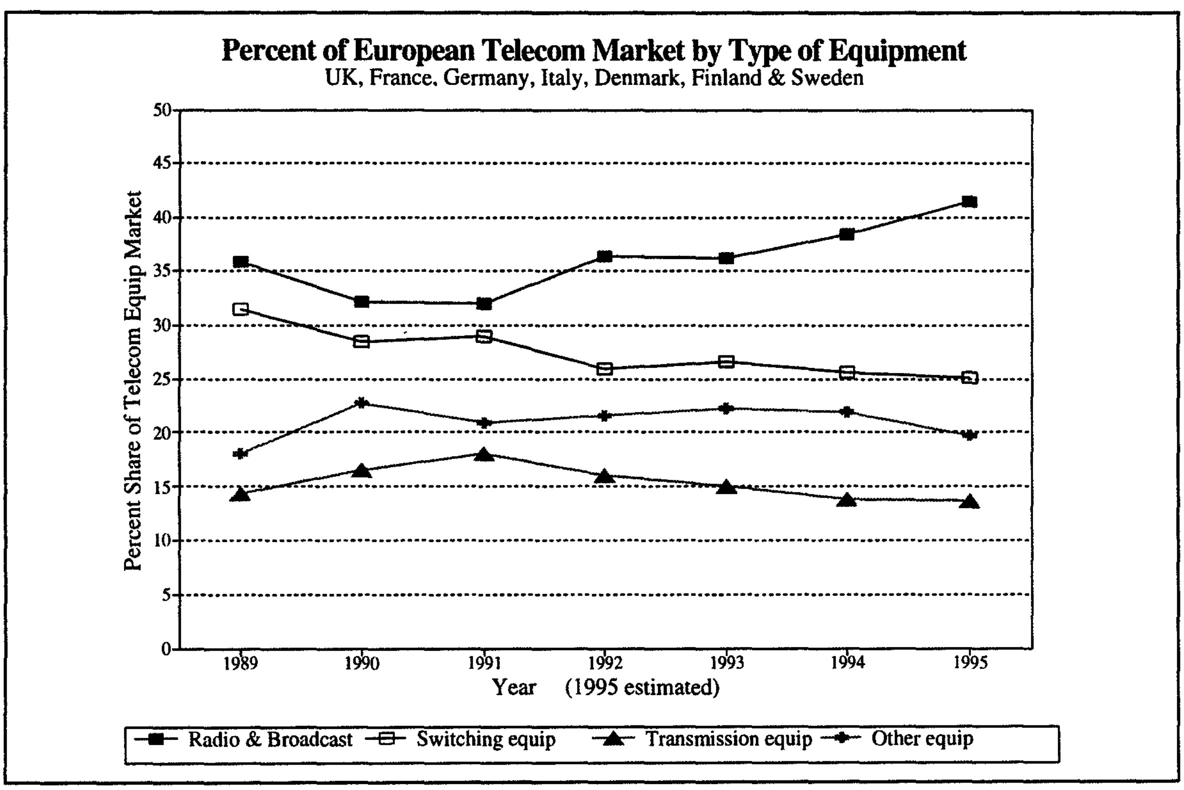
total sales from telecom equipment, which ranges from a high of 93.3% for Italtel to 5.8% for Philips. Between 1992 and 1994 the sales of the two largest firms, both producers of public and private network products, changed very little, while the sales of firms in mobile communications, such as Ericsson and Nokia, increased very rapidly. As a result, Nokia moved from 10th place in 1992 to fourth place in 1994.

1.2.Telecom Equipment Markets

Growth rates in the telecom equipment market during the 1980s ranged from 3% to 6% in the US, Japan and Europe (YWED, 1991). Between 1989 and 1992 the telecom equipment market in the EU-15 countries increased approximately 8% per year from 31.6 billion US to 39.5 billion US, before falling to 32.2 billion in the 1993 recession in this sector. Between 1993 and 1994 the market recovered, growing by 5.9% to 34.1 billion US (See Appendix Table B-2 for full results by EU country).

The generally consistent growth in European telecom markets, with the exception of the recession year of 1993, obscures notable differences in growth rates by the type of equipment, as shown by the market share results given in Figure 1 for seven

Figure 1



European countries for which detailed data by equipment type is available. The percentage of all telecom equipment sales[2] in Europe due to radio and broadcasting equipment, over half of which are from mobile telephone systems, increased from 36.0% in 1989 to 41.0% in 1994, while the share of switching equipment fell from 31.5% to 25.0%. In absolute terms, the market for all line telephony equipment declined from a peak of 26.2 billion US in 1991 to 21.2 billion US in 1995. Continuing high growth rates are expected in radio and broadcasting, as shown in Table 1.3, but the market in the four largest EU economies for all other types of telecom equipment is expected to continue to decline. Similar patterns are expected in the two other mature telecom markets of the US and Japan.

Table 1.4 Forecasted annual market growth (1993 - 1999) in Germany, France, the UK and Italy by type of telecom equipment

	Radio & broadcasting (incl mobile systems)	Switching equipment	Transmission equipment	Other (telephones, fax, etc)
Germany	7.0%	-2.0%	-1.0%	-1.0%
France	4.0%	-2.0%	-1.0%	-3.0%
UK	5.0%	-6.0%	-8.0%	-2.0%
Italy	8.0%	-4.0%	0.0%	-2.0%

Source: YWED, 1996

These differences in market growth are also reflected in the sales growth rates of the worlds largest telecom equipment firms. The sales-weighted growth, between 1993 and 1994, was 6% for the 18 largest firms, including Alcatel and Siemens, whose main telecom products were public and private network equipment, 25.6% for the 8 largest firms in data networking and software (with no European firms), and 33.7% for the 8 largest firms in mobile communication equipment, including Ericsson, Nokia, and Philips (derived from CWI, 1995b).

The stable or declining growth rate for network systems presents a worrisome challenge for European telecom firms such as Alcatel or Siemens that derive a substantial proportion of their sales from these products. However, two trends could permit network equipment markets to increase in the future. First, new markets for large-scale networks are opening up in Asia and Eastern Europe, though there is some evidence that the historical domination of the international telecom equipment market by European firms may have begun to weaken. During the 1980s the US and Japan picked up substantial new shares of developing markets at the expense of European firms (Neu and Schnöring, 1989). Second, new technical developments such

[2] Source: YWED (1992, 1994, 1996). Excludes sales of accessories and parts, since an unknown proportion are inputs into the four equipment classes presented in Figure 1 and Table 4.

as broadband networks require high-capacity systems produced by network equipment firms (EC, 1994). This would also increase the market for network systems in the currently saturated markets of Europe, North America and Japan.

Though the future market for some major European firms is turbulent, substantial strength remains among European producers. For example, in 1992 Alcatel claimed that it held 25% of the world market share in telecom equipment and that it was the number one supplier of digital switching equipment, public line transmission systems, and microwave systems (CCA, 1994). Similarly, Ericsson claimed that its AXE family of digital switching technologies had captured about 40% of the world market for mobile network switching by 1993. Although these estimates by the firms themselves are difficult to substantiate, they indicate that some of the leading European telecom equipment firms retain a strong position in international markets.

1.3 Telecom Equipment Production and Employment

Worldwide production of telecom equipment in 1990 by the major producing countries is given in Table 1.4. The best estimate for the wide definition, including line telephony and radio and broadcast equipment, is 116.5 billion US. The EU 15 produced 48.7 billion of this total, for a global share of approximately 41.8%. The estimate of world-wide production limited to line telephony equipment is 65.2 billion US. The share of the EU 15 is 27.4 billion or 42.2%.

Table 1.4 Total 1990 Production by the World's Largest Telecom Equipment Producing Countries (US million dollars)

	Line telephony equipment	Line telephony & radio/broadcast
Japan	14652	22393
US	15670	31510[1]
Europe[2]	28123	50359
Other[3]	6757	12054[4]
Total	65202	116316

Source: Panorama, 1995; YWED, 1992.

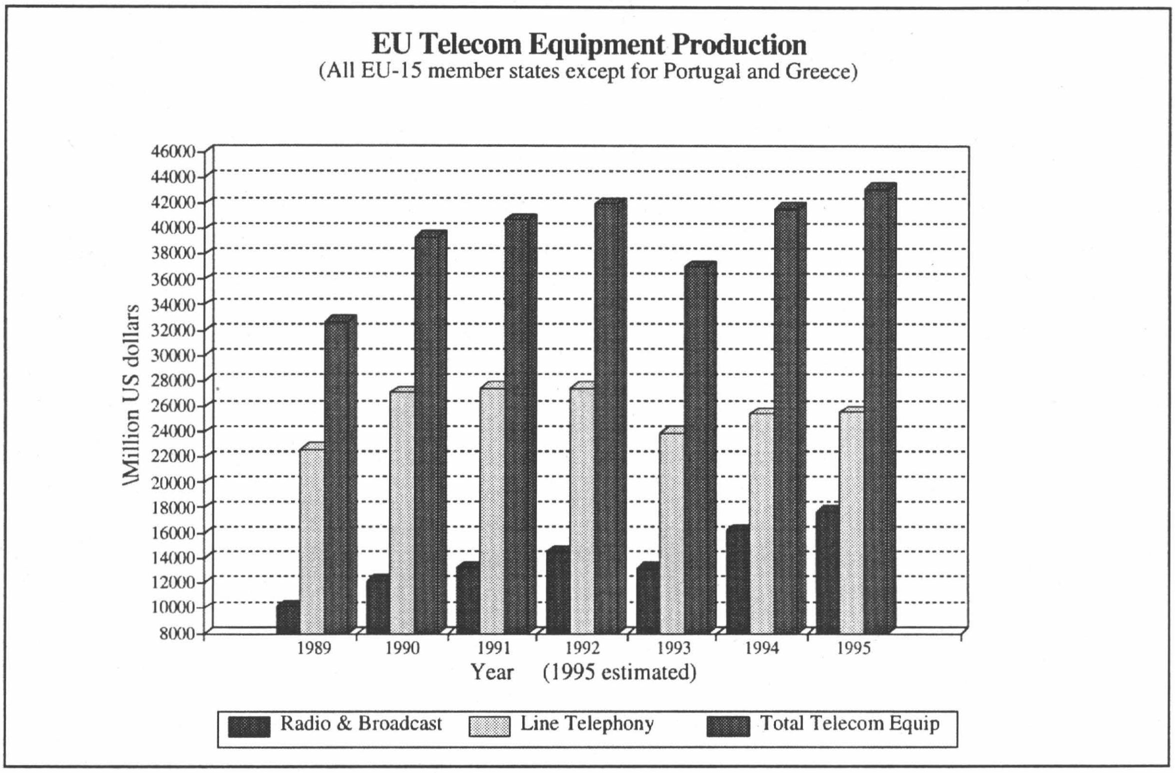
[1]: Excludes 16 billion for military/space applications.
[2]: EU 15 plus Norway and Switzerland.
[3]: Canada, South Korea, Taiwan and Brazil.
[4]: Estimated.

Figure 2 summarizes the production of telecom equipment in the 15 EU member states between 1989 and 1995[3] (See Appendix B, Table B-3 for total production by country). Results are given for radio and broadcast equipment, all line telephony equipment, and the total of both radio and broadcast and line telephony equipment. The peak production year for line

[3] Source: YWED, 1992, 1994, 1996. Production figures exclude imports and re-exports of finished goods. The data for radio and broadcast equipment includes related accessories and parts.

telephony equipment was 1992 at 27.4 billion US, compared to 25.5 billion in 1994.

Figure 2



In contrast, production of radio and broadcast equipment has increased considerably, from 12.2 billion US in 1990 to 16.2 billion US in 1994, or from 31.1% of total production in 1990 to 39.0% in 1994. The four main EU economies accounted for 74.6% of total production within the EU 15 in 1992 and 71.8% of production in 1995.

The percentage of total production in the high-growth sector of radio and broadcasting equipment varies by country. The percentage is below the European average for Germany, where radio and broadcast equipment accounted for 28.2% of total production in 1994, compared to 41.2% for France, and 50.7% for the three Scandinavian countries of Denmark, Sweden and Finland combined. The high percentage of radio and broadcast equipment in Scandinavia is largely due to the production of mobile phone equipment by Ericsson and Nokia.

1.3.1 Employment

The expansion of innovation-intensive industries such as aerospace, pharmaceuticals, and electronics sectors such as telecom equipment, were at one time believed to be essential to increasing European manufacturing employment. This view has been tempered with the realisation that employment gains can be minimal, as a result of high rates of productivity growth combined with intense international competition on price that can force firms to move some production to low-wage regions[4].

Employment data for the telecom equipment sector is incomplete because of differences in the methods used by countries to report employment in the electronics sectors. Incomplete time series data for at least two years is available for 10 EU countries plus Norway for either all electronic goods or a subcategory that includes telecom equipment (see Appendix B, Table B-4).

With the exception of Norway and particularly Ireland, employment in all electronics production, or for sub-categories limited to communication equipment, declined between 1986 and 1994. Employment in Ireland increased because of continuing new investment in assembly and related production by American, Japanese and other foreign firms that own 97% of the Irish electronics industry.The decline in employment in all other countries is not due to the recession of 1993, since employment also declined before 1992 when production was steadily increasing. The decline in employment in the telecom equipment sector is due to both rapid increases in labour productivity (EC, 1994) and to an increase in production outside of the home country (YWED, 1992, 1994, 1996).

1.4 R&D Expenditures and Public Funding of Telecom R&D

Reliable data on R&D expenditures in the telecom sector is sparse. The main problem is that many firms do not report their R&D expenditures by area of activity, but only give total R&D expenditures over all business units. Total expenditures on R&D is therefore an unreliable estimator of R&D expenditures on telecom for many firms such as Siemens, Bosch, GEC and Nokia with a substantial proportion of their sales in non-telecom products, as shown above in Table 1.2.

The available evidence, based on estimates of the proportion of R&D spent on telecom equipment or from surveys, indicates that the telecom equipment sector has one of the highest average R&D intensities (R&D expenditures/sales) of the main industrial sectors. An estimate for 1987, based on the world's nine largest telecom equipment firms[5], is for a sales-weighted R&D intensity of 9.52%. Sales-weighted estimates of average R&D intensities are available for 1992 from both the PACE study of Europe's largest industrial firms and from the CIS survey for both R&D performing

[4] The European Commission's recent *Green Paper on Innovation* (EC, 1995) takes a more realistic view of the effects of innovation on employment. The benefits are that a high rate of innovation can help to slow the rate of decline in manufacturing employment and shift the spectrum of work towards high-productivity and high-wage activities.

[5] OECD, 1991. Excludes AT&T, for which telecom sales included both equipment and services.

firms only and for all firms (see Appendix B, Table B-5). The sales-weighted R&D intensity for telecom equipment based on PACE is 7.35%, compared to approximately 11% in the CIS survey. Regardless of these differences, in both surveys telecom equipment is an R&D intensive sector compared to other industries, with notably higher intensities found only in aerospace and pharmaceuticals.

Several major European programmes that receive partial public funding, including EUREKA and the Framework Programme of the European Commission, have supported R&D in telecommunications, including both services and equipment, since the 1980s. Public support under the latter was 550 MECU for the second Framework Programme between 1987 and 1991, 548 MECU for the third programme between 1990 and 1994, and 630 million ECUs for the current, fourth programme which will run until 1998. However, funding for telecommunications, as a percentage of the total Framework budgets, has declined from 10.2% for the second programme to 5.1% for the fourth programme.

1.4 Import and Export Trends

For the world as a whole, imports of telecom equipment increased from 55.4 billion US in 1990 to 71.2 billion in 1993. Imports by the 15 EU countries have remained relatively stable at approximately 20 billion per year, while US imports increased from 11.8 billion in 1990 to 14.3 billion in 1993, and Japanese imports increased from 2 billion in 1990 to 2.8 billion in 1993. The fastest growth rate for imports, from 21.3 billion to 34.7 billion over the same time period, occurred outside of the three main blocks of Europe, the United States, and Japan (ITU, 1995). With a few exceptions, such as Canada, many of these countries have very small telecom equipment manufacturing industries and therefore offer large export markets to Japanese, American and European firms.

Exports and trade balances can serve as a proxy measure of competitiveness, since they are an indirect measure of how well firms from a specific country are able to compete in a world market.

Export and trade data is often dominated by a few firms exporting a limited line of products. This can create rapid changes in exports and therefore in trade balances. For example, a one billion US trade surplus in 1987 for Germany became a 0.4 billion trade deficit in 1991, while the Netherland's 1992 deficit of 0.4 billion in 1992 turned into a slight surplus one year later. These rapid swings suggest caution in using trade data as a measure of the competitiveness of the telecom equipment sector. Of the EU countries, Belgium, France, Denmark, Finland and Sweden ran trade surpluses in all of the years from 1987 to 1993 inclusive, while Italy, Norway, Greece, Portugal, Spain and Austria had consistent trade deficits (see Appendix B, Table B-6).

Figure 3

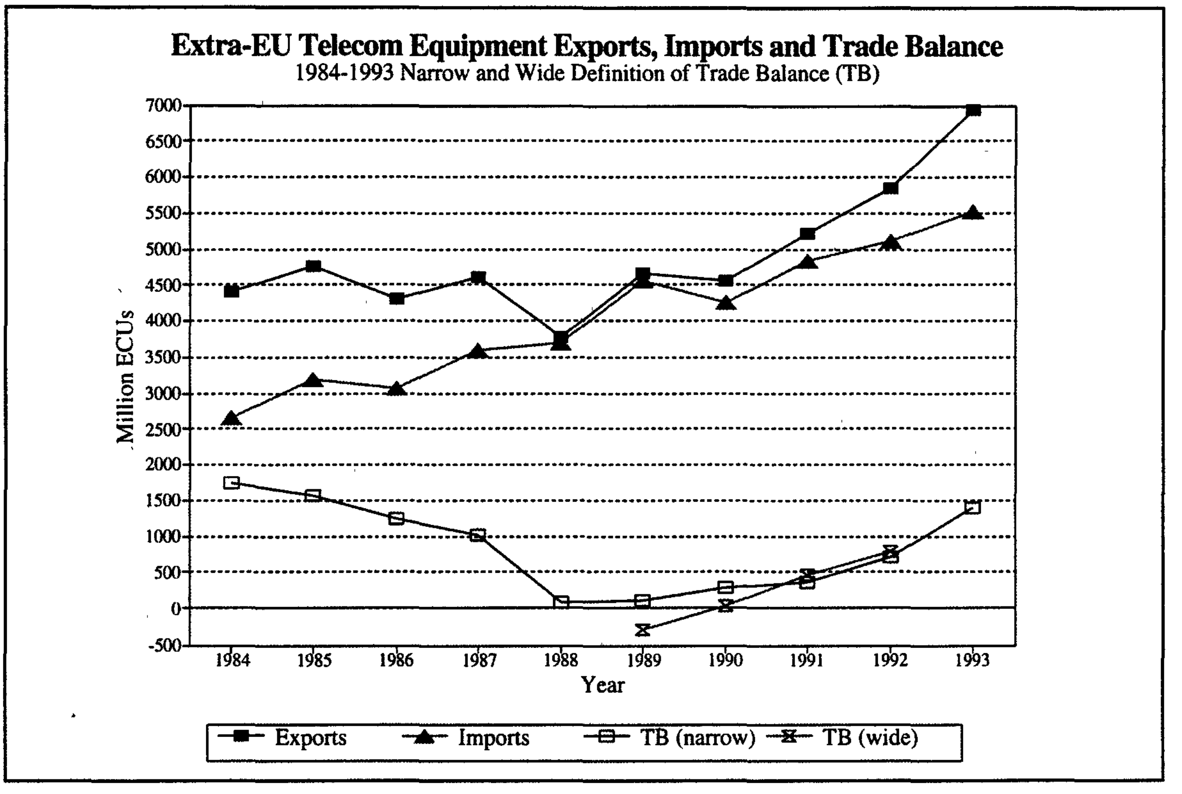


Figure 3 gives extra-EU trade data, based on total imports and exports into all 12 EU countries, between 1984 and 1993[6]. The export and import data are based on the narrow definition of telecom equipment, limited to line telephony equipment, while trade balance data appears to be available for both the narrow and wide definitions between 1989 and 1992. The results show that the EU has consistently run a trade surplus, using the narrow definition of telecom equipment, but the surplus was negative in 1989 using the wide definition and is much smaller for 1990 than the narrow definition. The trade surplus using the wide definition is slightly larger for 1991 and 1992 than that of the narrow definition. In 1993, most of the trade surplus for line telephony was due to a positive balance for switching and transmission equipment. The advent of Finland and Sweden to the EU after 1995 should increase the extra-EU trade surplus, using either definition, because of mobile telephone sales by both Ericsson and Nokia to American and Asian markets. On the other hand,

[6] Exports, imports, and the narrow trade balance are from the *Panorama of European Industry* (1995), Table 5. The trade balance data for the wide definition of the telecom sector is from *Communications Outlook*, Table 8.3 (OECD, 1995). However, this data is not fully described and may not fully cover radio and communication equipment.

using an extended definition that includes telecom software could reduce the trade surplus, though at this time there are no available trade statistics using this definition.

2 PATENTING BY EUROPEAN TELECOM FIRMS

The patenting activity of specific firms or by firms of a specific nationality has frequently been used as a measure of the technological competitiveness of firms or countries, on the assumption that the number of patents is positively correlated with competitiveness. Success in technical invention can then translate into increased sales, particularly in rapidly changing product groups such as telecom equipment. However, the accuracy with which patents can measure this type of competitiveness depends on a range of factors, including the propensity of a firm to patent its innovations (the percentage of innovations patented) and the technical value of each patent. The latter is particularly important, since patents vary enormously in both technical and economic value, but unfortunately no data on the value of telecom equipment patents is currently available[7]. If other factors such as differences in technical value are held constant, the ability of patents to measure technological competitiveness will increase with the propensity to patent in a given industry. For instance, patent count data is much more likely to capture technical competitiveness in an industry where firms patent 100% of their innovations than in an industry with very low patent propensity rates.

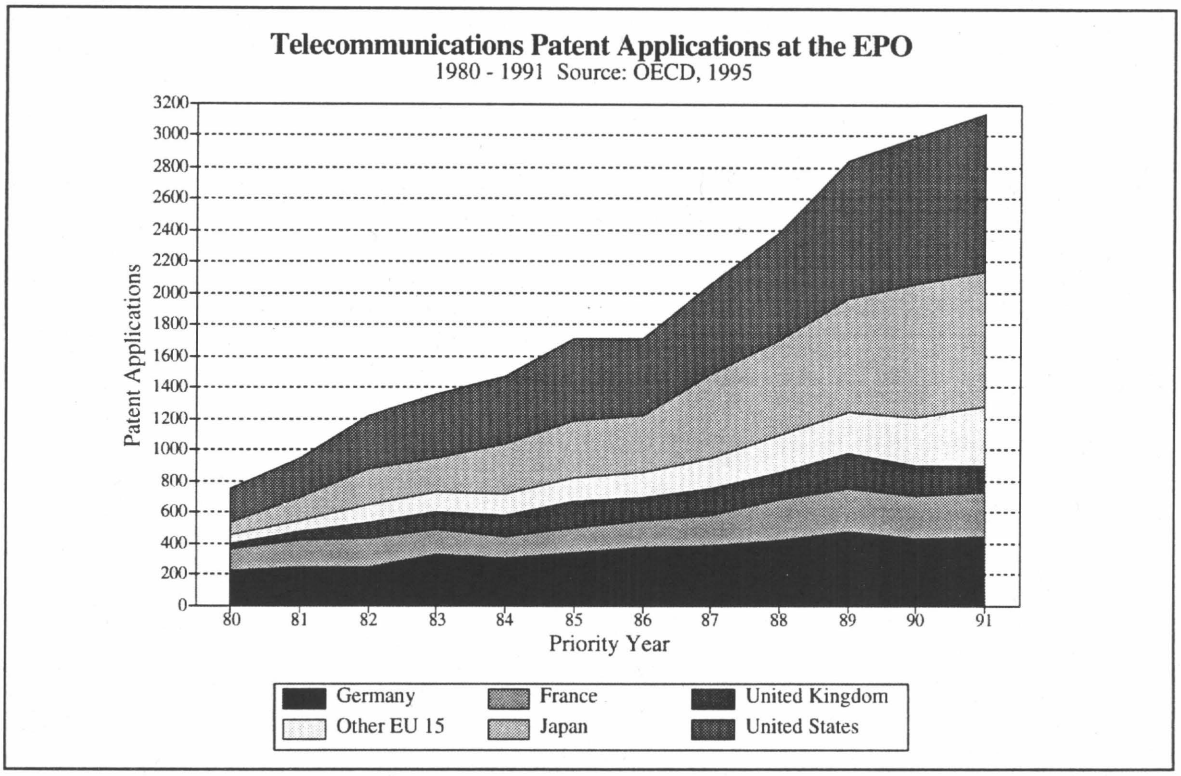
Patent propensity data is available for 16 industries in Europe from the PACE survey (Arundel et al, 1995). The mean propensity to patent product innovations is 40.1%, with a range from 16.7% in basic metals (ISIC 27) to 62.7% in pharmaceuticals (ISIC 2423). For process innovations, the mean is 28.0%, with a range from 14.6% for electrical equipment (ISIC 31) to 47.7% for petroleum products (ISIC 23). The patent propensity for telecom equipment is 42.5% for product innovations, which is slightly higher than the mean, and 17.3% for process innovations, which is considerably below the mean. These generally low patent propensity rates in the telecom sector suggest that caution must be used when using patent count data to measure of technological competitiveness.

Figure 4 presents the number of patent applications at the EPO for telecom equipment for the three main EU economies, all other EU-15 countries combined, the

[7] Trajenberg (1990), in a study of computer tomography equipment, establishes that the value of patents varies considerably.

US, and Japan[8].

Figure 4



Overall, there has been a 319% increase in patent applications for telecom equipment between 1980 and 1991. However, patent applications by German and French firms increased by only 97.8% and 99.3% respectively, compared to an increase of 323% for the UK, 500% for other EU 15 countries, 346% for the US, and 990% for Japan. The rapid increase in patents for American and Japanese firms is probably due to both an increase in inventive activity and expansion into the European market and the consequent need to apply for patents to protect their innovations within Europe. This latter interpretation is supported by the fact that patent applications by American firms in the US increased by only 78% over the same time period[9]. Conversely, the rapid increase in patent applications by other EU 15 countries is likely to reflect a much faster increase in innovation. Much of this increase is due to patent applications from Finland, whose share of patents in this group increased from less than 2% up until 1984 to 26% in 1991. Finland's share of total telecom equipment production

[8] The main international patent classification (IPC class) group for telecom equipment is HO4 (electric communication technique), with the exception of HO4S (Stereophonic systems).

[9] Data for the US patent office also includes electronic components. This will bias the true change in patent applications for telecom equipment by the difference between the patent application rate for components versus telecom equipment.

within the EU 15 also increased faster, between 1989 and 1990, than any other country (see Appendix B, Table B-2). In this case there appears to be a clear link between patent activity and future market success, but this is also because the patent data and production data for Finland measure the growth of a new industry.

It is more difficult to interpret the available patent data in terms of market success for the established telecom industries, particularly in Germany and France. French patent applications grew more rapidly than for Germany, while production grew more slowly. Any relationship between patents and production could be distorted by several factors, such as changes in the types of products produced by the telecom industry, differing patent propensity rates, the proportion of production conducted outside the home country, or semi-closed domestic markets, which can permit production to increase rapidly in response to new infrastructural investments without a large increase in technical inventiveness. Lacking more complete data at the firm level, it is difficult to conclude, for example, that the patent data suggest that French and German firms are falling behind in technological competitiveness. However, the patent data, combined with production data for specific areas of telecommunications, indicates that the rapid growth in both patents and production by other EU 15 countries is due to increasing technological strength by existing firms in Italy, the Netherlands, and Sweden in mobile communications and by new entrants in this technology by firms such as Nokia in Finland.

3 TECHNICAL TRENDS FOR TELECOM EQUIPMENT

3.1 Introduction

Innovation in the telecom equipment sector is subject to an arguably more complex set of influences than in many other industries. R&D provides an enormous number and variety of new technologies, albeit often at a very high research cost, but their successful implementation depends on a range of factors, including market demand, standards, legacy systems, and the need to combine several technologies.

Unlike other markets which are largely limited to individual consumer demand, the telecom market is influenced by individual consumers, public network demand, and the peculiarities of networks whereby their attractiveness to potential users increase with the number of other users. Standards interact with market forces by their crucial influence on the size of the potential market, thereby influencing the attractiveness of a technology to new users. The result is that it is impossible to disentangle technological trends in telecom equipment from the influence of market demand and standards. To complicate matters, telecommunications systems are based on substantial existing or legacy investments in switching, line and other equipment. The introduction of new technologies often faces strong operator and user commitment to these systems. This attracts investment in R&D to upgrade legacy systems to provide similar types of services, at lower cost, as those promised by new technologies.

In the following sections we look at the main technological trends in the telecom sector and the role of European firms in these developments. It is a complicated story where standards, markets, legacy systems, the need to combine technologies, and uncertainty continually influence the future direction of telecom systems. Telecom service firms face a range of new technologies that potentially offer extensive new services and capabilities. The problem is often one of migration paths, or how and what route will be chosen to move from existing legacy systems to the promised "Information Society", based on high bandwidth systems capable of transmitting voice, data, and video. The result of these movements can be compared to trying to negotiate a boat through a narrow passage in which wind direction, the prevailing current, and the presence of other boats must all be taken into account. The story is, not surprisingly, technically complex. Wherever possible, we have moved technical and other details to the footnotes.

3.2 The Main Emerging Telecom Technologies

There are five key emerging technologies in telecom systems: 1) switching, transmission and network management, 2) the Intelligent Network (IN), 3) mobile communications, 4) customer premise equipment and private networks, and 5) the integration of fixed and mobile networks. The discussion below outlines the technological trends, the factors influencing their success or failure, and the implications for European telecom equipment firms.

3.2.1 Switching, transmission and network management

Innovation in this field focuses on how to upgrade existing telephone systems to one that supports Integrated Broadband Communications (IBC). IBC is necessary for advanced services such as high speed data communication, interactive television, and video telephony. IBC requires new switching, transmission and network management concepts. Several alternative technologies and migratory paths are available.

The Plesiosynchronous Digital Hierarchy (PDH) environment was introduced in the 1970s for high speed transmission. Since then, the Synchronous Digital Hierarchy (SDH) has become generally available for public networks, although PDH networks still predominate. Many operators are moving towards SDH because of its superior capacity, reduced complexity and more advanced network management[10]. An important standard by the International Telecommunication Union (ITU) reconciles differences in SDH transmission speeds between European and American systems[11], broadening the market for SDH equipment and promising to increase its deployment.

The most *significant* new technology for public and private digital networks is the Asynchronous Transfer Mode (ATM) which uses short, digital data packets or "cells" of uniform length for voice, audiovisual, or data signals[12]. ATM is a considerable improvement over previous packet techniques because it is suitable for both the transmission of intermittent data bursts and for uninterrupted or real-time voice and image communication. ATM also promises to be suitable for both private computer and public networks, and it can interface with older microwave and coaxial cable systems as well as with newer optical systems.

Although many markets will continue to use PDH systems or migrate to SDH, the future shape of the public network, and hence the strategic planning of telecommunication suppliers and users, will be strongly influenced by the networking philosophy first embodied in ATM. ATM essentially reverses the long established approach in public networks to concentrate the switching and routing of network traffic at central nodes[13]. At full capacity, ATM can use the 'intelligence' available in advanced user terminals to perform most of the functions that are now performed by central switching facilities in public networks and by processors in private networks. This change offers significant advantages that have attracted the commercial interest of virtually every segment of the computer and telecommunication industries.

---

[10] PDH uses multiplexing of digital telecommunication messages (the combination of voice and data traffic into high speed, high capacity channels). SDH is also closely linked to the development of optical technologies and is designed to accommodate virtually all of the requirements of B-ISDN in an optical transmission environment.

[11] The ITU officially makes "recommendations", but we adopt the common usage of referring to these as standards.

[12] The cells include a header that routes the packet and an information field of 48 bytes. Although ATM is frequently promoted as a technology that developed after SDH and which will eventually replace SDH, ATM and SDH are closely linked. ATM principles evolved from Asynchronous Time Division Multiplexing (ATDM) a technique with antecedents extending back to the cell relay experiments carried out in the 1960s at AT&T's Bell Laboratories. Cell relay was ahead of its time because it required powerful computers that did not become available until the late 1970s.

[13] ATM goes beyond the Intelligent Network (IN) concept whereby some of this control is distributed to various decentralised network nodes.

However, five problems are currently inhibiting the diffusion of ATM. These are due to basic tensions in the telecommunication industry that have important implications for the strategies of suppliers and users of network-based services.

The first problem is how to implement ATM, which is largely linked to the availability of SDH networks[14] because of a decision by telecom operators to avoid a 'standards war' by agreeing to a standard to allow ATM to be used on SDH networks[15]. However, ATM does not require SDH and some experts argue that other systems, such as fibre-optic PDH networks, could be an acceptable vehicle for ATM. Second, ATM is by no means a stable or thoroughly tested technology for all potential uses, with technical problems with data loss for some uses[16]. Third, the ATM strategies of public operators have usually assumed that ATM would appear first in the public network and then diffuse to private networks. This assumption has meant that established European suppliers of network equipment have been slow to respond to the demand for consumer premise applications for ATM, thus leaving this market open to American competitors from the computer and software industries. The belated response has been a flurry of alliances between the major telecom equipment manufacturers and these American firms[17]. Fourth, some public networks in Europe charge high prices for broadband connections, reducing the potential market[18]. Finally, the established switch manufacturers and public network operators

---

[14] SDH is only beginning to appear as operators work out different technical options for migrating from PDH to SDH. Many PDH systems, first deployed in the mid-1970s, have reached or are approaching full depreciation and are ready for replacement. Most existing operators will likely adopt a mixture of migration strategies, but new operators in markets with some degree of infrastructure competition could base their services on SDH. Energis, for example, the UK electricity company, has recently received a license to offer telecom services and plans to build its entire network on SDH.

[15] The conflict was due to the commitment of Alcatel, AT&T, Fujitsu, and NorTel to ATM and other companies to SDH. A standards war would have caused both systems to suffer from divided markets and uncertainty.

[16] Many of the first ATM trials, mostly in private networks, experienced data loss problems because of switch software, specifically in buffer-management systems, that could not cope with high traffic volume or with the chaotic nature of ATM transmissions. Opinion is divided as to whether the solution lies in better buffer management, more buffer capacity, or increased circuit capacity. It is clear, however, that some marketed ATM products lack the technical capability to meet expectations.

[17] For example, Siemens is reselling ATM products developed by Cascade Communications, a US company. Siemens is also allied with Sun Microsystems and Scientific Atlanta over LAN and multi-media oriented ATM. Ericsson is engaged in similar joint ventures with Texas Instruments and Hewlett-Packard. AT&T, the large American telecom equipment firm, is also engaged in joint ventures with General DataComm to supply ATM products in China and the Netherlands.

[18] Although higher transmission rates are only marginally more expensive to provide, they normally incur substantially higher charges. Basic connection costs in France, for example, start at about US$ 8,000, as opposed to only US$ 650 in Germany. Depending upon the connection time per

have relied heavily upon the development of ATM standards by the ITU for public network use. However, the ATM Forum, an association of over 300 users and manufacturers of private network systems, moved more quickly and developed ATM standards for private networks first[19]. This has created problems in the development of compatible, industry-wide standards[20].

3.2.1.1 *The importance of Legacy systems*

The market potential of SDH and ATM is limited by substantial operator and user commitments to existing methods. For example, the customer base for some long-established but less advanced alternatives, such as X.25[21] and Frame Relay[22], continues to grow. This suggests that demand for broadband services may not be as great as suggested by their promoters. One possibility, that users are simply taking up older technologies because newer ones are not yet widely available, is doubtful. It appears that the primary consideration in the adoption of a technology, whether old or new, is the trade-off between its capabilities and the price of network services

---

day, however, prices in Germany for a 155 Mbps network cost up to 50 times that of an equivalent network in Finland. Discrepancies such as these are typical throughout Europe.

[19] Established telecom firms initially downplayed the importance of the ATM Forum, which is dominated by computer equipment and software vendors, though participation by established firms has since been increasing. The ATM Forum has been able to quickly incorporate technical changes into its standards and to operationalise standards developed by the ITU. In comparison, the ITU has been slower to adapt to technical advances. The market opportunity for vendors of private network equipment and software, and, hence, for the ATM Forum, was provided initially by the lack of ITU standards for customer premise equipment, except for defining the interface to public B-ISDN, since the ITU is not responsible for standards for customer equipment. This meant that the customer equipment manufacturers were able to develop and exploit ATM products for customers while public network operators and their equipment suppliers were still trying to secure further levels of standardisation through the ITU.

[20] There are actually three problems: how to develop industry-wide standards that resist the pressure of individual ATM suppliers to impose their products as *de facto* standards; how to control, assimilate, and coordinate standards developed by the ATM Forum and the ITU; and how to balance the ATM standards requirements of public and private networks.

[21] X.25, despite its low speed and unsuitability for anything but intermittent data transmission, is the only packet switching protocol that is supported by practically every public network operator. The European market for X.25 is still growing because of its record of reliability, relative stability, and user familiarity (PNE, 1995). X.25 is projected to rise from the current level of about 59% of the European market for packet switched services, to about 69% by 1997 (CN, 1994). Furthermore, X.25 has been upgraded from 64 Kbps to higher speeds. France Telecom, is now providing X.25 services at 2 Mbps.

[22] Frame Relay, one of the first approaches to fast packet switching, retains a substantial following, though in some cases, European Frame Relay applications are driven by the necessity to interface with US firms where the technique is well established. The main European market for Frame Relay supplements rather than replaces X.25. Despite the growth of Fame Relay, opinion is currently divided as to whether X.25 or Frame Relay will provide the best route to ATM.

and peripherals. This is partly illustrated through the case of narrowband ISDN.

Narrowband ISDN is a legacy system that is far from the leading edge of network technology, but which has grown rapidly after a period of dormancy[23]. The basic reason for this upsurge is that ISDN lines, depending on use and national tariff levels, are cheaper than alternatives[24]. This new confidence in ISDN is also a result of improvements in the stability of European ISDN standards and new commitments on the part of American suppliers outside of the telecommunication sector to provide ISDN products that flexibly meet user requirements[25].

The future of European ISDN, however, is far from certain. ISDN has resurged because of comparably higher prices for competing systems, continued commitments by suppliers, and favourable standards. These conditions could change rapidly. Furthermore, the cost of ISDN terminals that meet European standards is typically eight to ten times more than the cost of non-standard equipment. These equipment costs could significantly reduce the growth potential of ISDN in Europe. Conversely, a rapid decline in prices, as in the US for line charges and peripheral costs[26], could extend the lifespan of ISDN.

3.2.1.2 Trends in transmission technologies

There is now little question that the major European public network operators plan to upgrade their trunk line networks to optical fibre because it offers an enormous expansion of capacity. The timing and degree to which these new capabilities will be provided to medium and smaller users will be influenced by the rate of technical progress, cost reduction in fibre cabling methods, prospective demand, and the extent

---

[23] By the end of 1993, only about 345,000 basic rate ISDN lines, and 38,000 primary rate ISDN lines had been sold in Europe. However, connection commitments to the end of 1994 in the UK, France, and Germany alone were for 623,000 basic rate ISDN lines, and 51,000 primary rate lines (CWI, 1994a).

[24] Whereas a typical 64 Kbps leased line between two European countries involves a flat charge of approximately US$ 6,000 per month, an ISDN line can cost about US$ 50 per month in rental, and US$ 1 per minute in usage charges.

[25] INTEL has made a substantial commitment to ISDN video-conferencing through its ProShare Personal Conferencing Video System 2000, and has made agreements with US and European public network operators to offer an ISDN interface. LAN interconnection is another market segment that is opening up for ISDN, with US firms like Cisco committed to ISDN for its router products.

[26] A large US ISDN market has grown for Internet and teleworking remote access, driven by rapid price falls. Such remote access now holds about 60% of the US ISDN Market (CWI, 1995a).

of competition[27]. These factors will influence the answer to the question 'How close to the service delivery point should the optical fibre terminate[28]?

As debate continues on the viability of various strategies for fibre cable systems, a possible interim solution is to use advanced electronics to enhance the capacity of existing legacy systems, based on 'twisted pair' copper wiring, at a lower cost than optical fibre[29]. These technologies are most likely to be used by established public network operators as an interim means of exploiting their extensive installed base of copper wiring. It is a less attractive option for new market entrants that deploy their own transmission infrastructure, such as new cable television systems.

3.2.2 The Intelligent Network

Originally defined by Bellcore in the mid-1980s, the Intelligent Network (IN) represented the first major re-think of telecommunication networks since the advent of automatic switching (Mansell, 1993), and was designed to enable incumbent public network operators to meet some of the commercial challenges raised by rapid changes in technology and markets. Essentially, the IN decentralises some of the network control tasks from centralised switching facilities to computer-operated nodes. This increases the flexibility of the technology investment plans of public operators by reducing their dependence on large switching facilities.

All of the technical developments discussed so far can be implemented using IN architecture. The questions concern the extent to which the IN is actually *necessary or desirable*. The 'distributed intelligence' aspect of the IN, for example, is similar to the distributed switching philosophy of ATM. The difference is that ATM does not *require*

[27] In the UK, the regulatory decision to support infrastructure-based competition has encouraged operators like City of London Telecommunications (COLT) to chose fibre connections for business sites. However, cable television franchises, who also provide telecommunication services to their domestic customers, remain mostly committed to coaxial cable, even for curb-side cabling. Some, like Southwestern Bell, the cable television franchisee in the Birmingham area in the UK, have opted for a mix, with 'fibre to the curb' and coaxial cabling to the home. Elsewhere in Europe, a variety of plans have been announced, including ambitious fibre to the home plans in parts of Italy, Belgium, and The Netherlands.

[28] The issue is not the cost of fibre cable which has become comparable to other types of cable, but rather the costs of the electronics employed in optical transmission. The costs of these electronic systems is subject to substantial reduction through economies of scale and learning effects created by high volume production.

[29] Equipment costs for Asymmetrical Digital Subscriber Line (ADSL), the best established technology for upgrading the existing copper-wire networks, are between US$ 2,000 and US$ 3,000 per line as compared with the estimated US$ 3,000 to US$ 5,000 per line for fibre, but both sets of costs are projected to fall.

the IN. In fact, there is a growing body of opinion that the IN is the most cumbersome way of implementing ATM and similar technologies - i.e. 'Why bother nesting one distributed system within another distributed system?'. Another problem is that high-speed switched LAN and WAN systems that handle voice telephony can meet the need for computer-controlled service nodes in the public network.

Most importantly in the short to medium term, public network standards for the IN are not emerging quickly enough, with the standards programme several years behind schedule. Most IN systems either use proprietary standards, or standards drawn from the private consortia that are proliferating in the computer networking industry. At this time, international IN capabilities are dependent upon bilateral arrangements between national operators.

In spite of these difficulties, European network operators and equipment suppliers remain committed to the IN[30]. Furthermore, the market prospects are still uncertain for alternatives such as SDH and ATM, both of which are still 'horizon' technologies. There are also many possibilities for minor reconfigurations of the IN to improve its attractiveness for public networks. For example, several major European public networks are considering moving some of the 'intelligence' to customer premises.

In terms of future capabilities, the IN remains the principal technical framework for the further development of advanced forms of 'virtual networks', and 'personal' communications. If ATM represents a potential revolution in the philosophies of switching and transmission, the provision of 'virtual' and 'personal' communications represents a corresponding revolution in the means of providing services over public networks. This will involve integrating mobile and private network technologies, the subjects of the next two sections.

3.2.3 Mobile Public Network Technology

The development in Europe of various types of wireless communication technologies has been affected by a number of significant policy initiatives, both in the EU and in its member states, particularly the UK. Mobile telephony, in fact, was singled out by policy makers as a vehicle for liberalising segments of the European telecommunication market, to reduce the technology dominance of incumbent public monopolies, and to create a new pan-European infrastructure.

[30] Ericsson is developing IN applications for digital cellular telephony based upon its already dominant AXE mobile switching technology, and the IN capability developed at GPT was a major factor in the decision by Siemens to acquire a 40% share of GPT stock.

The original EC strategy was to support the development of two basic approaches to digital wireless telephony. The first, digital cellular telephony, improved on earlier analogue systems by adding a roaming capacity which allows the same cellular telephone to be used in any national network. The second, digital cordless telephony, requires the user to be close to a fixed terminal that provides the radio interface. This system does not always allow a user to receive calls. The EU strategy has since been extended to include Personal Communication Networks (PCN), which forms the 'third leg' of its mobile communication strategy, though market response outside of the UK is limited[31].

The first approach was embodied in the Global System for Mobile Communications (GSM) standard, and the second in Digital European Cordless Telephony (DECT). Both received substantial political backing from the EU, and, in the case of DECT, financial backing as well. The original EU strategy has partly been overtaken, although unevenly throughout the EU countries, by changing market and technological conditions. Nevertheless, the EU remains strongly committed to GSM and DECT as the two core standards for a pan-European mobile services network. In contrast, the major European telecom firms have a strong commitment to the further development of GSM, but an uncertain commitment to DECT.

GSM is a very successful European standard and a strong contender to become the internationally accepted standard for digital cellular telephony[32]. The future of GSM, however, may depend on how well it is accepted in the US. In addition, a key strategic problem for European manufacturers of GSM products is to maintain a single GSM standard. Ironically, one of the most attractive features of GSM to users - its roaming capability - is also one of the chief impediments to its international success. Ensuring roaming capacity requires complex international administrative agreements that are very difficult to negotiate in a way that meets the criteria of the

[31] PCN employs low power terminals and micro-cellular technologies. PCN has undergone a number of revisions in different national markets, most significantly in the US where the idea of providing world-wide PCN networks through satellites gained prominence. Initially, this system was promoted by the Iridium project fronted by Motorola, but other consortia have since formed, with Globalstar attracting major commitments from European public network operators.

[32] There are currently about five million GSM subscribers world-wide, and this is expected to exceed eight million by the end of 1995 (PNE, 1995a). GSM is rapidly replacing analogue cellular services in most major European markets, and is achieving significant penetration in Asian markets. GSM is estimated to have captured more than 80% of the existing subscriber base for digital cellular telephony (CI, 1995b). Planning is also underway to upgrade the GSM standard to increase the number of user channels. This major evolution to a Phase 2 GSM standard would support data, fax and supplementary services. While GSM is presently limited to voice grade services, the mobile data capability is particularly significant in the light of recent forecasts that this market may approach US$ 1bn by the turn of the century (PNE, 1995b).

European Telecommunication Standards Institute (ETSI).

Although heavily promoted by the EU as the second leg of its strategy for wireless telephony, DECT is still seeking a market role to supplement that of GSM[33]. DECT-based systems originally suffered from an inability to receive calls. Ericsson has invested heavily in a two-way version that could both send and receive calls (CT3).

The capabilities of DECT go substantially beyond simple cordless telephony, since it can be configured to offer many of the same services as emerging GSM and PCN standards. The two most promising markets for DECT products are cordless PBXs, discussed below, and wireless local loop applications. The latter was first introduced in Europe by Deutsche Telekom, using its NMT technology, to increase telecom services in former East Germany[34]. However, the future of DECT is unclear, partly because other technologies such as GSM offer better and more flexible services.

3.2.4 Customer Premises Equipment and Private Networking

Distinctions between the capabilities of public and private networks are disappearing quickly. It is often argued that only regulatory definitions continue to distinguish the two, but such arguments understate the commercial significance of historical differences between these networks and the market structures of the computing and telecommunication sectors. The technology options for a private network are still determined by these historical differences and by their effects on the R&D alliances among equipment manufacturers in both sectors. Three main customer premise technologies are discussed below: private branch exchanges (PBX), Computer Telephony Integration (CTI) systems, and Local Area Networks (LAN).

Private branch exchanges (PBX): PBX equipment was first introduced to reduce the cost of internal calls within a company by avoiding the need to purchase new lines from the public network. Currently, PBX is gradually being combined with other

[33] The original goal of the DECT programme was to stop the proliferation of cordless telephones in Europe that did not conform to any recognised standard. However, the potential to use the same handset at multiple base stations was soon recognised. In the late 1980s, a UK-developed technology, Cordless Telephony 2 (CT2), was promoted as an alternative to pay-phones. CT2 was later taken up again in North America by Nortel and Motorola, where a duplex version (CT2-plus) was introduced into several US and Canadian markets.

[34] Since then, several systems have been installed or planned, using different technologies. Ionica is licensed to provide competitive local loop access to the British Telecom network and is using its own technology, developed with Nortel. Telefónica d'España, is employing Motorola's 'WiLL' products to provide some 500,000 fixed cellular customer drops in rural areas. Likewise, in Hungary, HTC is employing Ericsson's 'RAS 1000' products in the local loop, although a Hungarian cellular operator, Pannon, is planning to use a GSM interface.

technologies that allow the transmission of both voice and data and by Computer Telephony Integration (CTI), which allows desk-top PCs to perform telephony functions. The commitment of all of the major European telecom equipment suppliers to the development of PBX and other private network technologies, usually referred to as business networks, are growing substantially[35].

The first response of public network operators to growing PBX use was Centrex, a system for emulating PBX functions using the public network. Centrex was essentially a pricing strategy to reduce the cost of using the public network for internal calls. Although Centrex was widely accepted in the US by the 1970s, Centrex was not offered in Europe until the 1980s. Acceptance in Europe has been slow because of a lack of pricing incentives, since both PBX equipment and Centrex were only available from the same public monopoly. Centrex has since achieved a modest market share in the UK, but most of Europe is still slow to adopt Centrex.

Where competitive equipment provision is allowed, Centrex, and later VPN, exploit two potential weaknesses in the structure of the PBX market. First, the capital cost of PBX equipment can be high relative to its capabilities over its life span. Second, the PBX customer is dependent upon the PBX supplier for any changes to its system because of a lack of non-proprietary PBX standards. In contrast, Centrex users require no investment in on-site technology and the cost of reconfiguring their internal networks is usually less than reconfiguring a PBX.

VPN originally extended Centrex services by using the public network to link individual Centrex or PBX installations for both local and long-distance calls. Its commercial possibilities therefore depended on its technical ability to link different PBX systems. This has encouraged the major equipment firms to develop non-proprietary inter-PBX signalling protocols, though most VPNs use proprietary signalling protocols[36]. In the past ten years, a move has been underway to develop a non-proprietary standard interface. One result would be the provision of more open

---

[35] As of mid-1994, Alcatel claimed to be the third largest supplier of business systems world-wide. By 1993, some 30% of Ericsson's revenues were generated by the business network market as opposed to only about 20% from public network equipment. The purchase by Siemens of a stake in GPT was in large part inspired by the desire to increase the 'intelligent' business systems profile of Siemens. Alcatel, Siemens, Ericsson, and GPT are engaged in a number of R&D projects, mostly with US-based computer equipment and software suppliers, to develop 'intelligent' business networks that combine PBX, B-ISDN and CTI capabilities (MDIS, 1994).

[36] The ISDN-based Digital Private Network Signalling System (DPNSS), proprietary to British Telecom, is currently among the most widely used inter-PBX interfaces, with a world-wide base of about 2 million users but it is only one of four major proprietary standards. Other standards have been developed in the US, Japan, and Australia.

and flexible conditions for VPN[37]. Q.sig, a new standard developed out of an Alcatel initiative[38], allows more intelligent signalling between PBXs in an ISDN framework, and is a migratory route to inter-PBX broadband services.

Q.sig is an attractive alternative to proprietary standards in the UK, France and Germany. However, Q.sig is not completely compatible with the US, Japanese and Australian systems and there are problems with the certification procedure and in aligning different versions of the standard. The primary problem with Q.sig, however, is that public operators and equipment firms are not equally committed to its adoption. The equipment suppliers would like Q.sig to be immediately implemented as the primary VPN access, while public operators largely favour retaining proprietary protocols over the short to medium term[39].

Computer-Telephony Integration: CTI systems link desktop computers to voice switches and advanced telephone handsets. CTI's first commercial use was to handle customer inquiries. Using the 'call line identification' and related capabilities of modern electronic switches, company employees can automatically retrieve customer data files in response to the customer's incoming telephone number, or to previously assigned registration numbers that customers can key in to their telephone. CTI has developed in three directions; call centres, voice cards, and PC-based voice processing[40]. Voice

---

[37] Another variation on VPN is Switched Mulit-megabit Data Services. Like VPN, SMDS is less a new technology than a new approach to configuring and marketing existing network capabilities. SMDS is a is a 'fast packet' approach with built-in security mechanisms, capable of delivering high 'on-demand' bandwidth for data services using public network facilities. Although still at the trial stage in most markets, SMDS is emerging as a serious option in the US and a possible option in the UK. An SMDS Interest Group has been formed, led by AT&T and Bellcore, that includes the European telecom equipment firms Alcatel, Siemens, Ericsson and GPT, public network operators in the Netherlands, Sweden and Italy, and US-based computer firms Digital Equipment and Hewlett-Packard.

[38] An Alcatel initiative to provide an alternative to British Telecom's proprietary standard DPNSS grew into IPNS, an international standard for an inter-PBX interface. The IPNS Forum is a consortia of European and North American telecom equipment firms committed to this goal. The members are Alcatel, AT&T, Ericsson, GPT, Italtel, Matra, Nortel, Philips, Siemens, and Bosch-Telenorma. The basic IPNS product is 'Q.sig', a standard first defined by the European Computer Manufacturers Association (ECMA). Q-sig was subsequently adopted by the European Telecommunications Standards Institute (ETSI) and the International Organisation for Standardisation (ISO). Q.sig takes its name from the designation of the mid-point between PBX configurations as point 'Q'. It is ISDN compatible and nearly 100% compatible with DPNSS.

[39] To date, the only significant application of Q.sig is between British Rail and SNCF, the French railway company, where it links the private networks, based on different proprietary protocols, of both railways. The need for a link was created by the Channel tunnel.

[40] The market for call centres has evolved considerably from a centralised to a distributed computing environment. IBM's CallPath, for example, originally a mini and mainframe application, has moved into a PC-based client/server environment. The market for PC voice cards is also growing,

applications in the latter two directions are becoming more closely related because of standards and the difficulties in establishing stable CTI markets[41].

Both the applications software firm Microsoft and the network software firm Novell are developing CTI, but using different technical approaches[42]. European PBX vendors are developing CTI capabilities largely in collaboration with US computer vendors and software firms. Siemens is allied with IBM, and Ericsson is allied with IBM, Intel, and Novell.

Switched Local Area Networks (LAN): As LAN applications require higher transmission speeds, LANs are increasingly moving to switched hub architectures. The market for switched hubs, which was worth US$ 90 million in 1993, is estimated to approach US$ 600 million in 1996 and 1.2 billion in 1998 (CI, 1995b). Given the integration between LAN and PBX environments, and the increasing profile of ATM in LAN technology planning, this migration from hub-and-router to switched hub technologies is potentially significant for the manufacturers of public network and PBX switching equipment.

3.2.4.1 The future of PBX

Digital PBXs are commonly referred to as a 'fourth generation' technology for customer premises, but it has not changed substantially since it was first introduced in the early 1980s. Even though most of the PBX equipment purchased in the early to mid 1980s is now coming to the end of its useful life, 'fifth generation' PBX is not likely. Instead, equipment firms are trying to integrate PBX, LAN, and PC environments by adding computer processing power to their newer PBX lines. Thus, some new PBXs may become 'intelligent' by being able to perform some of the

---

but the European presence in this segment is modest, with most of the larger switch manufacturers concentrating instead on multi-media interfaces incorporating video images. Active players in the voice card market are typically specialised, US-based firms like Dialogic and Rhetorix. PC-based voice processing involves interactive voice response and messaging.

[41] The first CTI standard, the Multi-Vendor Integration Protocol (MVIP), emerged in 1990, the product of a collaboration among a small group of CTI vendors. In 1993, however, Dialogic brought out its Signal Computing System Architecture (SCSA), a proprietary system. An SCSA advisory council has subsequently been set up and currently has over 100 members, with about 260 additional firms supporting the standard (CI, 1995a). Although originating in the stand-alone PC environment, SCSA has migrated into distributed computing environments, and is now claimed to support virtually the whole range of telephony service scenarios. Whereas MVIP currently has the larger share of the market, SCSA promises more in the way of broadband applications.

[42] Microsoft is stressing desktop-mounted CTI where the PC controls the telephone handset. Conversely, Novell, is stressing the network server approach and is co-ordinating its products with PBX developments through the co-development of a standard application programming interface.

control, management, and enhancement functions that are now being done outside the PBX, for example by PCs[43].

The pressing question is how PBX will migrate to a broadband environment. To date, even the move to ISDN-PBX has not been made by all PBX manufacturers, thus raising questions about their possible strategies for incorporating new systems concepts like ATM. The ISDN strategies of the major European manufacturers vary, with Alcatel supporting one strategy and Ericsson keeping its options open[44].

A potential new market for PBX and a possible way to leapfrog to ISDN and broadband interfaces is wireless customer premises equipment. The advantage of wireless technologies is that they eliminate much of the need to reconfigure PBX systems to accommodate the movement of employees and departments from one location to another. GPT was an early entrant into this market, but the results have been uncertain. A major problem is the conflict between standards. Although DECT is suitable for PBX applications, it is relatively complex and costly to implement. CT2 is simpler and cheaper but offers less technical scope than DECT. The situation is further complicated by EU support of DECT over CT2 for all European cordless services. Moreover, although Ericsson is committed to using DECT in Europe, its proprietary CT3 technology is at the core of much of its export strategy.

3.2.5. Integrating Fixed and Mobile Networks

A potentially important new market is 'personal communication' systems that allow users to transfer their own personal telecommunications account among networks and terminals (CI, 1995c). The success of this system depends on providing the high level of network intelligence required to locate the user's position, authenticate the agreed service profile, and deliver the service. This could emerge as the most important medium-term market opportunity for the IN, but the eventual form of this network intelligence is open to speculation. Three competing approaches, largely based on public networks, are described below. None have been implemented to any substantial degree, but their progress has potentially important implications for the commercial strategies of European equipment firms.

[43] GPT, for example, is developing an interface to IBM's CallPath CTI systems. The most important developments in this area, however, are occurring in the US, particularly between AT&T and Novell.

[44] Alcatel helped secure a Memorandum of Understanding in 1994 with AT&T, Ericsson, GPT, Matra, Nortel, Philips, Siemens, Telenorma, Italtel, Ascom, and SAT to test multi-vendor ISDN PBX interconnection based on ETSI/ECMA Q.sig standards. Ericsson, however, remains committed to both Q.sig and DPNSS.

Universal Personal Telecommunications (UPT) defines the building blocks for personal access systems. The basic idea of UPT is to separate the number from the terminal. The UPT number is thus a 'personal' number that can be linked to any available terminal, fixed or mobile, in both public and private networks. UPT standards have been developed for voice telephone and are being upgraded for other services[45].

The major problems with UPT concern third-party protection and supplementary services. UPT users must 'register' their location on the nearest available terminal. In many cases, the procedure involves 'borrowing' a terminal from another party. Devising a way to protect the 'lending' party from paying for the costs of the UPT user is one of the chief obstacles to the further development of UPT[46]. Due to these problems, full UPT implementation involving the integration of all types of networks may be a distant goal. UPT is more likely to be useful for limited environments that integrate the current proliferation of radio-based systems.

Personal Communication Systems (PCS) combine terminal-based mobile communication techniques with intelligent 'personal mobility' capabilities - essentially a mixture of UPT and terminal-based mobile telephony. PCS has become an influential model for the future development of mobile services in the US, where the Federal Communications Commission (FCC) has already auctioned radio spectrum to prospective PCS providers.

For European telecom equipment firms, the most important aspect of American support for PCS is that PCS could harm the acceptance GSM in the US, depending on whether or not GSM is taken up by US PCS operators. DCS 1800, the micro-cellular variant of GSM that was originally developed for the European PCN market, has been implemented in the US market using a different frequency[47]. A major part

[45] Early attempts at UPT were little more than highly automated call forwarding services, and were confined to national markets (the only extensive service offering is in Australia). UPT is now being defined in the ITU Standardisation Bureau (ITU-T), ETSI, and the US 'T1' Committee. At present it consists basically of the UPT Service Set 1 as defined in ITU-T Draft Recommendation F.851, and in the ITU-T Recommendation E.168 on UPT numbering (based upon the E.164 Recommendation - ISDN Numbering Plan). Service Set 1 supports basic PSTN, ISDN and land-based mobile network services. Service Set 2 is under development, and is intended to support the whole range of ISDN supplementary services.

[46] The problem is compounded for UPT Service Set 2 in that no mechanism is yet clear to enable interaction between the 'host' user's supplementary service profile, and that of the 'visiting' user.

[47] The European 1.8 Ghz PCN band allocation is set at 1.9 Ghz in the US. There are concerns that DCS 1900 will gain only the support of a small number of new US PCS licensees. A version of DECT at 1.9 Ghz is also a contender in the US for applications based on smaller cell sizes for mobile systems that permit the addition of more users or higher capacity connections necessary for advanced

of the problem is the strategic decision of AT&T to link PCS to a change in the technical standard for digital transmissions to permit higher capacities[48]. The new standard will be incompatible with the current GSM standard. As yet, Europe has not responded to this new, upgraded, standard, making it possible that GSM will be bypassed in the US market.

Universal Mobile Telecommunications Service (UMTS) provides an alternative to the myriad of separate technology and service domains for current land-based mobile communications systems. For several years, plans have been discussed in the ITU to migrate from these systems to a single service environment[49].

The aim of UMTS is to offer global coverage for voice and low to medium bit rate services that are ISDN compatible, along with more localised coverage for higher bandwidth services. The provision of UMTS, however, depends upon successful R&D to solve several problems with battery technology, integrated circuitry, end-to-end encryption, and multi-mode, multi-cellular interfaces to enable the dynamic use of cells of different sizes and power levels. Perhaps the most critical need is to develop the required network intelligence, using either the IN or some other method.

3.3 Conclusion: Technological Trends and European Competitiveness

This review identifies the main technological trends for telecom equipment and illustrates the important role of non-technical factors on these trends. Among the most important of these factors are standards and the role of legacy systems and market demand on migration routes.

Conflicts over standards, for example between ATM and SDH, delays in introducing standards, as in the slow response of the ITU to develop ATM standards for public networks, and a lack of international agreement over standards, can fragment

communication services.

[48] AT&T plans to migrate from FDMA and TDMA (the core multiplexing technologies of GSM and DECT) to Code Division Multiple Access (CDMA) multiplexing. Some estimates are that CDMA offers as much as 20 times TDMA capacity for mobile communications, but its reliability is still considered by some of AT&T's competitors to be unproven. The choices are (1) commit to CDMA now in the expectation that CDMA will be sufficiently developed by the time PCS services actually roll out (the AT&T strategy), or (2) split the commitment by implementing TDMA now and migrating to CDMA. Although the use of CDMA is being discussed in GSM circles, no co-ordinated strategy has emerged.

[49] This ITU programme is referred to as the Future Public Land Mobile Telecommunication System (FPLMTS). The European version of FPLMTS is the Universal Mobile Telecommunications Service (UMTS), a project that received its initial impetus in the RACE programme, and is now largely administered by the ETSI Special Mobile Group 5 (SMG-5). The spectrum allocation for UMTS is 230 Mhz in the 1.8 - 2.2 Ghz band -roughly the same band allocation as for PCN and PCS.

markets, create uncertainty, and promote market turbulence. Yet harmonised international standards are a two-edged sword. They allow European producers to gain markets outside of Europe but they also open European markets to foreign competition. This is the case for a variety of equipment used in ATM and in virtual private networks. The interaction between standards and innovation is also complex. Innovation that offers greater technological capabilities can force changes to existing standards, but this can create problems for technologies based on the earlier standard. The potential conflict between PCS and GSM in the US is an example. As in Europe, decisions in North America on standards are viewed strategically as a means to create critical market sizes and to support the technological capabilities of American firms.

Uncertainty over migration routes to new technologies is increasing risk and market turbulence. The current enthusiasm for multi-media and the "Information Society", dependent on high bandwidth technologies, hides the fact that most of the current European market for public and private voice and data services still relies upon fairly old technology. Even in cases where migration to newer technologies occurs, it is often for the purpose of providing existing services more reliably or cheaply, and not because higher bandwidths are desired. In this respect the continual technical improvement of legacy systems remains an important market segment in Europe and elsewhere. Public operators are unlikely, for some time to come, to abandon their commitments to 'intermediate' systems such as the Intelligent Network in the face of even newer technologies such as ATM.

Yet, the general trend in the evolution of network technology is to provide more bandwidth, either through adapting legacy systems or by introducing new technologies to respond to the growing information content of modern business and the increasing opportunities for delivering advanced consumer services. This trend can be divided into two components; to provide greater bandwidth flexibly according to demand, and to decentralise control over the network functions that use this bandwidth. However, since there is often a large gap between the development rate of new technology and the growth of new markets to use these technologies, the dominant factor influencing the future shape of telecom services is not technological, but the migratory paths that will most likely be followed to get from one technology to another: PDH to SDH, SDH to ATM, GSM to PCS and so forth. In Europe, the choice of a migratory route is not only affected by legacy systems and demand factors, but also by the discrepancies between EU countries in technology, regulation, service pricing, market structure, and peripheral hardware and software costs.

In response to market demand, telecom equipment firms are shifting their focus from public network technologies to business networks and various forms of hybrid personal access systems. Furthermore, as the ATM example showed, the role of public networks as a driving force behind innovation is declining as the technology lead shifts decisively to the private networking sector. New entrants, particularly American firms, are leapfrogging over the public network technologies, configuring their networks instead around the integrated voice and data requirements of private networks where equipment standards and supply are broadly internationalised.

3.3.2 Can the GSM Experience be Replicated?

The European experience with GSM is an outstanding success story and a major factor behind the rapid growth in the European market share for radio-based telecom equipment, the sole sector where European market share has increased in recent years, following the decisive early lead taken by European firms in this technology. Does our review of technological developments suggest the possibility for replicating this experience with other technologies? Our conclusions on this point are mixed.

European capabilities are dangerously concentrated in the telecommunication side of network-based markets, with major weaknesses in software and computers. This is a serious problem because a common feature of many new telecommunication technologies is the importance of both increasing and decentralising system intelligence, which requires greater processing capabilities and software. Today, digital electronic components and design principles dominate the design of new telecom equipment. Therefore, expertise in computer and software technologies is vital and telecom firms must be able to combine telecommunications, computer, and software technologies. With this change, the specialised advantages (or core capabilities) of telecom equipment firms have become less unique and the possibilities for competitive entry by non-telecom firms has grown. Partly as a result, European firms have only been able to successfully market new products in a small number of the key technological areas outlined above. This erosion of the unique capabilities of telecom manufacturers is accelerated by standards to permit the connection of different types of equipment and the increasing availability of generic solutions for switching and transmission systems.

Furthermore, the European lead in telecommunication technology, though supported by EU programmes such as RACE and ESPRIT, is narrowing, while the European lag with its American and Asian competitors in the complementary computing technologies is *not* narrowing. European firms have not been competitive in computer hardware and software since the 1970s (STOA, 1995)[50]. And, while RACE and ESPRIT

[50] Only a third of European computer needs could be supplied by European-owned firms in 1990 (EC, 1991), while the US and Japan dominate the world-wide market for semi-conductors (ET, 1995).

have developed and tested many new technologies, these technologies are only slowly reaching the market. A well-documented response to these problems by European telecom equipment firms is to seek alliances with US computer firms, as has occurred for the development of CTI, PBX, and the Intelligent Network. It appears likely that reliance upon non-European firms for network intelligence and new service concepts will remain a feature of the European telecom industry for some time to come. This raises concerns that European firms could miss future technological developments in products or services that are vital to competitive advantage.

The future development of European technologies for network-based services will depend upon creating conditions that support the evolution of new technologies, as embedded in products, in accordance with changing technological and market conditions world-wide. In this respect, the traditionally high profile of European standards making organisations are on trial. The ability of European telecom equipment firms to control the content and pace of development of standards has historically been a major support mechanism for their product development strategies. This is breaking down. The standards structure is decentralising and much of it is moving out of the telecommunication sector altogether, as shown by the history of the ATM Forum. New standards are frequently ambivalent as to their public or private network orientations. Moreover, the attitude of European firms to European standards is often ambiguous.

In addition, "made-in-Europe" standards will not always lead to long-term competitive advantages for European firms. The current European lead in mobile communications, for example, also depends upon the decisions that will be taken in the US concerning PCS standards, as well as PCS markets, over the next 5-10 years.

The European Commission has played an active role in attempting to strengthen the competitive capabilities of European telecom equipment firms. These policies have been guided by three main goals. The first is to support R&D, for example through the Framework Programme, in order to improve the technological capabilities of European firms (Barry, 1990). The second is to introduce common standards to form a critical mass for new technologies in the EU. The third is to support the single market. Some EC policies have promoted market integration in general, but other policies are specific to telecommunications, such as programmes to encourage the construction of trans-European telecommunication networks as a means of accelerating the construction of a single market[51]. Policies to support the single market also permit the use of the economic power of a large European market as a base for the effective exploitation of foreign markets for European technologies.

The experience with GSM indicates how future developments can be harnessed to achieve more positive outcomes. The environment in which GSM appeared and prospered was a high point in the expectations of the creation of a single market and the willingness to take policy actions on behalf of this development. Yet some of the force of these developments and some of the confidence that the single market would provide the critical mass for European telecom equipment technologies have waned.

Implementing the telecommunication features of the Trans-European Network (TEN) vision is one means of harnessing European service demands to maintain demand for telecommunication equipment. In this respect the TEN vision reproduces the conditions that led to the success of GSM. What has changed in the interim, however, is that other regions of the world, and especially the US, share a common vision for the development of advanced communication services and are actively attempting to accelerate movement toward their own versions of the Information Society. In Europe, this requires a decline in the importance attached to public switched telecom networks in favour of private networks and a much more internationally competitive structure of telecommunication equipment supply[52]. Failure to keep pace with new telecom technologies is likely to lead to inadequate service levels, with its negative consequences for the competitiveness of European industry and services. For European telecom equipment firms the only way to sail the boat appears to be forward, and at an increasing speed.

---

[51] The White Paper on Growth Competitiveness and Employment (EC, 1993) provides a more extensive rationale for this policy direction.

[52] While private networks are an increasing market, the strength of the European telecom equipment sector over the medium term is likely to be influenced by procurement by European network operators, with their large share of world telecom service markets. Of the top ten international telecom carriers (as ranked in 1993), five are European: Deutsche Telekom, Cable & Wireless, France Telecom, British Telecom, and PTT Netherlands (CWI, 1994b).

PART TWO

RESULTS OF THE CIS SURVEY

5 INTRODUCTION

The analyses of the CIS data are limited to six topics of interest to policy that were identified through the evaluation of the European telecom sector in Part One[1]:

1. *Innovative status and innovative success.* The design of good policies to support innovation requires basic information on the factors that determine whether or not a firm innovates and the factors that determine innovative success.

2. *Types of innovation activities:* Information on the relationship between firm size and the type of innovative activity can improve our understanding of the specific needs of smaller firms, while the amount of effort that firms expend on product versus process innovation can help to identify cost-reduction from new product market strategies.

3. *Sources of technical information and new technologies.* EC funding support for electronics and informatics research encourages research links between firms, which could be particularly important in telecom in order to integrate telecom equipment, electronic components, and software. The CIS survey permits an evaluation of the types of external information sources and alliances that are of value in this sector.

Innovation goals. Long-term competitiveness in telecom equipment partly depends on an aggressive innovation strategy to develop new products and seek out new markets, particularly in Asia and North America. At the same time, the Maastricht Treaty identifies a cleaner environment as an important social objective of European policy. The CIS results are used to examine both issues.

---

[1] One topic of interest that is not examined in this report, other than in several footnotes, is the effectiveness of appropriation methods to protect innovations from copying. The relevant CIS questions are of great interest to policy because of the assumption that strong appropriation conditions encourage firms to innovate. Patents have attracted the most attention because they are amenable to policy actions, such as programmes to assist SMEs to use the patent system to their advantage. The recent *Green Paper on Innovation* (EC, 1995), for example, notes that 'effective legal protection is a vital incentive for innovation' and supports policies to improve the ability of firms, particularly SMEs, to use patent and other intellectual property rights. Unfortunately, the results for the CIS questions on appropriation are available for only 52 component and 44 telecom firms, which is too few to be able to adequately investigate appropriation conditions in the telecom sector.

Regulations and other factors hampering innovation. Standardization is an important influence on the direction of research in the telecom sector because of its effect on reducing uncertainty in the face of a wide range of technical options. Innovation can also be hampered by a lack of skilled personnel, information on technologies, or opportunities to cooperate with other firms.

Export rate. The telecom sector is one of the few high-technology sectors in Europe where the EU runs an export surplus (see Figure 3, Part One), while most European countries run a large deficit in components (YWED, 1996). The policy goals are to maintain or improve the performance of the telecom sector while improving conditions for components. The CIS data is analyzed to discover what factors are associated with the export success for telecom and the export failure for components.

Each of these six topics is evaluated below, after a brief overview of the methodology.

6 METHODOLOGY

6.1 Available CIS Data for the Telecom Sector and for Comparison Groups

Data for the telecom sector is only available for Norway and six EU countries: Germany, France, Italy, Holland, Belgium, and Ireland. This is not a serious limitation, since these six EU countries account for 80% of total EU telecom production in 1992. The most important limitation is the lack of data for the UK and Spain, which accounted for 13.7% and 5.7% respectively of EU production in 1992[2]. The number of cases available for analysis is further limited by a lack of data in several countries for several questions of interest, such as on R&D expenditures or a change in sales, and by missing responses to some questions for many of the cases.

The maximum number of cases available for analysis for all NACE 32 firms, for components and telecom separately, and for a comparison group of other Hitech firms, are given in Table 6.1 for both innovating and non-innovating firms. An innovator is defined as a firm that introduced a technologically changed product or process between 1990 and 1992[3].

[2] Further details on the CIS coverage of telecom firms are given in section A2.1 of Appendix A.

[3] Firms that did not introduce a product or process innovation between 1990 and 1992 but which stated that they planned to introduce one between 1993 and 1995 are not classified as innovators. This exclusion is unlikely to influence the results since only 5.8% of telecom firms fit this category.

Many of the analyses use the components sector as a comparison group for telecom firms. The comparison group 'Other hitech' consists of cases from the office equipment (NACE 30), electrical equipment (NACE 31), and instruments sectors (NACE 33). All three contain a high percentage of R&D intensive firms that use technologies such as computerisation and electronics that are also of importance to telecom equipment.

Table 6.1 Number of CIS Cases by Innovation Status and Sector

Sector	Total	Innovators	Non-innovators
Other hitech	2465	1368	1097
NACE 32[1]	569	402	167
32.1 Components	202	134	68
32.2 Telecom	210	148	62
other NACE 32	60	40	20

[1]: The sub-totals do not add up to the total number of NACE 32 cases because of missing data and because a breakdown of NACE 32 to the 3-digit level is not available for 97 cases. See Table B-3, Appendix B, for a full description of the available weighted and unweighted data by country for NACE 32.

6.2 Statistical Methods

The CIS survey provides cross-sectional data on the state of innovation over a three year period. A major problem for statistical techniques such as regression analyses that make cause-and-effect assumptions is that it is often impossible to determine if a specific factor is the *outcome* or the *cause* of an innovative strategy. The problem is complex because Kline and Rosenberg's chain-link model of innovation, which provides the theoretical foundation of the CIS questionnaire, assumes that innovation includes many feedback loops where a cause can become an outcome, and vice-versa. For example, sales can grow because of past innovation or the profits earned from high sales growth can be spent on current innovative activities. Our approach to this problem is to first present simple, descriptive results that make no assumptions about cause and effect. Where relevant, these are followed by logit, probit, or tobit regressions that make cause and effect assumptions and which should therefore be interpreted cautiously.

6.2.1 Weightings

Unless stated otherwise, all results are based on analyses that use the EUROSTAT weights to account for the varying response rates by country and sector[4]. Statistical

[4] The use of weightings introduces other problems such as overestimating the size of the European telecom industry (see discussion in Appendix A, section A2.2) or magnifying the importance of a few firms with high weightings. Results are similar between unweighted and weighted regressions that

significance is calculated using rescaled weights based on the actual number of cases.

6.2.2 Descriptive results

Two methods are used to present summary descriptive results for the CIS questions that use a five-point subjective scale, varying from 'not important' to 'crucial'. The first measure is the *extreme score*, which is the percentage of firms that give a score of 4 or 5 (very significant or crucial) to a question. For example the extreme score is 20% if 20 out of 200 firms give a score of 4 or 5 to a subjective question.

The second measure is the *most important score*, or the percentage of respondents who give their highest score to a specific question in a group of questions. Both a respondent that gives a score of '5' to a question on the importance of universities and 4 or less to other information sources, and a respondent that gives a score of '3' to universities and 2 or less to other sources, are indicating that universities are more important to their firm than other sources of information[5].

6.2.3 Regression analyses[6]

The most commonly used regression method employed here is the logit model, which is an appropriate technique for dichotomous (two-valued) dependent variables. All regressions include variables for country and firm size, measured by the log of the number of employees. Country is always included to control for response biases[7], but the results for country are not given to avoid the temptation to make possibly meaningless comparisons between countries. Given the exploratory nature of this research, forward stepwise selection, based on Likelihood Ratios, is then used to select from a list of *optional variables* that could plausibly influence the results and which are unlikely to strongly violate the cause and effect assumption[8]. All optional

---

control for country and firm size, though weighted regression results are always given here.

[5] Tie scores are assigned equally, for example three maximum scores of 5 are counted as 0.333 each. The total sum of the most important scores always adds to 100%.

[6] The relatively short observation period of the CIS limits the possibility for simultaneous equation modelling methods that could accommodate the dual role of variables. The regressions are estimates of reduced form behavioural relationships where the structural equations remain unspecified and unestimated.

[7] The proportion of all firms that completed the CIS questionnaire varies by country, from a low of 21% and 22% respectively for Germany and France to a high of 76% for Norway. These differences in sampling appear to have biased the results, with the proportion of innovating firms increasing in inverse proportion to the response rate.

[8] Results are only given for optional variables where p is less than 10%. The value p may be thought of as the probability that a meaningful effect is occurring in the regression for that parameter.

variables are described in Table B-7 of Appendix B.

In order to maximise the size of the data set used in the analyses, some of the analyses are repeated with and without firms with missing data for important variables such as R&D intensity. The comparison groups are always limited to an equivalent set of firms, using identical inclusion and exclusion criteria.

6.2.4 Bias from values estimated by EUROSTAT

EUROSTAT used regression methods to estimate missing values for some variables. Replicating these regressions could produce spuriously high R^2 values. This problem is avoided, where relevant, by excluding cases where the dependent variable was estimated by EUROSTAT. (See Appendix B2 for further details).

7 INNOVATIVE STATUS AND SUCCESS

7.1 Introduction

A basic question of interest is what influences whether or not a firm innovates, and if it does innovate, the factors that influence the amount of effort that it expends on innovation. A second research question concerns the identification of the factors that are associated with innovative "success", as reflected in sales growth, an increase in profitability, and a higher percentage of sales from innovative products.

The CIS questionnaire does not contain data on profitability, but it is possible to determine the change in sales between 1990 and 1992 for all countries except Germany and Norway and to determine the percentage of product sales in 1992 that are unchanged, incrementally changed, or significantly changed. Using this data, we develop two measures of innovative success and determine the influence of a range of variables on these two measures of success.

7.2 Descriptive Results for Innovative Status

Table 7.1 gives the proportion of innovating and non-innovating firms for the telecom and comparison sectors. Telecom has the highest proportion of innovators, at 71.3%, followed by Other hitech at 67.0% and components at 66.0%. The proportion of innovators increases with firm size, as is clearly shown in Table 7.2. The proportion of innovators also varies by country (results not shown), but it is not significantly different between countries in comparisons limited to firms with more than 100 employees. Only 10% of telecom and 4.9% of component firms innovate but do not

Table 7.1 Weighted Proportion of Innovating and Non-innovating Firms in the Telecom Sector and in Comparison Industries		
	Non-Innovators	Innovators
All Industries (NACE 15-36)[1]	47.1%	52.9%
Other hitech sectors[1]	33.0%	67.0%
All NACE 32 Firms[1]	34.0%	66.0%
32.1 Components[2]	40.1%	59.9%
32.2 Telecom[2]	28.7%	71.3%
32.3 HEE[2]	34.1%	65.9%

[1]: Excludes the UK, Portugal and Greece where weightings are not available.
[2]: Excludes the UK, Portugal, Greece, Luxembourg, Denmark, and Spain where either weightings or three-digit level NACE data are not available.

conduct formal R&D[9]. Firm size is also a factor. For all NACE 32 respondents, 3.3% of innovating firms with over 500 employees do not conduct R&D, compared to 5.9% with less than 100 employees and 12.8% with between 100 and 499 employees.

Table 7.2 Weighted Percentage of Innovating Firms by Size Class for Telecom and Components		
Employees	Telecom	Components
1-19	10.0	47.6
20-99	72.5	64.0
100-249	91.6	67.3
250-499	93.9	100.0
500-999	100.0	100.0
> 1000	100.0	100.0
Trends statistically significant ($p < 0.001$)		

7.2.1 Innovation Intensities

Table 7.3 gives the results for four measures of innovation intensity: R&D expenditures per employee, total innovation expenditures per employee, R&D expenditures as a percentage of sales, and total innovation expenditures as a percentage of sales. Total innovation includes R&D plus the cost of patents and licenses, product design, trial production, and market analysis. Each intensity measure is provided for 1) R&D performing firms only (RDP) and 2) for all firms (AF), including both non-innovators and innovators that do not conduct R&D.

Expenditures per employee on R&D by telecom firms are much higher than the equivalent expenditures for all industries (NACE 15 - 36) and among similar hitech sectors, but expenditures per employee on R&D are highest in the component sector, followed by telecom, though expenditures on all innovation activities is slightly

[9] This excludes French firms for which there is no data on R&D. There are no NACE 32 firms that conduct R&D but which have not introduced an innovation in the preceding three years.

higher in telecom than in components. However, R&D intensity is considerably lower for telecom firms compared to components and total innovation intensity (TII) is lower for telecom firms than for all comparisons groups with the exception of HEE.

Table 7.3	1992 R&D and Total Innovation Intensities (TII) by R&D Performance Status (RDP = R&D Performing Firms Only, AF = All Firms)							
	Expenditures ('000 ECUs) per employee				Expenditures as a percent of sales			
	On R&D		TII		On R&D		TII	
	RDP	AF	RDP	AF	RDP	AF	RDP	AF
All Industries	2.60	0.66	6.70	3.53	3.5%	0.9%	13.8%	7.3%
Hitech sectors	3.70	1.67	12.99	5.9	5.1%	2.3%	20.2%	9.1%
32.1 Components	8.86	5.17	11.84	7.29	17.9%	10.5%	24.5%	15.1%
32.2 Telecom	6.64	3.48	12.80	7.91	6.0%	3.1%	10.0%	6.2%
32.3 HEE	2.29	1.11	7.28	4.21	2.6%	1.3%	7.6%	4.4%

All calculations limited to countries with data on weights, R&D expenditures, and NACE codes at the three-digit level: Germany, Italy, Holland, Belgium, Ireland, and Norway.

Excludes firms where R&D expenditures exceed total innovation expenditures and French firms (no data on R&D), outlier firms with R&D intensities above 100% are also excluded.

Note: Estimates are by firm. Sales-weighted R&D intensities are considerably higher (see Table 1.7).

The results show that sectors with high R&D intensities spend comparatively less on non-R&D innovation costs than sectors with low R&D intensities.

Figure 5 gives the weighted frequency distribution for sales-based intensities for R&D expenditures and total innovation costs, using class ranges of 2%[10]. For example, 14.2% of the firms have an R&D intensity between 0% and 2%, for a midpoint of '1'. The midpoint of '0' refers to a few firms that reported R&D expenditures of zero, while the midpoint of -1 consists of non-innovating firms with no expenditures on R&D or other innovation costs, as relevant. As expected, the distribution of total innovation intensity is shifted to the right in comparison with R&D intensity and the distribution of both intensities is strongly skewed to the left, with most firms having low R&D intensities. The frequency peak at the midpoint of 33% for R&D intensity and at 39% for total innovation intensity is due to high weightings on a few cases.

[10] Excludes firms with higher expenditures on R&D than on total innovation costs and French firms, for which there are no data on R&D or total innovation expenditures.

7.2.2 Firm Size and R&D share, export share, and sales growth

Figure 5

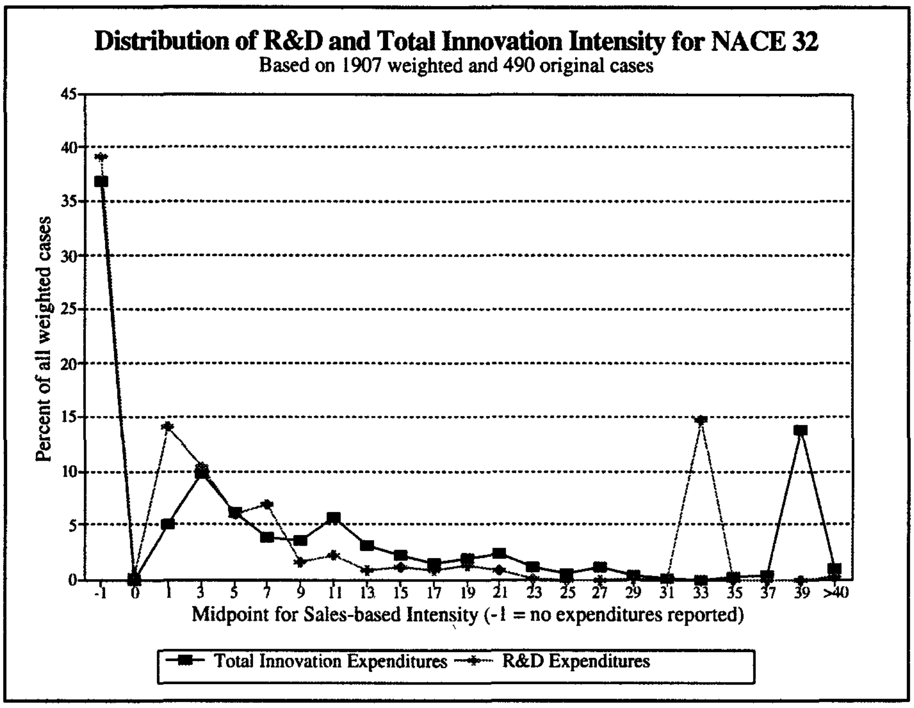


Table 7.4 gives correlation coefficients between firm size and the proportion of total innovation expenditures due to R&D, the share of exports in total sales, and the change in sales between 1990 and 1992. For all industries, the export share increases with firm size, but there is no correlation between size and the change in sales between 1990 and 1992. The results for R&D expenditures as a share of total innovation costs differ by industry. The R&D share increases with size for Other Hitech, there is no significant relationship for components, while the R&D share declines with firm size for telecom.

The proportion of firms with sales growth was calculated for innovators and non-innovators. Overall, there is very little difference either by sector or by innovation status. For example, 59.5% of innovating and 60.6% of non-innovating telecom firms reported some growth in sales.

Table 7.4 Correlation Coefficients between Firm Size (log of employee number) and Share of R&D in Total Innovation Expenditures, Export share, and Change in Sales (Statistically significant coefficients in bold)

Sector	R&D share[1]	Export share[2]	Sales Change[3]
Other Hitech	**0.16**	**0.29**	0.00
Components	0.11	**0.29**	-0.01
Telecom	**-0.43**	**0.49**	0.00

[1]: Based on questions 10di and 13a and limited to R&D performers. Excludes firms where R&D expenditures > total innovation expenditures, firms where the R&D intensity is > 100%, and firms from France.
[2]: Data available for all countries (except the UK, Portugal and Greece).
[3]: Excludes Germany and Spain where sales data for 1990 is not available.

The equivalent rates for Other Hitech firms are 56.5% for innovators and 53.3% for non-innovators, and for components the rates are 50.9% for innovators and 43.8% for non-innovators[11].

7.3 Regression Results for Innovative Status

A maximum of six variables are available for both non-innovating and innovating firms: nationality, size (number of employees), export share, sales growth, industry sector, and foreign versus domestic ownership.

Both firm size and export share could influence the probability of innovating: larger firms are more likely to have the financial resources to invest in innovation, while export oriented firms could be forced by exposure to international competition to innovate more rapidly than firms that produce for a more protected domestic market. Firms with rapid sales growth could be more likely to innovate because of an increase in income. Finally, the probability of innovating could be influenced by the ownership status of a firm, with foreign-owned subsidiaries based on assembly operations less likely to innovate than domestic firms.

7.3.1 Results of Regression Analyses

Table 7.5 provides the results of a probit model for the probability that a firm innovates (Prob1 and Prob2) and a Tobit model to determine the effect of these Two probit model results are given to maximise the amount of available data. Prob1 uses the full data set for all NACE 32 firms. However, no data on R&D intensity or other related variables is available for France. Therefore, the Prob2 results exclude French respondents and use the identical set of cases as used in the Tobit models.

A robust and consistent result is that the probability of innovating increases with firm size (LEMPLOY), which is significant in all regressions. Sales growth, between 1990 and 1992, has no effect on the probability of innovating, even though European telecom sales increased rapidly between these two years. Furthermore, there is no difference in the probability of innovating between telecom and other NACE 32 firms, after controlling for firm size and country. Export intensive firms are less likely to have high R&D intensities in two Tobit regressions (Models 2 and 4). As shown in model 5 which includes ownership status, this unexpected result could be caused by foreign-owned assembly plants[12].

[11] The average sales growth is higher in the telecom and component sectors among the innovators compared to the non-innovators, but the variances are so large that the differences are not significant.

[12] Almost a quarter of the firms do not export. A second set of regressions, limited to exporting firms, found that the export rate had no effect on the probability of innovating.

Table 7.5	FACTORS INFLUENCING INNOVATION STATUS: Probit and Tobit Model Results (** = p <0.01, * = p< 0.05) For Probit: 0 = non-innovator, 1 = innovator. For Tobit: dependent variable is ln (1 + R&D intensity)														
	1			2			3			4			5		
	Prob1	Prob2	Tobit	Prob1	Prob2	Tobit	Prob1	Prob2	Tobit	Prob1	Prob2	Tobit	Prob1	Prob2	Tobit
Constant	-2.54**	-3.63**	-0.14**	-2.98**	-4.83**	-0.15**	-1.45**	-2.46**	-0.21**	-4.13**	-4.63**	0.02	-1.48**	-2.00**	0.09
EXPORTS	-0.05	-0.12	-0.07	-0.21	-0.44	-0.12*	0.35	0.35	-0.01	-0.42	-0.46	-0.16**	0.16	0.20	-0.08
LEMPLOY	1.60**	2.14**	0.06**	1.88**	2.88**	0.07**	0.91**	1.41**	0.08**	2.68**	2.89**	0.05**	1.17**	1.36**	0.02
TELECOM				0.00	0.02	0.00							0.00	0.11	0.00
S-GROWTH							0.00	-0.01	0.00				0.00	-0.04	-0.01
DOMESTIC										-0.11	-0.20	-0.14**	-0.39	-0.41	-0.18**
# Cases	545	425	425	475	359	359	428	315	315	398	359	359	323	288	288
Pseudo R^2	0.63	0.73		0.63	0.82		0.52	0.61		0.78	0.82		0.57	0.75	
-2LL	559.2	398.2		480.1	310.4		478.8	303.0		350.8	311.2		329.0	285.2	
% Correct	72.5	72.7		71.2	72.4		68.9	61.0		72.4	71.3		69.7	69.1	

EXPORTS: Percentage of total 1992 sales from exports. LEMPLOY: Log of the number of employees. TELECOM: '1' if the telecom sector, otherwise '0'. S-GROWTH: Percentage increase in sales in 1992 compared to 1990. DOMESTIC: '1' if firm is domestically owned, '0' if foreign owned.

All Models exclude the UK, Portugal, and Greece. Respondents from France are only included in the first column of each model. For each model, the following additional exclusions are made due to differences in the CIS questionnaire by country: Model 1: none; Model 2: Excludes respondents from Denmark and Spain; Model 3: Excludes respondents from Germany, Spain and Norway; Model 4: Excludes respondents from Denmark and Spain; Model 5: Excludes respondents from Germany, Denmark, Spain and Norway.

All models include dummy variables for country.

A combined Probit/Truncated model is often more appropriate than a Tobit model, but attempts to fit the data to the Truncated model failed. The R&D intensity of non-innovators is set to zero. Some of the variables are not available for all countries.

7.4 Innovative Success: Sales and Changed Products

Successful innovation should lead to a higher proportion of innovative products and an increase in sales. Firms are defined as successful if they had an increase in sales (0% and above) and if more than 25% of their sales were from incrementally or significantly changed products. Firms are defined as unsuccessful if their sales had declined (negative change in sales) and if less than 25% of their sales were from incrementally or significantly changed products. Firms which succeed on one variable but fail on the other are defined as mixed-success firms.

Table 7.6 Percentage of successful, unsuccessful, and mixed-success component and telecom firms

	Components	Telecom
Unsuccessful	14.6	8.6
Successful	25.1	26.6
Mixed-success	60.3	64.8
Total	100.0	100.0
Actual count	128	119

The weighted percentage of successful, unsuccessful, and mixed-success firms are given in Table 7.6[13]. The majority of firms in each sector are of mixed-success and are excluded in a series of analyses to determine if there are differences in the strategies used by the two extremes of successful and unsuccessful firms. The results of simple comparisons are given in Table 7.7 for several firm characteristics, the percent that find public research to be an important source of information, and the average index for the importance of external information sources[14].

Few of the differences are statistically significant, though this could be due to the small number of cases. Nevertheless, a higher percentage of successful telecom firms are domestically-owned, though the reverse is true for components, and they have a slightly higher R&D intensity (though the highest R&D intensity is among the mixed-success firms). Successful telecom firms are also larger than unsuccessful firms. A significantly higher percentage of both successful component and telecom firms find universities or government labs to be important than their unsuccessful counterparts.

A logit regression was also used to determine which factors had a significant effect on the probability of success or failure in the telecom sector (results not shown). In addition to firm size and dummy variables for country, the regression included

[13] The analysis excludes German and Norwegian firms where data on 1990 sales is not available.

[14] The questions on barriers to innovation were not included since these questions were not asked in France. Their inclusion would considerably reduce the number of available cases.

variables for the importance of universities and government laboratories, and whether or not the firm participates in cooperative R&D. The only significant factor is firm size. Larger telecom firms are more likely to be successful than smaller firms.

Table 7.7	**Characteristics of Unsuccessful (U) and Successful (S) Pooled Sample of Component and Telecom Firms** (*Italics* = $p < 0.10$; ***Bold and italics*** = $p < 0.05$)			
	Components		**Telecom**	
Factor	**U**	**S**	**U**	**S**
Firm characteristics				
Domestically owned[1]	***81.1%***	***50.1%***	44.0%	62.2%
Participate in cooperative R&D	47.9%	34.1%	49.6%	49.7%
Average R&D intensity	5.6%	8.3%	4.3%	6.7%
Number of employees	239	223	*121*	*600*
Sources of information				
Universities or gov labs	*30.9%*	*55.6%*	***0.0%***	***46.8%***
Index of outward orientation	***20.5***	***27.8***	22.4	25.7

[1]: Excludes France where this data is not available. For comparison, domestic firms account for 61.6% of all component and 73.0% of all telecom firms.

7.4.1 The Proportion of Changed Products in Total 1992 Sales

The percentage of incrementally or significantly changed products out of total 1992 sales is used as the second measure of innovative success. Three different measures are investigated: 1) the percent of incrementally changed products, 2) the percent of significantly changed products, and 3) the percent of incrementally and significantly changed products combined. Models 1 and 2 gave poor results and therefore are not presented here, but relatively good results are available for model 3 and presented in Table 7.8[15].

Model 3 was first explored using variables obtained from information sources, innovation goals such as the importance of accessing European and foreign markets, barriers to innovation, participation in cooperative R&D programmes, domestic ownership, and R&D intensity. Only four of the 17 variables are significant factors in explaining the proportion of changed products.

7.5 Concluding Comments

The results of both measures of innovative success show that the probability of success increases with firm size. This could reflect structural conditions in the telecom

[15] The value for the percent of changed products had been estimated by EUROSTAT for almost 20% of the cases. Including these cases significantly increased the adjusted R^2 values, suggesting a bias. These cases are therefore excluded from the analyses given in Table 3.2.

sector, where innovation is very expensive and only large firms can succeed. A related explanatory factor is the important role of large national champions and service providers in the European telecom equipment industry, which could have encouraged the concentration of innovative expertise into large firms. Second, firms that use publicly-funded research are more successful, though this result is much more tentative than the result for firm size.

Table 7.8 OLS regression coefficients for the natural log of the percentage of incrementally and significantly changed products in 1992 sales by Telecom firms. Statistically significant variables in at least one model. (* = p < 0.10, ** = p < 0.01)

	Model 3.1[1]	**Model 3.2[2]**
QUALITY	-0.56**	-0.62**
COPYEASE	0.35*	-
PUBRES	0.29*	0.14
Lemploy	0.34**	0.41**
Adjusted R^2	0.22	0.34
Signif F	0.0000	0.0000

[1]: Excludes France and Norway, permitting variables on factors hampering innovation (ie COPYEASE).

[2]: Includes firms from France, Norway, Germany, Italy, Holland, and Belgium.

QUALITY: dummy for the importance of improving product quality as a innovation objective; COPYEASE: dummy for the importance of ease of copying as a barrier to innovation; PUBRES: dummy for the importance of universities and government laboratories as a source of information.

Two interesting results in Table 7.8 are the importance of the ease of copying as a barrier to innovation, with a positive coefficient, and the negative coefficient for the importance of improving product quality as a goal of innovation. In the former case the result indicates that poor appropriation conditions impel firms to maintain a higher share of changed products in their product line, suggesting that the overall effect of poor appropriation conditions is to *encourage* rather than discourage innovation in the telecom sector[16]. The negative role of the importance of quality as a goal suggests that telecom firms are opting for innovations over quality. Alternatively, this effect could be spurious, with quality getting a relatively lower rating among successful firms compared to other goals, such as developing new products, while retaining an equivalent importance, in real terms, as firms that rate quality as

[16] Analysis of the questions on appropriation conditions show that telecom firms find strong protection methods such as patents and secrecy to be less effective than component firms. The only relatively effective methods for telecom are lead time advantages and technical complexity, but even these are seen as less effective by telecom than by telecom firms. These results indicate that appropriation conditions in the telecom sector are relatively poor compared to components.

an important objective of innovation.

Some of the results suggest that component firms are less successful or innovative than telecom firms. However, a sales-weighted estimate of the proportion of all sales in the component and telecom sectors that are incrementally or significantly changed shows a higher rate of innovative products in components than in telecom: 34.1% and 32.8% of all component sales are incrementally or significantly changed, compared to 23.3% and 25.6% of all telecom sales. These results point to the need for caution, since using the firm as the unit of analysis can give different results than those produced by looking at the entire sector as a whole[17].

8 TYPES OF INNOVATIVE ACTIVITIES

8.1 Introduction

The innovative effort of firms is usually measured through expenditures on R&D or by R&D intensity. R&D activity does not, however, take an invention right through to the market, nor can R&D intensity alone tell us much about the purpose of innovation or whether it occurs within the firm or purchased from external sources.

The CIS survey permits us to look more closely at each of these questions. First, respondents are asked to estimate the proportion of their firm's total innovation costs that are due to R&D, acquisition of patents and licenses, product design, trial production, training and tooling-up, and market analysis, as well as a write-in 'other' category. Other than patent purchases, these activities are often necessary to market a new product or introduce a new process innovation. Second, a separate question provides an estimate of the proportion of R&D related to product and process innovation. The choice of whether to focus on product versus process innovation could be linked to strategies to reduce costs versus seeking new markets. A third question asks for the percent of total innovation costs spent on external services for R&D, training, etc, which could be an important source of innovation for some firms.

8.2 Results

Figure 6 gives the distribution of innovation costs for component, telecom and other Hitech firms, while Figure 7 provides the distribution by firm size for telecom alone. Figure 6 shows that R&D costs are a considerably higher fraction of all innovation costs for telecom than for component or other hitech firms, largely due to

[17] We have chosen to concentrate on the firm because this perspective provides a better description of firm behaviour, with possible policy implications, than taking a sectoral approach. In addition, methodological limitations of the CIS data suggest caution in weighting results by sales or the number of employees (see Appendix A2.2).

proportionately lower costs for trial production. Figure 7 shows that smaller firms spend proportionally more than large firms on non-R&D activities.

Table 8.2 gives the results for components, telecom and other hitech for the percent of R&D spent on product innovation, the ratio of product to process innovation, and the percentage of total innovation costs spent externally. All three sectors focus considerably more on product than process innovation. However, telecom firms spend relatively more on process innovation, as shown by their lower product/process ratio. Telecom also firms spend a higher fraction of their total innovation costs on external sources than component firms, but less than other hitech firms.

Table 8.1 Innovative activity by sector

	Components	Telecom	Other hitech
% product	83.6	77.8	69.4
Product/Process ratio	5.1	3.7	4.1
% ext. services	12.9	25.8	30.9

Table 8.2 gives regression results for the percentage of total innovation costs due to R&D (R&D share), the percentage of total costs spent on external services (External share), and the product/process ratio (a measure of the relative importance of product versus process innovation).

The R&D share for all NACE 32 firms *declines* with firm size (LEMPLOY), though there is no effect for telecom firms for firm size, in contrast to the results given in Figure 7. This is explained by the increase in R&D share with the absolute amount spent on R&D (LRDEXP), which has a more important impact on R&D share than the number of employees, but which is correlated with firm size. Similarly, LRDEXP is positive for all NACE 32 firms, indicating that the negative coefficient for LEMPLOY is capturing large firms with low R&D activities such as assembly operations. Unexpectedly, for all NACE 32 firms, R&D share declines for variables that measure different successful innovation outcomes or objectives that should require high R&D activity to develop new innovative products: the proportion of new innovative products (IPRODSH), exports as a share of total sales (EXPORTS), and the importance of creating new markets in Europe (EURMARK). One possibility is that these measures of success or goals require significant investment in trial production and product design to succeed.

The share of all innovation costs spent on external services should be related to outside sources of information such as cooperative R&D or consultants (CONSULT).

Figure 6

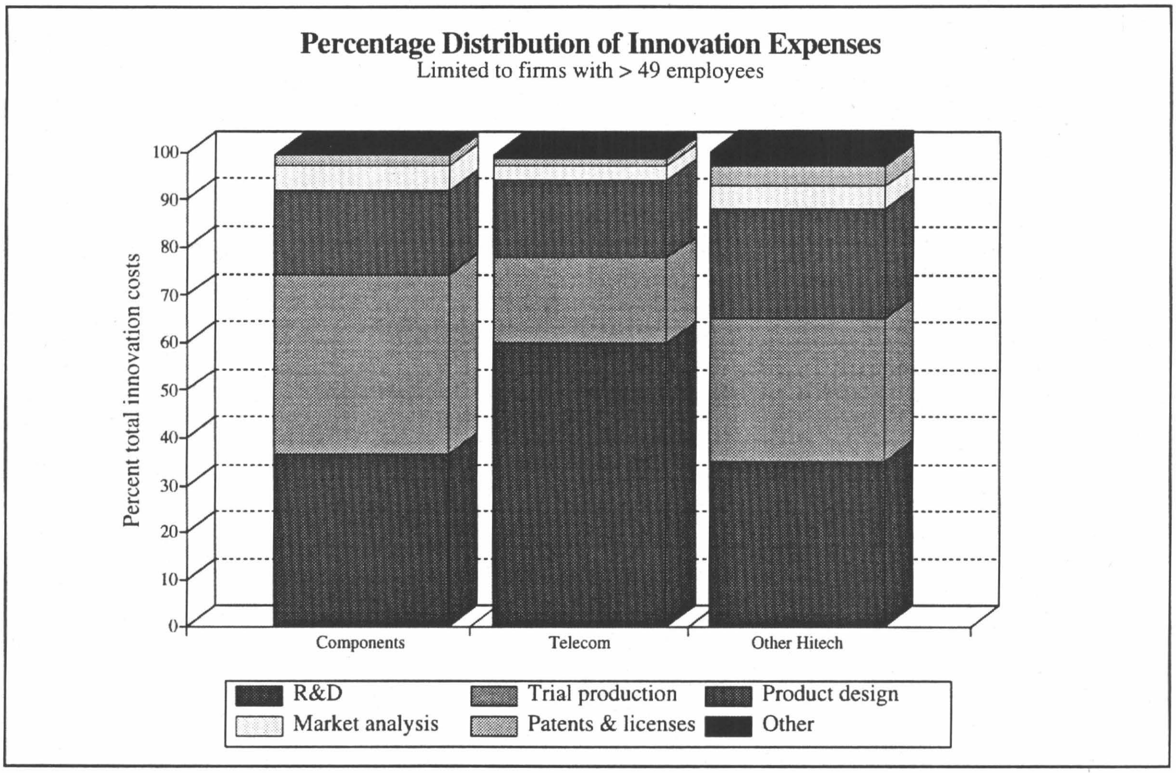


Figure 7

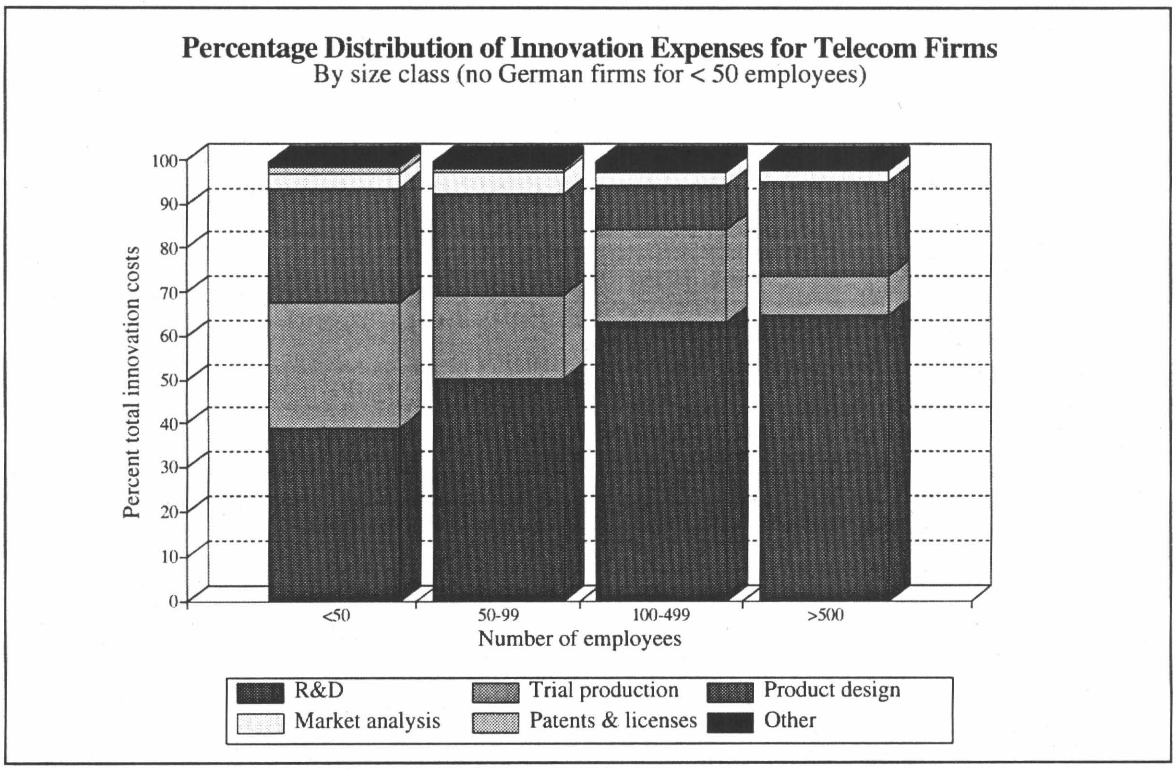


Table 8.2	TYPE OF INNOVATIVE EFFORT: OLS regression results for R&D share and external share of total innovation costs, and product/process ratio. For All NACE 32 firms and Telecom firms only (* = $p < 0.10$, ** = $p < 0.01$)					
	R&D Share[1]		**External share[2]**		**Product/process ratio[3]**	
	All 32	**Tel**	**All 32**	**Tel**	**All 32**	**Tel**
Constant	0.27*	0.15	0.44**	0.82**	4.55**	-6.06*
Telecom	0.03		-0.08		0.14	
Optional variables						
DOMESTIC						3.64*
LEMPLOY	-0.21**					
LRDEXP	0.26**	0.13**				2.43**
IPRODSH	-0.14*		-0.49**	-0.52**		
EXPORTS	-0.15*			-0.33*		
R&D INTENSITY					12.60**	9.21**
EURMARK	-0.18**			-0.34**		
NEWPROD	0.11*					
MAINPROD					-2.14*	
LOWCOST			0.20**			
CONSULT	0.08*			0.21**		
COMPET		0.11*				
PUBRES				-0.44**		
Cases	180	84	123	44	234	107
Adjusted R^2	0.51	0.35	0.25	0.64	0.17	0.41

[1]: Exclusions: firms with less than 50 employees (no data for these firms from Germany), French and non-R&D performing firms who were not asked the question, firms with R&D intensities above 100%.
[2]: Exclusions: Italian, French, non-R&D performing firms (not asked question), firms with R&D intensities > 100%.
[3]: Exclusions: French and non-R&D performing firms (not asked question), firms with R&D intensities > 100%.

See Appendix Table B-7 for a description of the variables. Optional variables are only shown in the Table if they were selected through stepwise forward selection in at least one regression. FORMARK and COOPRD were included in option list but never selected.

There is no effect for cooperative R&D (therefore this variable is not included in Table 8.2), but there is a positive effect for the importance of consultants for telecom firms. Neither firm size or R&D intensity influence the external share. An interesting result is that the external share declines with IPRODSH for both all NACE 32 and telecom firms, and the external share also declines with exports and the importance of creating new European markets for Telecom firms only.

The ratio of product to process innovation for both all NACE 32 and telecom firms increases with R&D intensity, as well as total expenditures on R&D for telecom firms. Domestically-owned telecom firms (DOMESTIC) spend a higher proportion on product development than foreign-owned firms. However, a high export or innovative product share has no effect on the product/process mix.

8.3 Concluding Comments

A higher proportion of the total innovation expenses of telecom firms is spent on R&D than for component and other hitech firms, but relatively more of this R&D component is focused on process instead of product innovation. This could be due to technical factors, for example if reducing component production costs occurs during product design and trial production, whereas these could remain part of R&D in telecom. The regression results show that both the R&D share and the focus of product innovation increase with the absolute level of R&D expenditures in the telecom sector, indicating that new product development is more common among larger telecom firms. The results for external share suggest that the more successfully innovative firms are less likely to acquire innovations from external sources, indicating that success depends on the ability of firms to develop their own innovative strengths.

9 SOURCES OF INFORMATION AND NEW TECHNOLOGIES

9.1 Introduction

There are two main research questions that concern the importance of external sources of information to the innovative activities of the telecom sector.

First, the policies of the European Commission to support research and innovation, for example via the Framework Programme, encourage firms to cooperate with other firms and with the public research infrastructure. The promotion of cooperative research is justified by the belief that alliances and research collaboration are essential to maintain competitiveness in sectors, such as telecom, with rapid technological progress. This need results from the growing complexity and cost of research. Especially for large firms, a broad portfolio of technological capabilities is necessary to avoid being "nibbled to death" by smaller specialised producers.

Second, collaboration could be particularly important to the telecom sector, where success depends on integrating innovation in telecom equipment, electronic components, and software. Given the poor technical competitiveness of the European components sector, and the fact that the single European market is not supposed to substitute for global participation, we would expect European telecom firms to form alliances with Japanese and American firms for components and with American firms for software. This should create a general tendency for telecom firms to acquire new technologies from sources outside of Europe.

The first research question largely concerns the importance of the public research infrastructure and participation in cooperative R&D. The second research question concerns both the importance of commercially-mediated information sources, such as information obtained from suppliers, clients, and consultants, and the different means firms use to acquire and transfer technologies. The types of cooperative R&D agreements that firms enter into are also of interest to the second research question.

9.2 The Value of Public Research

The CIS respondents evaluated the importance of 13 information sources to the innovation activities of their firm, including questions on three types of publicly-funded research institutions: universities, government laboratories, and technical institutes. Descriptive results for many of these sources are given in Figures 8 and 9. The results for public research are amalgamated because of the generally low ratings given to them. Both figures show that the telecom respondents give public research a very low rating, both relative to other information sources and in comparison with the component and other hitech sectors[18].

Logit regression results for the telecom sector and for all NACE 32 firms, given in Table 9.1, show that the most important factor influencing the importance of public research in the telecom sector is firm size.

Among the optional variables, ECONCOST, a composite measure of the importance of four economic cost factors as barriers to the ability to innovate, is negative for universities and positive for government laboratories, suggesting that firms that are worried about the cost of innovation are even less likely to use university research, perhaps because of its expense or because it tends to be far from the market, and more likely to use government laboratories, perhaps because their work is more practical, with immediate application.

Though there is no difference in the importance of any public research between telecom and other NACE 32 firms (mostly components firms), this aggregation disguises a significant difference for universities, which telecom firms value less as sources of information than components firms, and for government laboratories, which is a more important source of information for telecom firms. This suggests that government laboratories are more likely than universities to be conducting the type of research that telecom firms find useful. The percentage of product sales from

[18] This result confirms the findings of the PACE report of Europe's largest firms, which asked about the importance of public research and five other external information sources. The telecom respondents gave the lowest rating to public research of six high technology sectors. Out of a total of 16 sectors, including high, medium and low technology industries, only rubber and plastics and fabricated metals gave lower ratings to public research.

Figure 8

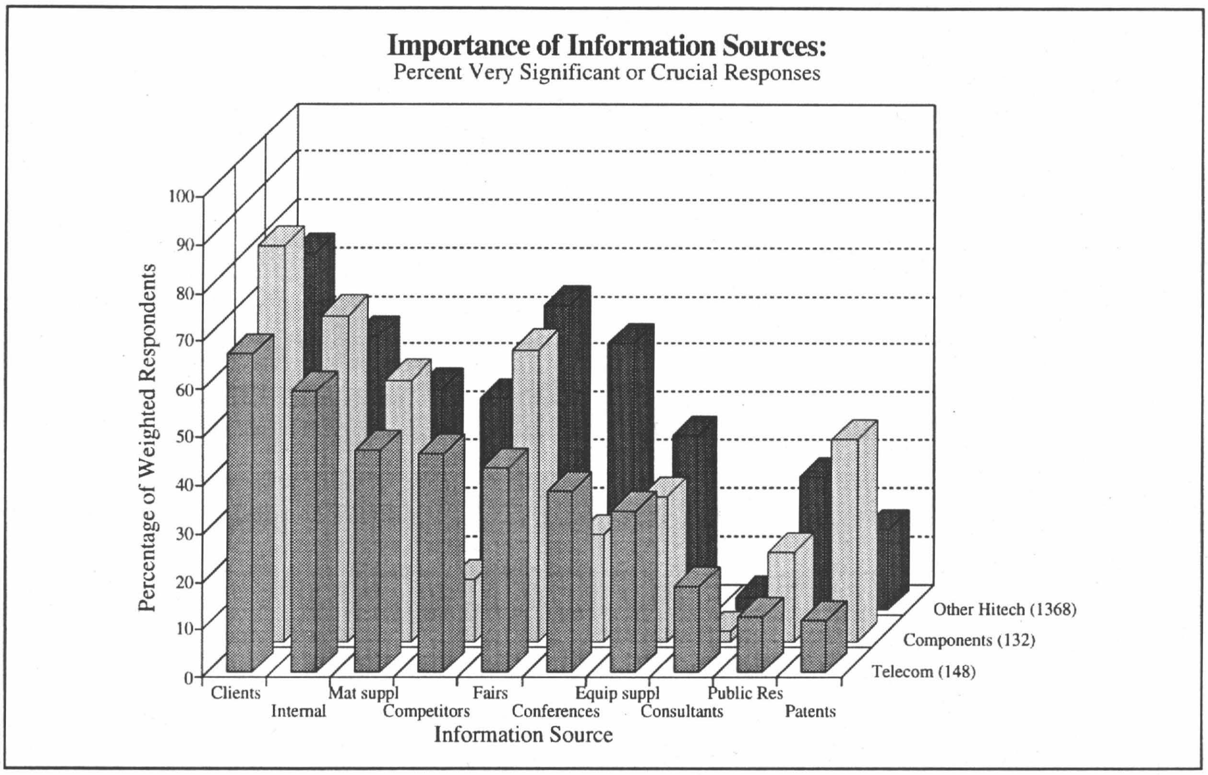


Figure 9

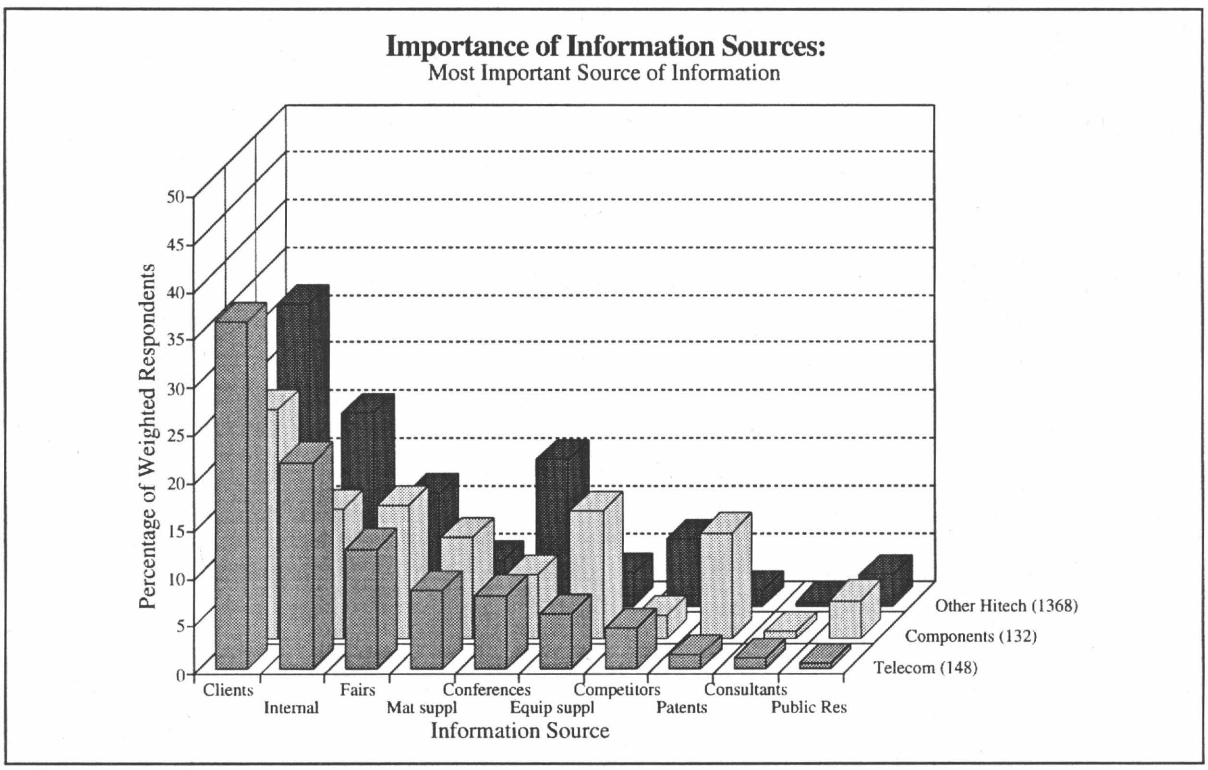


Table 9.1	IMPORTANCE OF PUBLIC RESEARCH: Logit Results for 321 NACE 32 cases and 148 Telecom cases. The dependent variable is coded as 1 = moderately, very, or crucially important, 0 = not important or slightly important. (* = p < 0.10, ** = p < 0.01)							
	Universities/ higher educat		Government laboratories		Technical institutes		Any public research	
	All 32	Tel	All 32	Tel	All 32	Tel	All 32	Tel
Constant	-0.95	-2.6**	-7.50**	-7.40**	-4.83**	-4.80**	-3.43**	-3.30**
LEMPLOY	-0.32	0.88*	1.07**	1.17**	1.03**	0.94*	0.15	1.03**
TELECOM	-0.63*		0.63*		-0.48		0.07	
Optional variables								
EXPORTS	-1.64*		1.64*					
COOPRD	1.34**						0.95**	
DOMESTIC			1.60*				1.40*	
LACKPERS			1.43**					
LACKINFO			1.22*		2.27**			
ECONCOST		-1.76**		2.17**			0.59*	
IPRODSH	2.08**		1.40*	2.52*	-2.20*		1.64**	
R^2_L	0.33	0.30	0.21	0.38	0.30	0.34	0.23	0.23
R^2_L options	0.10	0.07	0.11	0.09	0.08	0.00	0.08	0.00
-2LL	294.6	118.2	241.4	90.5	174.3	72.0	339.0	157.5
% Correct	75.7	81.8	85.1	91.2	88.5	90.5	76.0	75.2

See Appendix Table B-7 for a description of the variables.

incrementally or significantly changed products (IPRODSH), is also positive and significant for the importance of government laboratories. This suggests that successfully innovative telecom firms, with a higher proportion of innovative products, are more likely to find government laboratories useful than less innovative telecom firms. This result recapitulates and supports the hypothesis that the historical concentration of technological activities in generally large national champions is an important element in the system of innovation in this sector.

9.3 Alliances and Cooperation for Innovation

Ideally, given the structure of the European telecom sector, questions on alliances and cooperation would ask specifically about the sources of technical information on components and software. Unfortunately, the CIS questionnaire is designed for the entire industrial spectrum and does not ask questions at this level of detail.

Another area of interest to an evaluation of the telecom sector, given the need for telecom firms to combine innovation in components and software with telecom equipment, is the importance of cooperative R&D. Participation in cooperative R&D programmes is addressed in two CIS questions. The first is a simple question that asks the respondent if their firm had any cooperative arrangements on R&D with other enterprises or institutions in 1992. Results are available for 148 telecom and 134 components firms[19]. The second question asks the respondent to check specific types of cooperative R&D that they are active in, by region. Unfortunately, the number of available responses to this question is too low for these questions to be of any use in an analysis of the telecom sector[20].

Given these limitations, the evaluation of alliances and cooperation is restricted to the general importance of market-mediated information sources, whether or not the firm participated in any form of cooperative R&D programmes, and the percentage of firms that used one of seven methods to either acquire or transfer new technologies by six geographic regions. Three of these regions are in Europe (national, other EC, and non-EC) and three are outside of Europe (US, Japan, and other). Though separate questions on software and components are not available, we assume, given the superior technical competitiveness of American and Japanese component and software firms, that telecom firms should find foreign sources of new technology to be relatively important, with 'new technology' possibly referring to software and components as well as other inputs.

9.3.1 Market-mediated sources

As shown in Figure 8, clients are less important to telecom firms than to components and other hitech firms, while competitors and consultants are considerably more important to telecom than to component firms[21]. There is little difference in the importance of material and equipment suppliers. Other analyses show that the importance of clients, competitors and consultants is not due to their involvement in cooperative R&D programmes.

9.3.2 Participation in cooperative R&D

The participation rate of innovating firms in cooperative R&D programmes is 38.0% for telecom firms, 35.8% for other hitech firms, and 63.6% for component firms. The higher participation rate for component compared to telecom firms is statistically

---

[19] The question is available for all countries where data at the three-digit NACE level is available (Germany, France, Italy, Holland, Belgium, Ireland, and Norway).

[20] The low number of useable responses is due to a large number of missing values, no data for Italy, and no data for many of the questions for France. Depending on the question, the number of available responses ranges from 95 to 49 for telecom and component firms combined.

[21] These differences between telecom and component firms are statistically significant after controlling for country and size effects in Logit regressions.

significant after controlling for firm size and country.

The results of separate Logit regressions of the factors that influence the probability of participation in cooperative R&D are given in Table 9.2. The factors that influence participation by telecom firms in cooperative R&D programmes are similar to that of other Hitech firms, except that telecom firms with a high proportion of innovative products in total sales (IPRODSH) are less likely to participate, whereas the reverse is true for the Hitech sector. In contrast, the only similarity between the telecom and component sectors is that both are more likely to participate in cooperative R&D if they find public research (PUBRES) to be important. The negative coefficient for IPRODSH combined with the positive coefficient for firm size indicates that cooperative R&D in the telecom sector is most likely to be used by large firms with low innovative success.

Table 9.2 PARTICIPATION IN COOPERATIVE R&D PROGRAMMES: Logit model results for the Telecom, Component and Hitech sectors (* = $p < 0.10$, ** = $p < 0.01$)

	Telecom	Component	Hitech
Constant	-9.94**	-3.33*	-5.46**
LEMPLOY	3.51**	0.08	0.41**
EXPORTS	1.11	-0.64	1.35**
IPRODSH	-2.50*	2.82*	0.92**
PUBRES	0.49	2.66**	1.18**
EURMARK	0.99	-2.01**	1.05**
Number of cases	148	132	1,360
R^2_L	0.54	0.47	0.22
2LL	90.3	92.5	1380.4
% correct	88.6	81.8	81.8

Results for the Hitech sector based on forced entry for country and LEMPLOY while other variables selected through forward stepwise selection, using the Likelihood Ratio. The results for components and telecom are based on forced entry for the identical variable set as selected for the hitech sector.

9.4 Acquisition and Transfer of Technology

For simplicity, the results for the acquisition and transfer of technology are aggregated into two main geographic areas, Europe and outside of Europe, though where relevant, the discussion refers to the results by sub-region. The percentage of telecom and component firms that have used each of the seven methods to acquire or transfer a new technology from or to each of the two main regions is given in Table 9.3.

9.4.1 Acquisition of new technologies

The most common method for telecom firms to acquire new technologies from within Europe is through communication with specialist services from other enterprises[22], equipment purchases, and the hiring of skilled staff. For all methods the dominant

[22] We assume that this obscure phrasing refers to the R&D or other specialised divisions of other firms, and not to specialist firms *per se*, such as consultants.

source within Europe is the home country. The use of legal rights, such as licenses, copyrights, and patents to acquire new technology is relatively infrequent.

Non-European sources are used much less frequently than European sources, with only equipment purchases and communication used by over 25% of the telecom firms

Table 9.3 ACQUISITION AND TRANSFER OF TECHNOLOGY: Percentage of component and telecom firms that have acquired or transferred a technology within Europe (Europe) or outside of Europe (Other) (Statistically significant differences in bold ($p < 0.05$)[23]

	ACQUISITION				TRANSFER			
	Europe		Other		Europe		Other	
Method	**Comp**	**Tel**	**Comp**	**Tel**	**Comp**	**Tel**	**Comp**	**Tel**
Legal rights	10.3	12.9	4.8	6.8	14.8	25.2	4.6	8.3
Contract R&D	25.8	30.5	3.1	1.5	66.6	40.3	3.5	2.9
Consultancy	23.7	34.5	1.7	1.9	**72.1**	**34.3**	3.3	3.2
Firm purchase/sale	9.0	8.3	2.6	2.4	6.0	3.0	0.8	1.5
Equip purchase/sale	**78.8**	**62.2**	**9.5**	**32.4**	28.5	34.9	**9.4**	**19.2**
Communication	69.1	63.1	**7.4**	**25.3**	71.0	60.8	6.0	5.8
Hiring/mobility	**69.4**	**43.8**	3.1	2.0	51.5	29.4	3.0	4.4

to acquire new technologies from outside of Europe. The use of legal rights, though very low, is in third place compared to seventh place for within Europe. The use of legal rights to acquire new technologies is dominated by American sources. This pattern reflects the role of intellectual property rights in these sectors. Participation in networks of cross-licenses is necessary to prevent lawsuits and therefore a steady "background level" of licensing activity may be expected to occur, even if little revenue or significance is attached to this activity by the firms involved.

The only significant differences between telecom and component firms for sources within Europe are for equipment purchases and hiring, both of which are used more frequently by component firms than by telecom firms. This result complements the finding that component firms valued university research more highly than did telecom firms. It suggests a significant gap between the technological needs of telecom firms and university activities in *both* teaching and research. Conversely, telecom firms are more likely to obtain new technologies through the purchase of equipment and by communication with firms from outside of Europe. Again, this suggests that telecom firms are obtaining needed technologies from foreign firms.

[23] Controlled for country and firm size. Many of the results for Other countries are unsatisfactory because of the very low number of cases that acquire or transfer a technology outside of Europe.

Table 9.4 gives the results of logit regressions for the telecom sector alone. Firm size has the most important effect on the use of a specific method to obtain new technologies. Participation in cooperative R&D programmes increases the probability of using contract R&D to acquire new technologies, while decreasing the probability

Table 9.4 TELECOM AND TECHNOLOGY ACQUISITION: Logit Model Results for Methods to Acquire Technology from within Europe (EUR) and from other regions (OTH)[1]. (= $p < 0.01$, * = $p < 0.10$)**

	Legal rights		Contract R&D	Consul-tancy	Equipment purchases		Communi-cation		Hiring staff
	EUR	OTH	EUR	EUR	EUR	OTH	EUR	OTH	EUR
Constant	-5.88**	-9.30**	-4.40**	-5.70**	-0.31	-7.48**	-2.71**	-11.9**	-1.57*
LEMPLOY	1.88**	2.57**	0.87**	0.99*	0.58	2.10**	1.25*	2.27**	1.18**
Optional variables									
EXPORTS							1.77*	3.69*	
IPRODSH						2.32**			-2.48**
COOPRD			1.43*		-1.92**	-2.31**	-2.08**	-3.07**	
PUBRES				2.13**				3.08**	
EURMARK				3.11*		1.49*		3.93**	
LOWCOST					1.74**				
R^2_L	0.29	0.53	0.36	0.42	0.26	0.33	0.33	0.55	0.16
R^2_L options	0.00	0.00	0.03	0.18	0.11	0.14	0.06	0.36	0.05
-2LL	80.4	34.5	116.9	110.4	145.8	124.5	109.4	50.1	169.3
% Correct	90.5	95.3	83.8	83.1	81.9	85.8	74.2	91.9	73.7

[1]: No results for Firm purchases (Question 6.4) and for Other regions for several methods because of an unacceptable fit to the model.

of equipment purchases and communication with other firms. The former could be due to a tendency for firms to view contract and cooperative R&D as a similar activity. The latter, however, suggests that equipment purchases and communication are alternative means of obtaining new technologies that displace cooperative R&D[24].

9.4.2 Transfer of new technologies

The most common method for telecom firms to transfer technology within Europe, as shown in Table 9.3, is through communication with other firms, contract R&D

[24] An alternative explanation is that equipment purchases and communication are used by less R&D intensive firms, since the probability of participating in cooperative R&D is higher for R&D intensive firms. R&D intensity was not added as an independent variable, however, because it would considerably decrease the number of cases available for analysis. In addition, R&D intensity in the telecom sector increases with firm size, so controlling for the effect of size in the logit regressions should partially adjust for the effect of R&D intensity.

done for other organisations, equipment sales, and consultancy. Transfers within the home nation dominate, except for legal rights, which are slightly more frequently transferred to organisations in other EC countries (15.7% versus 12.1%). The most important transfer method to regions outside of Europe is equipment sales, mostly to regions outside of the US and Japan. The only statistically significant difference between the component and telecom sector is for consultancy within Europe, which is used more frequently by component firms, and for equipment sales outside of Europe, which are more frequent among telecom firms. This could reflect the better export performance of the European telecom versus components sector in non-European markets. Transfer through sales to foreign markets is also dominated by sales to countries other than the US and Japan, possibly because these markets are more open to non-domestic firms.

Table 9.5 TELECOM AND TECHNOLOGY TRANSFER: Logit Model Results for Methods to Transfer Technology (= p < 0.01, * = p < 0.10)[1]**

	Legal rights		Contract R&D	Con-sul-tancy	Equipment sales		Communi-cation	Hiring staff
	Europe	Other	Europe	Europe	Europe	Other	Europe	Europe
Constant	-5.50**	-7.72**	0.79	1.84*	-0.25	-8.47**	-0.90	-0.95
LEMPLOY	1.90**	2.01**	-0.61*	-1.86**	0.19	0.86*	0.41	0.70*
Optional variables								
EXPORTS					1.85*			
IPRODSH					-3.00**	3.81**		-2.10++
COOPRD			2.41**	2.23**		-1.74*		
PUBRES		-1.60*		1.00*	-1.10			-1.33**
EURMARK			-0.91*		1.06*	2.20**		
LOWRCOST			-1.12*	-1.82*				1.03*
R^2_L	0.34	0.36	0.20	0.26	0.20	0.35	0.34	0.23
R^2_L options	0.00	0.04	0.14	0.15	0.16	0.20	0.00	0.12
-2LL	110.7	54.7	159.1	140.3	153.6	94.3	146.3	154.6
% Correct	84.5	92.6	77.2	85.2	75.7	92.0	77.4	78.7

[1]: No results for Firm sales (Question 7.4) and for several methods for outside of Europe because of an unacceptable fit to the model.

Logit model results for technology transfer for telecom firms are given in Table 9.5. The effect of firm size on technology transfer is not consistently positive as it is with technology acquisition. Instead, the probability of transferring technology through contract R&D and consultancy is higher for smaller firms, perhaps due to the effect of small, specialised firms that conduct R&D for other firms, and there is no relationship for equipment sales or communication within Europe. The proportion of innovative products (IPRODSH) appears to assist equipment sales abroad, but has a negative effect within Europe. This result could reflect alternative routes for technology transfer, with transfer within Europe occurring through more direct methods such as cooperative R&D, contract R&D or direct communication, while transfer outside of Europe is largely perceived as occurring through sales. This interpretation is also supported by the positive coefficient for export share and for the importance of creating new European markets (EURMARK) as an objective of innovation[25].

The pattern for cooperative R&D (COOPRD) is identical to that for acquiring technologies, with a positive effect for contract R&D and consultancy and a negative effect for equipment purchases.

9.5 Concluding Comments

The ability of telecom firms to acquire knowledge from outside of their firm, and the importance of this knowledge, is strongly linked with the size of the firm. Compared to smaller telecom firms, large firms find public research more important, are more likely to participate in cooperative R&D programmes, and are more likely to acquire new technologies from sources within and outside of Europe. This is in contrast to the results for components, where firm size is a less important factor in the importance of both public research and the probability of participation in cooperative R&D.

The importance of government laboratories and acquiring technologies from other firms in Europe and other countries is greater for successful telecom firms, when success is defined either by export share or the percentage of innovative products. In contrast, participation in cooperative R&D programmes, though more likely among firms with a high export share, is less likely among firms with a high percentage of innovative products. Again, the results for the component sector, particularly for participation in cooperative R&D, are the opposite. The participation rate in cooperative R&D is also much higher for component firms, at 63.6% compared to 38% for telecom firms.

Though European subsidies for public research have had relatively little impact on the telecom sector, with telecom respondents giving public research a very low rating compared to other sources of information, the importance of public research varies by the type of public research, with government laboratories appearing to be more important than universities or technical institutes. In particular, telecom firms with

[25] The importance of creating new foreign markets is not included as a variable because it would require excluding Norwegian firms.

a high proportion of sales due to innovative products are more likely to find government laboratories to be an important source of information than telecom firms with a low proportion of innovative products.

The results for technology acquisition indicate that telecom firms use some foreign sources more frequently than component firms. This could reflect the need to acquire components and software from outside Europe, but unfortunately there is no information on the types of technologies that are acquired through each of the seven methods evaluated in the CIS questionnaire. Equipment purchases and communication with foreign firms are the most important means by which telecom firms acquire new technologies from outside of Europe. Both are linked to success, with a positive relationship between exports and communication with non-European firms and between innovative product share and equipment purchases from outside of Europe.

10 GOALS OF INNOVATION

10.1 Introduction

Results on the importance of eighteen main goals of innovation are available for innovating firms. Several of these goals measure an "aggressive" versus "defensive" innovative strategy. An aggressive strategy is defined as first, seeking new markets outside of Europe and second, by moving into new products rather than replacing existing products that are being phased out. A defensive strategy is characterised by maintaining existing market share and replacing existing products. Other goals, such as improving quality or reducing costs, can be part of both strategies. It is difficult to completely define a defensive strategy using the CIS results since the question on market share also includes *increasing* market share, which can be part of an aggressive strategy. Though a defensive strategy is of value, the long-term success of the European telecom equipment industry depends on an aggressive strategy of developing new products and actively seeking growing markets outside of Europe. The first section of this chapter briefly examines the importance of aggressive and defensive strategies. Further discussion of these goals can be found in Chapter 7 on innovative success and Chapter 12 on exports.

In addition, four objectives that are of relevant to EU environmental policies are also examined. Two are of primary concern; to reduce energy consumption and environmental damage, and two are of secondary importance to environmental issues; to reduce materials consumption and improve safety and working conditions.

10.2 Aggressive Innovation Strategies

The percentages of telecom, component, and similar hitech firms that stated that each objective was very important or crucial are given in Figure 10 and the most important objectives are given in Figure 11. Both are listed in descending order of importance based on the results for the telecom sector. Over 80% of respondents from all three sectors rate increasing market share as an important objective, followed closely by product quality for the telecom and other hitech sectors. Objectives that are part of an aggressive strategy are rated as important by considerably fewer firms. Developing new products (NPnf) is important to fewer than 40% of telecom firms while less than 20% find creating new markets in North America (NMna) or Japan (NMj) to be important. In Figure 11, the two questions on extending the product range within and outside the main product field are combined into 'New prods'. This is the fourth most important goal for telecom firms, though it lags considerably behind improving product quality. Creating new markets outside of Europe are combined into 'For marks'. This is the *least* important objective for telecom firms, and relatively less important than in components and other high tech.

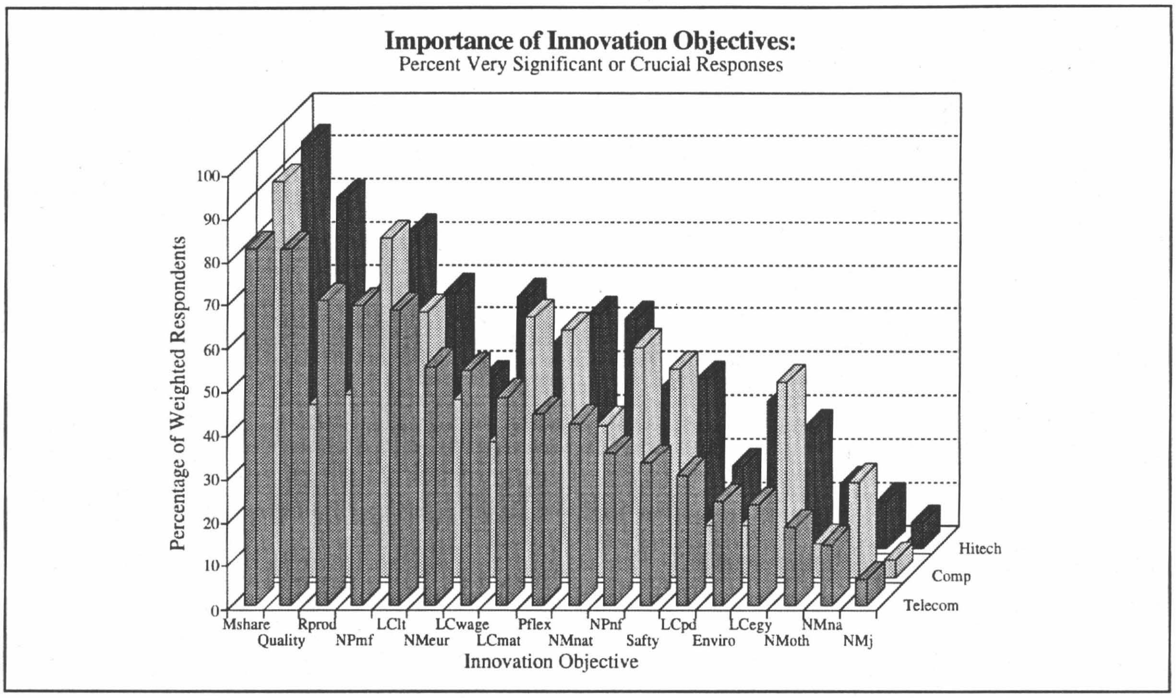
Table 10.1 gives the results for telecom firms of logit regressions for several objectives that are related to aggressive versus defensive innovation strategies.

Table 10.1 INNOVATION OBJECTIVES: Logit results for 148 telecom firms (* = p < 0.10, ** = p < 0.01)

	Lower costs	Market share	Improve quality	Main products	New products	Foreign markets
Constant		0.87	-0.73	-1.17*	-1.82**	-0.22
LEMPLOY	1.20**	0.50	0.18	0.84**	0.67**	0.12
Optional variables						
EXPORTS	1.35*			4.00**		2.76**
COOPRD	-1.92**					
DOMESTIC						
PUBRES	-1.00*			-0.95*		-2.12**
SPRODSH			-1.30*			
R^2_L	0.36	0.38	0.11	0.22	0.07	0.19
-2LL	183.1	129.4	273.7	208.7	262.0	241.8
% Correct	76.6	83.9	68.8	81.7	67.0	74.1

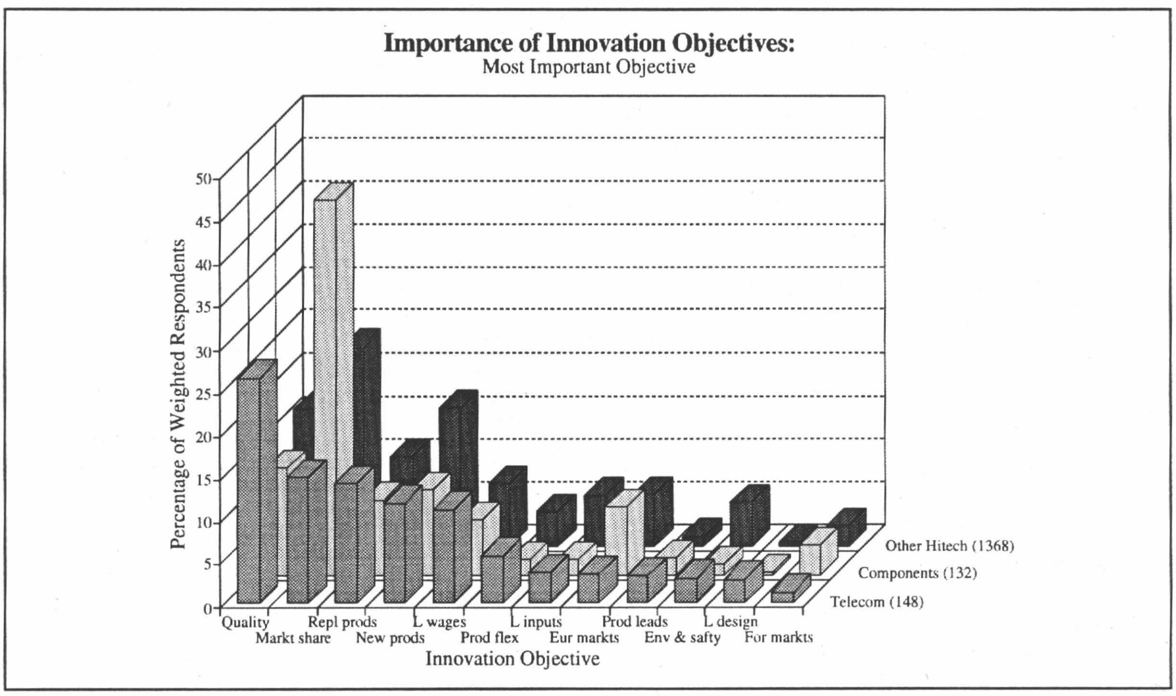
Optional variables limited to avoid erroneous cause and effect relationships. Only optional variables with at least one significant result are included. See Appendix Table B-7 for a description of the variables.The objectives are arranged approximately in order from the most defensive position (lower costs of wages, materials and energy) to the most aggressive strategy (create foreign markets in North America, Japan, or other locations outside Europe). The importance of lower costs and extending the product range, either in the main product field (Main products) or in a new field (New products), increases with firm size (LEMPLOY), but

Figure 10



Mshare = Increase or maintain market share, Quality = improve product quality, Rprod = Replace products being phased out, NPmf = develop new products within main product field, NPnf = develop new products outside main field, NMnat = create new national markets, NMeur = create new markets in Europe, NMna = create new markets in North America, NMj = create new markets in Japan, NMoth = create new markets in other countries, LCwage = lower share of wage costs, LCmat = lower material costs, LCegy = lower energy consumption, LCpd = lower product design costs, LClt = lower costs from production lead times, Enviro = reduce environmental damage, Pflex = production flexibility, Quality = improve product quality, Safty = improve working conditions/safety.

Figure 11



there is no effect for creating foreign markets. Other than the variables for country (not shown), none of the variables influences the importance of increasing market share, probably because this goal is important to all types of firms. A high export share (EXPORTS) and finding public research to be an important source of information (PUBRES) have the most frequent influences on these six goals, though in opposite directions.

High export shares increase the probability that lower costs, developing products, and creating foreign markets will be important goals. This is not surprising, since low cost products are needed to compete in foreign markets and export intensive firms should also be more likely to want to develop new export markets. Conversely, finding public research to be important (and participation in cooperative R&D (COOPRD) in one case), *decreases* the probability that each of these three objectives are important to the respondent's firm. Unfortunately, there is no indication here as to where public research is important. Finally, the proportion of significantly changed products out of total sales (SPRODSH) is negatively associated with improving quality. This is a perfectly reasonable result since quality improvements are not significant innovations, but it does suggest that firms make a choice between strategies. Otherwise, we would expect no relationship between SPRODSH and quality improvements.

10.3 Environmental Goals

Figure 10 shows that 19.9% of telecom firms find reducing energy use and 27.3% find reducing environmental damage to be important goals for innovation. After controlling for firm size and country effects, the higher importance of safety and the lower importance of environmental goals for telecom compared to component firms are statistically significant ($p < 0.1$), while the differences for energy and material use are not significant. Reducing environmental damage is more important to telecom firms than to component firms, while the reverse is true for reducing energy costs. The two secondary environmental goals are important to a higher percentage of telecom firms, 45.7% for reducing energy costs and 37.6% for improving safety.

Since very few firms rate any of these goals as the most important, the results in Figure 11 combine reducing energy and material input costs (L inputs) and environmental damage and safety goals (Env & safty). Both are rated as most important by less than 5% of the telecom respondents, compared to slightly over 10% of other hitech firms and under 3% by component firms.

Attempts to fit a logit model to the data in order to determine the factors that influence whether or not a firm finds each of the four environmental goals to be of importance were generally unsatisfactory. The best results, given in Table 10.2, were achieved using a limited range of optional variables and by including R&D intensity.

The latter required excluding French firms. Firm size has little effect on the importance of environmental goals, except for improving work and safety conditions.

Table 10.2	ENVIRONMENTAL GOALS FOR INNOVATION: Logit Regressions for 124 Telecom firms (* = p < 0.1, ** = p < 0.01)			
	Reduce material use[1]	Reduce energy use[1]	Reduce enviro damage[2]	Improve work conditions & safety[2]
Constant	-1.34	-0.45	-0.50	-1.36
LEMPLOY	0.47	-0.65	0.03	0.85*
RDINTENS	-5.89*	-11.86*	-2.52	-6.36*
Optional variables				
Exports	1.73*		1.95*	3.61**
Cooprd		2.29**		-1.31*
Pubres			1.70*	
R^2_L	0.20	0.26	0.16	0.23
R^2_L optional	0.02	0.07	0.05	0.07
2LL	130.7	112.5	144.8	114.5
% correct	82.1	83.1	69.1	81.5

[1]: 1 = a very significant or crucial response.
[2]: 1 = a moderately significant, very significant, or crucial response.

In contrast, the importance of all environmental goals declines with R&D intensity, though this is perhaps because the firms find other goals relatively more important. The importance of three of the environmental objectives increases with export share. The results suggest that cooperative R&D could be used in innovative projects to reduce energy consumption, while public research could be a source of information for reducing environmental damage.

10.4 Concluding Comments

Telecom firms are less likely than component and other high tech firms to find aggressive innovative strategies such as developing new products or creating new markets outside of Europe to be important. However, the probability that firms will find several goals that are related to future export success - lowering costs, developing new products in the main product field, and creating foreign markets, increases with the share of the firm's sales from exports. In contrast, firms that find public research of importance are less likely to find these three goals of importance, with the implication that publicly funded research in telecommunications is not of much relevance to firms pursuing an aggressive strategy.

These results, though admittedly sparse and exploratory, suggest that the European telecom sector is relying too much on defensive innovation strategies. There may also be policy options to improve the relevance of publicly funded research to the aggressive innovation goals.

Environmental goals are relatively unimportant to telecom firms compared to other innovation objectives such as improving product quality and market share. Though firm size has no effect on the importance of most environmental goals, R&D intensity is an importance factor, with more R&D intensive firms considerably less interested in environmental goals. We suspect that this is probably not true in absolute terms, but could largely reflect a relative increase in the importance of other goals. Alternatively, the greater importance of environmental goals to firms with low R&D intensities could be due to a greater emphasis on the production of standardised products, where improved economic performance would also depend on reducing input costs[26].

11. STANDARDS, REGULATIONS AND INNOVATION BARRIERS

11.1 Introduction

Data on the importance of 18 possible barriers to innovation is available for both innovating and non-innovating firms. Six of these questions are of particular interest to policies for the telecom sector: a lack of skilled personnel, lack of information on technologies, lack of market information, lack of opportunities for cooperation with other firms and technological institutions, uncertainty in the timing of innovation, and one question that unfortunately combines legislation, norms, regulations, standards and taxation. This is unfortunate because of the importance of standards to the telecom sector as a means of reducing uncertainty and to reduce entry barriers for smaller and more specialized firms. Combining standards, which could be interpreted positively by some telecom firms, with taxation, with a likely negative interpretation, could confuse the meaning of the responses to this question.

11.2 Basic results

Table 11.1 gives the percent of innovating and non-innovating telecom and component firms that find each of these six barriers to innovation to be either moderately, very, or extremely important[27].

[26] The low importance of environmental goals for telecom firms is probably due to the low cost of inputs relative to total costs in this sector and to a reputation for clean manufacturing operations. In a comparison of the importance of environmental and safety goals for all NACE two-digit industries, NACE 32 firms ranked last. These goals are most important to firms in bulk product sectors, reaching a high of 17% in petroleum products. Similarly, reducing input costs is most important in bulk product sectors such as food, wood products, chemicals and rubber, and among the least important in NACE 32 and similar Hitech industries.

[27] The percentage of respondents that find each of the six factors examined here to be 'very significant' or 'crucial' is usually below 10%. In order to increase the variation in responses, the 'important' category has been altered to 'moderately significant', very significant', or 'crucial'.

Table 11.1	BARRIERS TO INNOVATION: Percent 'Moderately', 'Very Important' or 'Crucial' Responses for Telecom and Component Firms. Statistically significant differences[1] (p< 0.05) between telecom and component firms in bold type.					
	Innovators			Non-Innovators		
	Telecom	Comp	Hitech	Telecom	Comp	Hitech
Lack skilled personnel	**31.6**	**40.6**	46.5	**49.1**	**15.2**	38.0
Lack info on technologies	18.7	27.6	25.7	**23.2**	**2.1**	13.7
Lack market information	**30.6**	**70.6**	35.9	22.8	4.3	24.7
Lack external cooperation	**19.4**	**72.5**	35.3	26.9	11.9	25.2
Innovation too easy to copy	**39.4**	**40.7**	57.9	13.8	6.8	26.4
Legislation, standards taxes	**24.7**	**73.2**	40.5	**37.1**	**12.5**	30.8
Uncertainty in timing	**27.8**	**75.1**	38.0	23.8	9.8	27.9

[1]: Controlled for country and firm size.

Two patterns immediately stand out. First, innovating telecom firms consistently find all of these six barriers to innovation to be less important than both component and other hitech firms. The pattern is partly reversed for non-innovators, where the Telecom firms find all barriers to be more important than component firms, though the results are mixed in comparison with other high tech firms. Second, innovating component and other hitech firms find all six barriers to be more important than non-innovators in the same sector. Again, the pattern is mixed for telecom firms, where innovators are more concerned than non-innovators about a lack of market information, the ease of copying innovations, and uncertainty in timing[28].

A plausible explanation for the first pattern, particularly in the comparison between telecom and component firms, is that the telecom firms are more confident innovators that generally experience fewer difficulties with obtaining adequate information and skills or in dealing with external factors since these are essential survival skills for telecom firms.

The second pattern is unexpected, since one would expect non-innovators to find many of the factors to be greater barriers to innovation than the innovators, but this is definitely not the case. An explanation for the higher importance attributed by the innovators to most of the barriers could be due to one or both of two basic reasons. First, the innovators should have greater experience with each barrier, and could therefore be more cognizant of their importance and, also, of ways to deal with it.

[28] The results are similar for the four questions on economic factors as barriers to innovation: excessive perceived risk, lack of appropriate sources of finance, innovation costs too high, and pay-off periods too long. The exception is that innovating telecom firms are more concerned about high innovation costs and long pay-off periods than component firms.

Second, the questions could mean different things to the innovating and non-innovating groups, with the former evaluating each question for its significance in influencing ongoing innovation, while the non-innovators interpret the question as referring to the reasons why their firm does not innovate at all.

11.3 Logit Results for Telecom Firms

Factors that influence whether or not a telecom firm finds a specific barrier to be important were investigated for both innovating and non-innovating firms. The results for the non-innovators were unsatisfactory, largely because of a small number of cases, which made it impossible to control for country effects[29]. The results presented here are therefore limited to innovators.

Several factors investigated in the CIS questionnaire could possibly be related to the importance of barriers to innovation. In addition to firm size, export intensity, and innovative success, these include information sources, which can be used to overcome barriers, and innovation goals, which could be directly hampered by barriers[30]. Preliminary analysis showed that many of the information sources were significant for at least one of the seven barriers, but there were no consistent results. Consequently, we limited the available optional source variables to a few of particular interest; public research (PUBRES), consultants (CONSULT), and competitors (COMPET). Preliminary analysis of the goals of innovation showed that the only important influence was the importance of foreign markets (FORMARKT).

The final Logit model results are given in Table 11.2. In contrast to other Logit models for the importance of information sources, innovation objectives etc, firm size is not an important factor, with a significant effect only for the importance of a lack of technical information (where larger firms have fewer problems) and for uncertainty, where larger firms find this a more important problem than smaller firms. This suggests a structural difference between large and small firms in the timing of innovations. The prospect for a large firm of a highly complex systems with enormous development costs being "dead on arrival" in the market is a larger risk than the risk facing smaller firms producing more specialised systems with

[29] This was a serious problem because almost all firms that found each barrier to be important were Italian, raising serious problems of bias.

[30] Another possible factor is interactions with other barriers to innovation. Preliminary investigation of the effect of other barriers to innovation on the seven barriers used an index of the importance of the four economic factors and drawbacks within the enterprise. Both were highly significant for almost all of the seven barriers, and contributed much more to the reduction in variance than all other independent variables combined. However, these results are impossible to interpret because of bias due to high correlations between adjacent barrier questions and similar ratings to all sub-questions in a question set. Consequently, the true contribution of other barriers, such as estimated by the indexes for economic and enterprise factors, cannot be separated from these two types of internal bias.

shorter and less expensive development cycles. In addition, the results are relatively poor, with R^2_L values ranging between 0.11 and 0.23.

The most important influences on these barriers are the export share, the percentage of incrementally or significantly changed products out of total 1992 sales (IPRODSH), and the importance of foreign markets as a goal of innovation. The negative coefficients for IPRODSH suggests that successful innovators are less concerned about barriers, including legislation and uncertainty. In contrast, the coefficients for both exports and FORMARKT are positive, indicating that both successful exporters, and firms with the goal of exporting to foreign markets, are very concerned about these barriers. This could reflect greater international competition, and a need to continually innovate to keep up, putting pressure on personnel resources and a greater need for technical information[31].

Table 11.2 Telecom Firms[1] **BARRIERS TO INNOVATION: Logit results for Innovating (* = p < 0.1, ** = p < 0.01)**

	Lack skilled personnel	Lack technical info	Lack market info	Lack external coop.	Innovation too easy to copy	Legislation, standards, taxes	Uncertainty in timing
Constant	-1.85*	-1.19	-1.48*	-1.41	-2.88**	-0.98	-2.25*
LEMPLOY	0.01	-0.91*	0.47	0.40	0.51	0.31	1.01**
EXPORTS	2.18*	2.67*			4.34**		2.66*
IPRODSH			-1.66*	-2.05*		-2.27*	-3.08**
PUBRES				1.38*			
CONSULT					2.39**		
COMPET		-1.90*					
FORMARKT	1.75**	2.00**	1.29**	1.18*		1.35**	1.02*
R^2_L	0.16	0.23	0.11	0.13	0.22	0.13	0.18
2LL	125.8	90.5	134.5	91.6	106.4	110.8	106.3
% Correct	75.8	86.3	69.4	82.3	83.9	73.4	72.0

[1]: All barriers are coded 1 = moderately significant, very significant, or crucial. Dummy variables for country consist of Germany and all small countries combined, with Italy as the reference group. The smaller countries had to be combined because of a lack of variation in the dependent variable.

The effect of information sources is highly specific. Public research is more important to firms that find a lack of external cooperation to be a barrier to innovation. Since

[31] There is no correlation between export share and either IPRODSH or R&D intensity, indicating that a high export share is not dependent on good innovative performance. This explains why successful innovators (IPRODSH) are less likely to find each barrier to be a problem, while export oriented firms are more likely to find them a problem.

public research is often used through cooperative R&D programmes, this raises the possibility that the responses to the barrier questions are biased by the cross-sectional design of the questionnaire. A lack of opportunities for external cooperation can be rated as highly important both by firms which do not cooperate (but would like to) and by firms which find this barrier important, and have therefore already taken steps to overcome it, for example by entering into cooperative R&D programmes with public research institutes[32].

Similar problems affect the interpretation of the question on legal barriers. Standards and regulations, in so far as they reduce uncertainty, could be considered as a positive factor. However, since the question is in a group of barriers to innovation, we assume that the telecom respondents interpret these legal factors as negative effects on innovation. The lack of any relation with exports suggests that these legal barriers are interpreted as within Europe, though this is contradicted by the positive coefficient for the importance of foreign markets.

11.4 Concluding Comments

Innovating telecom firms find each of the seven barriers to innovation evaluated here to be less important than both component and hitech firms, while for most barriers non-innovating telecom firms find them to be more important barriers than non-innovating component and hitech firms. The former paints a picture of a successful, innovative sector with few limitation due to a lack of capabilities, uncertainty, legislation, or poor appropriation conditions. The situation for non-innovating firms suggests that either the non-innovating telecom firms are more aware of the need to innovate, or that a crucial reason for not-innovating among component firms is missing[33]. Poor appropriation conditions is given the highest importance rating by telecom firms, but this factor does not appear to translate into real difficulties, since firms that find the ease of copying to be important are more successful innovators, as shown in Section 2.

The importance of most of these six barriers is not related to the size of telecom firms, but firms with a high export share and a goal to create new foreign markets are more concerned about their internal capabilities to innovate and uncertainty. This could reflect intense technological competition in export markets. This suggests that telecom firms that are export oriented and seeking to move into foreign markets, perhaps the most important section of this sector to European competitiveness, could

---

[32] Preliminary analyses showed that participation in cooperative R&D was not related to any of the barriers examined here.

[33] A main reason not to innovate could be that it is not part of the firm's strategy, particularly if it is a subsidiary or a supplier to a larger firm.

be confronting barriers in their ability to acquire skilled personnel, and technical and market information.

The question on legislation and standards is not formulated in a way that is particularly useful for this sector. It is not possible to determine if the low importance attached to this factor by telecom compared to component and other hitech firms is due to the respondents perceiving legislation as basically advantageous, or if they are simply less likely to view legislation as a negative factor.

12 EXPORT PERFORMANCE

12.1 Introduction

Successful innovation should lead to more competitive products. Therefore highly innovative firms should have a higher export rate than their competitors. However, several factors could confuse the relationship between innovative activity and the export rate. One factor is firm ownership. Foreign subsidiaries operating as export platforms within Europe could export a substantial proportion of their output to other European countries while conducting very little R&D in Europe. This appears to be occurring among the component firms, where foreign-owned firms have an R&D intensity of 7.2% and an export rate of 74.7%, while the R&D intensity of domestic component firms is higher at 19.1%, while their export rate is much lower at 8.8%. There is little difference between domestic and foreign-owned telecom firms in average R&D intensity, 8.1% for foreign compared to 9.3% for domestic, but there is a larger difference in export rates, with foreign firms exporting 42.7% of their output compared to 21.5% for domestic firms.

A second factor, that is also related to firm ownership, is that firms based in small countries will normally export a higher proportion of their output than firms based in large countries. For example, the average export rate for telecom firms in the three large countries of Germany, Italy and France is 15.3% compared to an export rate of 46.7% for the four small countries of Belgium, the Netherlands, Ireland and Norway.

These first two factors can be controlled for in the analyses by including variables for ownership and country. However, there is no information in the CIS survey on two other factors that could influence export rates. One is that the CIS data does not differentiate between exports to other countries within the EU and exports to countries outside of Europe. This distinction would be of interest, both because of the importance of foreign exports to European trade, and because of the assumption that competitiveness should be reflected in high foreign export rates. The second factor is that small, relatively young firms could be very innovative but export little, either because their current strategy is to supply other domestic firms, or because they have not yet had the time to build up the abilities needed to move into export markets. This effect can be partly captured by including a variable for firm size, but this is not completely satisfactory.

12.2 Basic Results and Export Status

Table 12.2 gives the percent of firms that export and the average export rate for telecom, component, and other hitech firms. A lower percentage of non-innovating telecom firms export compared to component firms, but the opposite is true for innovating firms. Among exporters, the difference in the export rate between telecom and component firms is not significant[34].

The factors that influence whether or not a firm exports were further investigated in a logit model including both innovating and non-innovating firms. The results (not shown) confirm the differences between innovating and non-innovating firms shown in Table 6.2. Furthermore, for all three sectors, the probability of exporting increases with firm size. Domestic telecom and component firms are less likely to export than foreign-owned firms, but these differences are not significant. However, the difference is significant for other Hitech firms.

Table 6.2 EXPORT RATES: Percent of Exporting Firms (export rate > 0.0%) and Mean export rates for Innovating and Non-Innovating Component, Telecom, and Other Hitech Firms (Statistically significant differences between Telecom and Components ($p < 0.01$) in bold[1])

	Telecom	Components	Other Hitech
Percent exporters			
Non-innovators	**26.4%**	**79.0%**	51.5%
Innovators	**85.1%**	**56.9%**	74.6%
Average export rate			
Non-innovators	4.5%	10.8%	11.6%
Innovators	20.1%	16.0%	24.0%

[1]: Controlled for country effects and firm size.

12.3 Export Share among Innovating Firms

For innovating firms only, the percentage of exporters ranges from a low of 14.9% in telecom to 43.1% in components. To avoid biased results, a Tobit model that accounts for firms with no exports is used to investigate the factors that influence the export

[34] From a sectoral perspective, 51% of the total output of the components sector is exported, compared to 20% for the telecom sector. This difference probably reflects the importance of sales to national service providers and the close links between national telecom service providers and equipment manufacturers.

rate. The results are given in Table 12.3[35].

Table 12.3	Tobit Results for Export Share for Innovating Telecom, Component, and other Hitech Firms (* = $p < 0.1$, ** = $p < 0.01$)				
	France Included			France Excluded[1]	
Variable	**Telecom**	**Components**	**Other Hitech**	**Telecom**	**Components**
Constant	-0.24**	-0.69**	0.25**	-0.087	-0.283
σ	0.19**	0.24**	0.27**	0.189**	0.199**
LEMPLOY	-0.007	0.327**	-0.0004**	-0.059	0.25**
RDINTENS				-0.022	-0.085
DOMESTIC				-0.082	-0.385**
IPRODSH	0.268**	0.147	-0.009	0.183*	0.023
COSTGOAL	0.014*	0.008	-0.011**	0.018*	0.022*
COOPRD	0.047	-0.059	0.052**	0.132*	-0.031
FORMARK	0.111**	0.176**	0.13**	0.146**	0.161*
PATENT	0.113*	-0.035	0.091**	0.088*	-0.069
MAINPROD	0.091*	0.165*	0.024	-0.128	0.145*
NEWPROD	-0.051	-0.178*	-0.159**	-0.100*	-0.162*
Cases	148	132	1287	124	113

[1]: No data on R&D or ownership status for French firms.

R&D intensity has no effect on the export share for either telecom or component firms. Unfortunately, the model including R&D intensity and ownership status for other Hitech firms did not fit the data.

For all three sectors, firms that find creating new foreign markets to be an important goal of innovation have a higher export share, while firms that attach greater importance to developing new products outside of their main product field have a lower export share. The first result is as expected, but the second suggests that firms with a higher export share have less ambitious R&D plans. This is not necessarily true, however, since the results could be confounded by firms that are failing in their main product area placing greater importance on new product fields.

Overall, telecom firms are more similar to other hitech firms than to component

[35] Preliminary analyses explored the effect of excluding cases where the export rate was based on values estimated by EUROSTAT. Including these cases had a minor effect on the telecom firms, but no effect on the component firms. Therefore, cases with estimated values are included in the regressions presented in Table 12.3.

firms. Export share for components increases with firm size, foreign ownership, and the importance of innovation to reduce costs (COSTGOAL). In contrast, there is no relationship between firm size and export share among telecom firms, nor with foreign ownership. Of perhaps greater interest are the positive results for patents as a source of information (PATENT), innovative product share (IPRODSH), and participation in cooperative R&D programmes (COOPRD). IPRODSH is a measure of innovative success based on a high percentage of new or changed products, while both PATENT and COOPRD can indicate advanced innovative activities. Firms that find patent searches, for example, to be a valuable source of information could either be searching for information on their competitors, keeping current with the latest developments, or determining if their innovations are patentable[36]. All of these reason are likely to be related to the closeness of a firm to the technological frontier. The same could be true for firms that participate in cooperative R&D.

12.4 Concluding Comments

The investigation of export share between telecom and component firms highlight several differences between the European telecom sector, where Europe exports more high technology products than it imports, and the components sector, where the reverse is true. The component sector has a higher export share by non-innovating than by innovating firms, and among innovators there are no positive effects for measures of innovative success or advanced innovative capabilities. Instead, the general picture is of high export rates by non-innovating firms and by large innovative firms, without any positive effects for measures of innovative success. In contrast, the telecom sector has a much higher export rate among innovating firms, a low rate among non-innovators, no relationship with firm size (perhaps indicating a healthy level of competitiveness among SMEs in this sector), and higher export rates among firms with a high percentage of innovative products in total sales.

[36] A better indicator of the latter would be to use the question on the importance of patents as a means of appropriation. This was not done because the appropriation questions were not asked in several key countries.

APPENDIX A

METHODOLOGICAL ISSUES OF THE CIS SURVEY

A1. INTRODUCTION

The CIS survey is designed to obtain data on innovation from a wide range of industrial sectors, across the full spectrum of firm size, and in all of the EU countries. It also introduced several questions on innovative activities that have not been widely tested in earlier surveys. Both of these characteristics can cause the CIS survey results for the telecom equipment sector to fail to meet expectations. Questions designed for all industrial sectors can miss important factors that are unique to telecom equipment and untested questions can give unexpected results. The purpose of this Appendix is to evaluate the ability of the CIS survey to adequately measure innovation in the telecom equipment sector and to make recommendations for future innovation surveys of this industry.

Three main methodological issues are explored below. The first section uses public data to validate the CIS estimates for several quantitative variables. This analysis concerns survey and sampling methods. The second section looks specifically at problems and shortcomings with the design of the questionnaire, while the third section looks at the issue of aggregation across industrial sectors.

A2. VERIFICATION OF CIS ESTIMATES

The CIS survey obtains data for a total of 210 EU firms producing telecom equipment in Norway and in up to six EU countries: Germany, France, Italy, the Netherlands, Belgium, and Ireland. The results for these firms, which form an unknown percentage of all telecom firms in each country, are used to estimate the innovative strategies of telecom firms in these countries, and by implication for the telecom equipment sector in general in the EU.

The CIS results given in Part Two are almost always based on weighted estimates, where the results for a few respondents are taken as representative for a much larger number of firms. The accuracy with which these CIS estimates approach the true, unknown values depends on three main factors. The first factor is the survey methodology, including the reliability of the sample frames, and the weighting factors. The second factor consists of any distortion of the original survey results introduced by the micro-aggregation process used by EUROSTAT to protect confidentiality (Eurostat, 1994). The third factor is the reliability of the values, for example for total sales and number of employees, provided by the respondents to the survey.

It is not possible here to untangle the contribution of each of these three factors to any errors in the CIS estimates, but it is possible to estimate the percentage of the EU telecom equipment sector that is covered by the CIS survey and the approximate size of the error for several quantitative variables by comparing the CIS estimates against publicly available data. Relatively complete and presumably accurate public data is available for the telecom sector for production, exports, and employment. Most of this data, derived from the series *Yearbook of World Electronic's Data* (YWED), has been presented in Part One or in Appendix B.

A2.1 CIS Coverage of the EU Telecom Equipment Sector

CIS data for the telecom equipment sector is available for only six of the 12 EU countries at the time of the survey. No useable data is available for the UK, Greece and Portugal because of low response rates, or the absence of weightings to adjust for differences in response rates, and it is not possible to separate telecom from component and television manufacturers for Luxembourg, Denmark, and Spain. However, based on production data (Table B-2), the six countries with useable data accounted for 80.0% of telecom equipment production in the EU in 1992[1]. The major drawback is the lack of data for the UK and Spain, which contributed 13.7% and 5.7% respectively of total EU telecom production in 1990. The lack of data for Denmark is less important since it only contributed to 0.7% of total EU production.

A related question concerning the coverage of the CIS survey is whether or not it includes Europe's largest telecom firms, who are probably responsible for the lion's share of production and innovation in this sector[2]. The micro-aggregation process makes it impossible to answer with any certainty whether or not any of these nine firms are included in the survey. However, the CIS data includes 17 firms with micro-aggregated sales over 0.25 billion ECUs and 10 with sales over 0.5 billion. This suggests that it is reasonably likely that some of Europe's largest telecom firms are included in the CIS results.

[1] Excludes Portugal and Greece, which have minimal telecom equipment industries.

[2] Total telecom equipment sales of the 14 largest European firms listed in Table 3 of Part One is 48.4 billion US, which in fact exceeds the total EU production of 41.9 billion in the same year. The discrepancy is probably due to several factors: the total sales of these 14 firms includes production outside of the EU, it includes re-exports, and includes some products that are excluded from the production figures, which are limited to line telephony and radio and broadcast equipment.

A2.2 Validation of CIS Estimates

CIS estimates for three quantitative variables, production, exports, and employment, are validated against the combined YWED data for line telephony and radio and broadcast communication equipment. This combination (equal to the wide definition of the telecom equipment sector in Table 1, Part One) is equivalent to NACE sector 322, used to classify telecom equipment firms in the CIS survey.

The results are given in Table A-1. The CIS estimates give the sum of production or exports across all respondents in a given country. For example, the unweighted CIS estimate for telecom equipment production for Germany is 4527 million ECUs, which is obtained by summing the sales of all German telecom equipment firms that responded to the survey. For Germany, the YWED estimate of total production is 8518 million ECUs[3]. This figure is used to calculate the proportion of actual production, in this case 0.53 (4527/8518), that is produced by CIS respondent firms.

The sum of the unweighted CIS values for exports and employees should be less than the actual values, though the amount by which they differ will depend on the percentage of all telecom firms that replied to the survey and their relative importance to the telecom industry. This sum, for example, could be a significant fraction of all exports if several of the largest exporters replied to the survey, even if the total response rate was very low. The sum of unweighted sales should be a relatively higher proportion of actual production values, compared to the equivalent proportions for exports and employees, because the production figures exclude imports and re-exports of finished goods, whereas both of these can be included in the sales reported by the firms on the CIS questionnaire. In theory, the weighted CIS estimates should roughly approximate the actual values for exports and employees, but the weighted sales values should overestimate actual production.

The results given in Table A-1 confirm several of these expectations. Unweighted production estimates are higher than the equivalent for exports and employees, and the weighted estimates for total sales considerably exceed the actual production values by 1.89 times. In contrast, the total weighted estimate for exports is very close to actual estimates, with only a slight overestimate of 3%.

The results by country, however, point to a few problems with the CIS data. The weighted sales values for Germany, Belgium, and Ireland of 2.68, 2.13, and 1.95 times higher, respectively, than actual production could exceed what would be expected

[3] The actual telecom production for each EU country is given in Table B-2 in US dollars. These values are converted to ECUs using an average US/ECU exchange rate of 0.77 for 1992.

after allowing for the fact that sales can be greater than production. This can be explained for Belgium and Ireland by sales of imports and re-exports, since Belgium serves as an entrepot centre for Europe while Ireland has substantial assembly operations using imported components (YWED, 1996). However, the high ratio of 2.68 for Germany suggests that the CIS results inaccurately overestimate the true value of German sales of telecom equipment. The number of employees for Germany and exports for Italy and Belgium are also substantially overestimated, though the CIS estimate of exports for Germany is very close to the actual value.

The cause of the overestimates, from poor sampling or inaccurate weightings, the micro-aggregation process, or respondent error, cannot be determined. However, one specific cause of error, which should be corrected in future surveys, is caused by the sampling unit. CIS data is obtained at the enterprise level, but as shown in Table 3 of Part One, not all of the sales of Europe's major telecom producers are in telecom equipment. For some telecom equipment firms, the majority of sales are in other product lines, while even major telecom manufacturers such as Racal or Alcatel have a significant proportion of their total sales in other products. This can create two types of error. First, firms with only a small relative proportion of total sales in telecom could be classified in another product group. This would underestimate total activity in telecom. Second, the telecom sector can include firms with sales in other product lines. This would overestimate telecom activity and could be the explanation for many of the overestimates, particularly of production and employees for German firms. The consistent overestimates for Italy for all three variables are also likely to be explained by this problem, since the results for Italy are based on a census that obtained responses from 70% of all Italian industrial firms. Therefore it is unlikely that errors in the sampling frame is the cause of these overestimates. The solution is to sample, wherever possible, at the level of the line of business, for example by sampling divisions or subsidiaries that specialise in one sector.

The practical effects of the tendency for the CIS data to give inaccurate estimates for several countries of these three key variables suggests caution in the use and interpretation of sales or employee weighted values for main innovation indicators such as R&D intensity. This is unfortunate, since for some purposes sales or employee weighted values give a better measure of actual conditions in a sector than the alternative of firm-based averages.

Table A-1 Weighted and unweighted CIS survey estimates of telecom equipment production, exports, and employees and the ratio of CIS estimates to actual figures for the telecom equipment sector in 1992

	Production[1]				Exports[2]				Employees[3]			
	Unweighted		Weighted		Unweighted		Weighted		Unweighted		Weighted	
	CIS est	Ratio	CIS est	Ratio	CIS est	Ratio	CIS est	Ratio	CIS est	Ratio	CIS est	Ratio
Germany	4527.5	0.53	22842.6	2.68	605.8	0.21	3032.0	1.03	32980	0.43	170211	2.20
France	4946.7	0.75	9127.5	1.39	1179.4	0.35	2120.4	0.63	36006	0.45	69441	0.87
Italy	6416.1	1.17	8179.3	1.50	863.6	1.40	1108.9	1.80	54341	1.05	67930	1.31
Holland	681.8	0.59	965.1	0.83	243.8	0.39	338.6	0.55	4784	-	6936	-
Belgium	2291.5	2.00	2435.3	2.13	1707.9	3.04	1737.4	3.19	16609	-	18559	-
Ireland	225.7	0.70	628.3	1.95	111.3	0.49	308.3	1.35	1388	0.13	3821	0.36
Norway	146.6	0.37	275.7	0.69	115.1	0.50	218.1	0.94	1081	0.21	2002	0.39
TOTAL	19235.9	0.82	44453.8	1.89	4826.9	0.56	8863.7	1.03	147189	-	338900	-

[1]: Actual production data for 1992 from YWED (1994), while the CIS data is for micro-aggregated sales data. Sales data can differ from production data since the later does not include imports or re-exports of finished goods.
[2]: Actual export data for 1992 from YWED (1994). Results are similar, though not identical, when ITU trade data is used. The CIS data is estimated from the respondent's estimate of the fraction of total sales that are exported.
[3]: Actual employee data based on Table 6, Part One. Data for France, Germany, and Italy includes military applications such as radar and navigational systems, data for Ireland includes consumer electronics, and data for Norway includes Radio, TV and communications equipment. All of these employee counts probably overestimate the actual numbers employed in NACE 32.2 activities. For example, NACE 32.2 excludes radar and navigational equipment. Results for Ireland, Italy and Germany also based on extrapolating employment for 1992 from other years.

A3. RECOMMENDATIONS FOR QUESTIONNAIRE DESIGN

The CIS questionnaire is designed to be applicable to all industrial sectors. Though this permits comparisons between industries, it unfortunately means that the CIS survey does not obtain information on several topics that are important to an assessment of innovation in the telecom equipment sector. These topics are briefly outlined below, including recommendations for changes to questionnaire design that would improve our knowledge about innovation in the telecom equipment sector[4].

Intra-firm linkages

The telecom equipment sector is characterised by a few large firms that control a substantial proportion of the market, plus a large number of small and mid-sized firms, many of which probably act as suppliers to a single or limited number of dominant firms. These ownership and supplier links can have a significant impact on the innovative activity of the supplier firm, for example if innovation is largely under the control of the parent or dominant firm.

The CIS questionnaire attempts to identify firms that are owned by a larger parent, though both an evaluation of the survey by Archibugi et al (1995) and our own research indicates that the relevant question groups (enterprise structure and question 4.1 and 4.2) are not effective in differentiating firms by ownership. Furthermore, it is not possible to determine if most of a SME's sales are intermediate goods that are sold to one or a few other firms. Better designed questions are therefore needed both to determine a firm's ownership and the proportion of its sales that go to final consumers and to other firms as intermediate inputs. It would also be useful to have information on the proportion of output that is purchased by national and foreign PTTs.

Product lines

As shown in Part One, the telecom equipment sector contains several main product lines with different growth rates and markets. For example, the market for mobile telephones and transmission equipment is growing in Europe and in other regions, while the major growth market for line telephony, with the exception of broad-band systems, is in developing economies. These different markets could influence innovation strategies. Therefore, it would be valuable to collect innovation data for sub-sectors of NACE 322 such as mobile communications, line switching and

[4] Some of these omissions in the CIS questionnaire also apply to other industrial sectors. In addition, the CIS questionnaire contains other shortcomings that are applicable to all industries, including telecom equipment. Most of these problems with the design of the CIS questionnaire are not discussed here, since they are addressed in both other studies and in on-going research at MERIT.

transmission equipment, and other terminal and peripheral equipment. This would require changes to survey design to sample firms at the line of business instead of the enterprise level.

Software development

Telecom equipment combines communication, computer components, and software technologies. The latter is growing particularly important, while at the same time European capabilities in this area are thought to lag behind American firms. This should be forcing European telecom equipment firms to acquire software, either through alliances, R&D cooperative agreements, or direct purchases, from American firms. It would be of great value to be able to determine the extent to which this is occurring by including separate questions for software in Section IV of the CIS questionnaire on the acquisition and transfer of technology. Similarly, question 10c should be revised to include the percentage of R&D expended on software development, and a question on software could be added to Question 12 on factors hampering innovation.

Standards and regulations

As shown in the section on trends in Part One, both the direction of innovation and the likelihood of success are influenced by standards and regulations. In many cases these standards are vital to successful innovation because they reduce uncertainty. However, the relevant question on barriers (12.16) combines standards with 'legislation' and 'taxation'. These various categories of government support or hindrance to innovation need to be separated. In addition, standards need to be defined.

Exports

The CIS questions on exports do not differentiate between exports to other EU countries and exports to the rest of the world. It would be worthwhile to collect this information, since data on exports outside of the EU would aid both in developing indexes of competitiveness and, combined with better data on product lines, provide insights into the types of telecom equipment products where European firms are most successful in export markets.

A4. AGGREGATION BY INDUSTRIAL SECTOR

Research on innovation has consistently shown that the sector of activity of a firm has a large influence on innovation strategies (Pavitt, 1984; Levin *et al*, 1987; Arundel *et al*, 1995; EC, 1995; Klevorick *et al*, 1995). All industrial classification systems use several levels of detail, so that a four-digit industrial class is more narrowly defined than a two-digit class. Most research studies on innovation use a two-digit classification group, either to protect confidentiality or to increase the number of observations in each group. This assumes that innovation strategies are relatively homogenous within each two-digit industrial class. A major question of interest is whether or not this assumption is valid.

This issue can be explored here because Eurostat provided, on request, data for the NACE sector at the three digit level. It is therefore possible to compare the results for telecom equipment (32.2) against components (32.1) and with all NACE 32 respondents for several key questions of interest. Telecom and components are related, since both are based on electronics and computerisation, and often the component sector produces intermediate inputs used by telecom firms. Despite this proximity, the results show that there are often statistically significant differences between telecom and component firms. These differences are, as expected, hidden by analyses at the two-digit level.

Figure A1

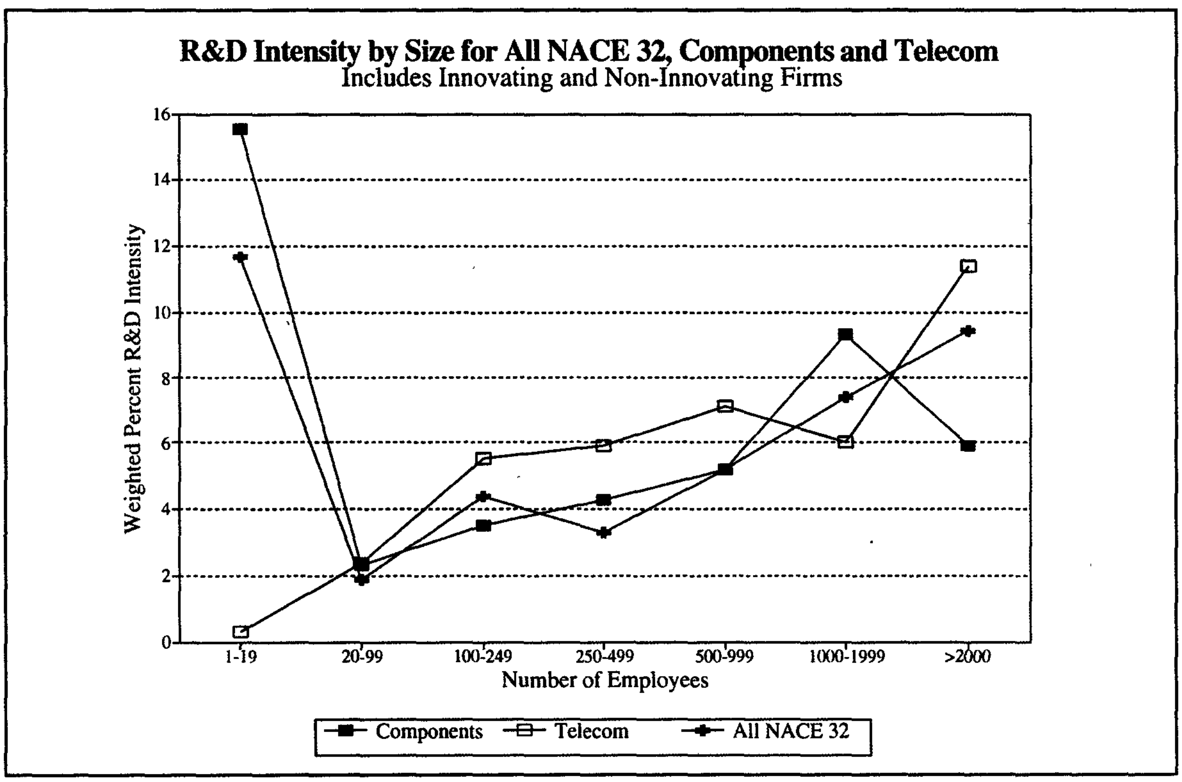


Figure A1 provides an example of how analyses at the two-digit level can mask very different results at a finer level of detail. The Figure graphs the relationship between firm size and R&D intensity for telecom, components, and all NACE 32 firms. The relationship is linear for telecom, but 'U' shaped for component firms, with the highest R&D intensity for the smallest and the larger size classes. Combining all

NACE 32 firms misleadingly suggests that the relationship between R&D intensity and firm size among telecom firms is also U shaped, when it is actually linear.

Table A-2 summarizes differences between the component and telecom sectors, drawing on many of the results given in Part Two.

Table A-2 Significant differences between component (NACE 32.1) and telecom (NACE 32.2) firms

Variable or factor	Explanation of differences
Proportion of innovators	40.1% of component versus 28.7% of telecom firms innovate, due to a very low percentage of small innovative telecom firms.
Innovation expenditures per employee	Component firms spend much more on R&D but telecom firms spend more on all innovation expenditures. This difference is due to the low innovation rates by small firms, and disappears once firm size is controlled for.
Importance of public research as a source of information	After adjusting for firm size and other effects, there are differences in the type of public research that is important to telecom and component firms. Universities are very important to the former and government laboratories to the latter.
Participation in cooperative R&D programmes	Telecom firms that participate in cooperative R&D, compared to telecom firms that do not, have a much lower percentage of innovative new products. The opposite is true of component firms.
Acquisition of technology	A high proportion of component firms acquire new technologies through equipment purchases within Europe, but very few acquire technologies from outside of Europe through this means. The opposite is true of telecom firms.
Innovation objectives	Increasing market share and new markets are considerably more important for component compared to telecom firms.
Innovation barriers	In general, a higher proportion of innovating component firms find specific barriers to be important than telecom firms. The opposite is true for non-innovating firms.
Appropriation methods	Telecom firms find patents and lead time advantages to be less effective than component firms, after controlling for the effect of firm size and R&D intensity.
Export rates	For innovators, export rates are positively correlated with the percentage of innovative products among telecom firms, but the relationship is negative for component firms.

The results show that there is a wide range of differences between components and telecom, all of which are hidden by analyses based on the 2-digit NACE 32 class. Many of these factors, such as the types of public research that are found to be of value, innovation barriers, or the importance of patents, have direct consequences for policy, since they are amenable to government intervention. Results based on all

NACE 32 firms combined could produce misleading results for policy, for example by suggesting that there is no relationship between participation in cooperative R&D programmes and the proportion of innovative products among a firm's total sales, when in fact the lack of a relationship for all NACE respondents is a result of combining a negative effect for telecom firms with a positive effect for component firms.

Though the results summarized in Table A-2 show that significant differences can occur between different industries that are hidden by analyses at the two-digit level, in many cases there are no differences between telecom and component firms, particularly after controlling for firm size, which is equally if not more important than industrial sector as an influence on a firm's innovative activities and strategies. the conclusion to be drawn is that whether or not different industries can be combined is an empirical question that should be investigated in preliminary analyses. In the case of telecom equipment, there are clearly enough differences between telecom and component firms to warrant their separation.

APPENDIX B

Table B-1	**Definitions of the Telecom Equipment Sector**			
	Narrow	**Wide**	**Extended**	**Mixed**
Main characteristic	Focus on line telephony	Includes telephony *plus* radio and TV communication and broadcast equipment	Includes line telephony, radio and broadcast equipment, *plus* related products	Includes non-communication equipment
Product areas included	Electronic switching equipment Transmission equipment Line, cordless, and cellular telephones Facsimile and other terminals	Radio communication equipment, including microwave and satellite systems Radio & TV broadcasting equipment Public broadcast TV cameras	coaxial and optical cables telecom software	Studies based on two- or three-digit sectoral classifications that include other products such as electronic components, electro-medical equipment, home entertainment equipment, etc.
Classification systems and major data sources that primarily use the definition[1]:	Panorama of European Industry (1994), Yearbook of World Electronics Data	NACE (1990), ISIC (1989), CIS survey, PACE Report (1995), SITC, Yearbook of World Electronics Data, OECD, 1991, Communications Outlook, 1995	Communications Week International	NACE (1970 version), European Report on Science and Technology Indicators (1994), Panorama of European Industry (1994)

[1]: Each classification system and data source are assigned to the closest definition of the telecom sector, but there is rarely a perfect match. Some data sources use different definitions, depending on the purpose. For example, the Panorama report sometimes uses the narrow definition while in other cases it uses a mixed definition that also includes electro-medical equipment and meters & measuring devices. The Yearbook of World Electronics Data provides data at a finer level of detail that permits analyses at both the narrow and wide definition of the telecom equipment sector.

Table B-2	Market for telecom equipment (radio & broadcast equipment plus line telephony) in million US dollars in the EU-15 countries[1] plus Norway between 1989 and 1995 (Market size for 1995 estimated)						
	1989	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**
Norway	538	622	631	643	615	680	698
Austria	475	576	528	690	659	780	806
Belgium	1042	1384	1409	1336	1371	1365	1342
Denmark	343	340	304	288	290	366	377
Finland	478	551	498	441	328	385	388
France	6041	7427	6994	7651	6795	7668	7722
Germany	5744	7183	9277	10073	8634	8263	8266
Ireland	255	326	330	346	314	343	359
Italy	5661	7400	7548	7534	5172	5500	5604
Netherlands	1394	1622	1725	1736	1520	1572	1580
Spain	2882	3871	3264	2446	1721	1911	1969
Sweden	1240	1360	1536	1534	1121	1209	1185
UK	6054	5843	5222	5400	4247	4721	4841
TOTAL (EU only)	**31609**	**37883**	**38635**	**39475**	**32172**	**34083**	**34439**
Share of big 4 (%)[2]	74.35	73.52	75.17	77.66	77.23	76.73	76.75

Source: YWED 1992, 1994, 1996.
[1]: Excludes Portugal and Greece.
[2]: France, Germany, Italy and the UK.

Table B-3	Production of telecom equipment (Radio & broadcasting plus line telephony) in the EU 15 countries[1] plus Norway in million US dollars between 1989 and 1995 (1995 estimated)						
	1989	1990	1991	1992	1993	1994	1995
Norway	445	550	576	521	466	500	516
Austria	345	401	384	508	496	624	601
Finland	750	934	663	817	1070	1607	1789
Sweden	2381	2660	2899	2977	2540	3184	3483
Belgium	1153	1471	1494	1486	1610	1866	1953
Denmark	361	395	280	255	264	297	315
France	6460	7989	7895	8533	7696	8590	8868
Germany	6649	8178	10280	11062	9616	10141	10315
Ireland	318	345	407	418	388	503	596
Italy	5324	6847	6878	7100	5060	5102	5127
Netherlands	1079	1375	1372	1507	1420	1395	1391
Spain	2399	3184	2834	2127	1752	1969	2039
UK	5493	5580	5281	5149	5143	6292	6704
TOTAL (EU only)	32712	39359	40667	41939	37055	41570	43181
Share of big 4 (%)[2]	73.14	72.65	74.59	75.93	74.25	72.47	71.82

Source: YWED 1992, 1994, 1996.
[1]: Excludes Portugal and Greece.
[2]: France, Germany, Italy and the UK.

Table B-4 Employment in electronic goods or a sub-category that includes telecom equipment between 1986 and 1994, for selected EU countries, depending on data availability

	Category	1986	1987	1988	1989	1990	1991	1992	1993	1994
Denmark	Radio, TV and communications equip					12,400		11,874		
Finland	All electronics Radio, TV and communications equip			37,000		28,500 11,400	28,900 11,100			
France	All electronics Communication (incl military) & telecom equip				386,500			189,138 79,760		170,601 69,600
Germany	Communication (incl military) & telecom equip		102,150		89,540					70,994
Ireland	All electronics Communications, telecom and consumer electr			27,000			33,500 10,000			37,200 11,800
Italy	All electronics Communication (incl military) & telecom equip		196,520					185,384		 47,405
Netherlands	All electronics and electrical						107,000		103,030	
Norway	All electronics and electrical Radio, TV and communications	13,000						14,461 5,144		
Spain	All electronics			58,430			52,680	48,028	41,877	40,442
Sweden	All electronics Radio, TV, communications				64,000	41,043 16,455				30,400
UK	All electronics Line telephony				367,820 41,662			364,793 38,091		351,866 31,025

Source: YWED 1992, 1994, 1996

Table B-5 Sales-Weighted R&D Intensities (percent) of Major Industrial Sectors			
Sector	**PACE[1]**	**CIS[2] (R&D performers only)**	**CIS[2] (all firms)**
Aerospace[3]	17.88	-	-
Pharmaceuticals[3]	11.88	-	-
Instruments[4]	7.88	7.90	7.51
Electrical equipment	7.88	6.43	4.46
Telecom equipment[5]	7.35	11.27	10.99
Computers & Office equipment	4.95	7.01	6.71
Rubber & Plastics	4.18	4.07	2.41
Automobiles	3.67	4.94	4.86
Chemicals[6]	3.06	4.07	3.81
Machinery	2.60	2.80	2.01
Non-metallic mineral products	1.35	4.06	3.00
Fabricated metal products	1.24	1.27	0.96
Petroleum products	1.03	0.13	0.13
Basic metals	0.88	0.97	0.87
Food and beverages	0.44	0.57	0.38

[1]: Limited to sectors with a minimum of 10 firms that reported results for both R&D expenditures and sales. Total number of PACE cases covered in this table is 418. Limited to firms that appeared to report R&D expenditures and sales *only* for their telecom equipment operations. Excludes France, Portugal and Greece.

[2]: CIS estimates do not use original data for each firm but are based on micro-aggregated data, estimates, and weights to account for differences in sampling and response rates by country. This could create inaccurate estimates of average R&D intensities. The estimate includes firms in Norway but excludes France, the UK, Portugal and Greece.

[3]: CIS data only available at the 2-digit level and therefore unavailable for these sectors.

[4]: PACE results based on the average per firm.

[5]: PACE data includes firms from Denmark, UK, Germany, Italy, Netherlands and Spain. CIS results limited to firms from Germany, Italy, Netherlands, Belgium, Ireland and Norway.

[6]: CIS estimate includes pharmaceutical firms, which will overestimate the average R&D intensity compared to PACE, where pharmaceutical firms are analyzed separately.

Table B-6 Trade Balance by EU Country for Telecom Equipment (Million US $)							
	1987	1988	1989	1990	1991	1992	1993
Belgium & Lux	266.44	24.63	129.87	86.20	80.63	83.96	0.00
France	790.70	321.06	135.44	238.04	202.52	250.17	484.47
Germany	1070.06	422.94	158.66	-181.85	-435.32	-184.27	123.19
Ireland	66.89	94.36	80.77	7.36	95.65	68.01	-348.10
Italy	-7.61	-464.60	-447.42	-676.95	-937.70	-696.80	-260.98
Netherlands	-80.02	-316.21	-441.51	-153.08	-407.63	-424.29	4.82
Norway	-247.34	-167.67	-125.01	-114.87	-109.99	-175.88	-225.26
Denmark	22.55	69.09	120.54	184.91	42.28	65.66	15.18
Greece	-113.56	-131.66	-175.33	-150.13	-188.55	-219.86	-78.90
Portugal	-120.60	-224.40	-166.18	-235.56	-305.79	-470.17	-52.05
Spain	-587.08	-776.98	-1182.78	-1366.45	-1249.40	-977.54	-1211.47
Austria	-120.32	-193.22	-296.13	-410.25	-351.20	-430.32	-542.26
Finland	79.98	92.82	198.39	373.62	114.68	372.48	725.34
Sweden	805.39	1137.23	1205.61	1378.64	1424.15	1572.85	1862.66

Source: Stars Database, International Telecommunications Union, 1994.

Table B-6	National Distribution of CIS NACE 32 Firms (N = number of observations, Weightd = number of observations after weighting)								
	Estimated Sampling Rate	NACE 32 All Cases		Nace 32.1 Components		Nace 32.2 Telecom		Nace 32.3 HEE	
Country		N	Weightd	N	Weightd	N	Weightd	N	Weightd
Germany	21.2%	66[1]	1280	29	738	15	257	21	280
France	22.2%	77	513	38	282	30	180	9	51
Italy	66.8%	249	397	103	165	129	204	17	29
Holland	46.8%	11	34	0	0	11	34	0	0
Belgium	50.7%	20	118	10	89	10	30	0	0
Lux.[2]	-	4	6	-	-	-	-	-	-
UK[2,3]	-	4	-	-	-	-	-	-	-
Ireland	38.5%	39	102	20	53	11	29	8	21
Denmark	38.5%	28	93	-	-	-	-	-	-
Greece[2,3]	-	16	-	-	-	-	-	-	-
Spain[2]	25.0%	42	194	-	-	-	-	-	-
Portugal[2,3]	-	2	-	-	-	-	-	-	-
Norway	76.1%	11	19	2	2	4	8	5	9
TOTAL	**47.5%**	**569**	**2757**	**202**	**1328**	**210**	**742**	**60**	**388**

[1]: Includes one firm that could not be classified at the three digit level.
[2]: NACE only available at the two-digit level.
[3]: No weighting data available.

TABLE B-7 Description of Variables Used in the CIS Analyses

Interval variables

EXPORTS	1992 exports / total 1992 sales
LEMPLOY	The log of the number of employees
S-GROWTH	Percent increase in sales from 1990 to 1992
RDINTENS	1992 expenditures on R&D / 1992 total sales
IPRODSH	Percent of incrementally and significantly changed products combined in total 1992 sales
SPRODSH	Percent of significantly changed products combined in total 1992 sales

Dummy variables

The rating for dummy variables based on subjective five-point scale questions is 1 = insignificant, 2 = slightly significant, 3 = moderately significant, 4 = very important, 5 = crucial.

COMPET	1 = importance of competitors as an information source is 4 or 5, 0 = other
CONSULT	1 = importance of consultants as an information source is 3, 4 or 5, 0 = other
COOPRD	1 = participate in cooperative R&D programmes, 0 = no participation
COPYEASE	1 = innovation too easy to copy as a barrier to innovation is 4 or 5, 0 = other
DOMESTIC	1 = firms with their head office in the country where they are located, 0 = other
ECONCOST	1 = any of the four economic barriers to innovation is 4 or 5, 0 = other
EURMARK	1 = creating new national or EC markets is a 5, 0 = other
FORMARK	1 = creating new markets in the US, Japan or other countries is 3, 4 or 5, 0= other
LACKINFO	1 = lack of technical information as a barrier to innovation is 4 or 5, 0 = other
LACKPERS	1 = lack of skilled personnel as a barrier to innovation is 4 or 5, 0 = other
LOWRCOST	1 = reducing either wage costs, materials consumption, or energy consumption is 5, 0 = other
MAINPROD	1 = importance of extending the main product field as a goal of innovation is 4 or 5, 0 = other
MSHARE	1 = importance of increasing or maintainin market share as a goal of innovation is 4 or 5, 0 = other
NEWPROD	1 = importance of creating new products outside the main field as a goal of innovation is 4 or 5, 0 = other
PATENT	1 = importance of patent disclosures as a source of information is 4 or 5, 0 = other
PUBRES	1 = either government labs or universities as a source of information is 4 or 5, 0 = other
QUALITY	1 = quality as a goal of innovation is 4 or 5, 0 = other
TELECOM	1 = telecom firms, 0 = other NACE 32 firms

Indexes

COSTGOAL	Sum of scores for the importance of reducing wage, materials, and energy costs.

B2: PROPORTION OF ESTIMATED VALUES FOR NACE 32 RESPONDENTS

In addition to the micro-aggregation process, which altered the value of variables reported by the respondents to the CIS questions in order to protect confidentiality, EUROSTAT also assigned values to questions that the respondent did not answer. The method used to estimate missing values varies from assigning a value of '1' to ordinal scale questions that were left unanswered to using regression techniques to estimate the value of interval data such as the amount spent on R&D. Though the former estimates are reasonable if at least one other question in a set of ordinal questions was answered, the latter technique could lead to spuriously good regression results, particularly if the regression largely repeats the estimation method used by EUROSTAT. In order to avoid this possibility, it is important to know the percentage of responses that are original and *not* estimated by EUROSTAT. A variable with a low percentage of original values (and therefore a high estimation rate by EUROSTAT) must be used with caution, particularly in certain types of regressions.

The original response rate can be estimated using the 'Q' flag variables in the CIS data. A missing value to the Q variable means that the value of the variable with the same name was not estimated by EUROSTAT. Results for ordinal scale variables are given in Table 1 and results for nominal and interval variables are given in Table 2. The results are based on weighted counts to reflect the true impact of estimated values in the data analyses. Variables for which less than 80% of the values are original are marked in bold type and variables for which over 80% but less than 90% of the values are original are in italics. We assume that variables for which less than 80% of the values are original could create serious problems in some regression analyses and caution is warranted for variables where between 80% and 90% of the values are original. Conversely, there should be few problems using variables where over 90% of the values are original.

The results for ordinal variables, given in Table A.1, show that the original value percentage for most variables is over 90%. The greatest need for caution is with the protection questions for process innovations. The results for nominal and interval variables shown in Table A.2, indicate that there are likely to be severe difficulties in using the variables for total innovation expenditures, 1992 external R&D expenditures, and the percentage of 1992 sales in the introductory to growth stages, since only 37% 69.7%, and 73.4% respectively, are original, unestimated values.

Table B-8 Percentage of Original Unestimated Values (UV) for Ordinal variables among the NACE 32 Respondents: Weighted Results

Sources[1] (Question 4)	UV	Objectives[1] (Question 5)	UV	Protection[1] (Question 9)	UV	Barriers[2] (Question 12)	UV NI	UV I
4.1	*85.2*	5.1	90.7	9.1a	*86.2*	12.1	98.0	97.1
4.2	95.8[3]	5.2	91.2	9.2a	*86.9*	12.2	99.6	98.2
4.3	91.9	5.3	*87.1*	9.3a	90.4	12.3	98.4	98.1
4.4	92.4	5.4	90.5	9.4a	*85.8*	12.4	97.6	97.0
4.5	92.6	5.5	92.4	9.5a	*87.3*	12.5	93.6[3]	94.7[3]
4.6	92.5	5.6	*89.8*[3]			12.6	97.5	97.5
4.7	91.8	5.7	90.9[3]	9.1b	*81.6*	12.7	97.5	97.8
4.8	92.3	5.8	90.0[3]	9.2b	*80.6*	12.8	97.5	97.9
4.9	91.9	5.9	91.4[3]	9.3b	*81.0*	12.9	98.8	97.6
4.10	92.1	5.10	91.9	9.4b	*80.0*	12.10	98.0	97.4
4.11	92.3	5.11	92.9	9.5b	**78.5**	12.11	98.0	96.0
4.12	92.2	5.12	92.8			12.12	97.6	97.6
4.13	92.1	5.13	92.3			12.13	93.1	*88.7*
		5.14	97.6[3]			12.14	94.6[3]	94.0[3]
		5.15	96.3[3]			12.15	98.0	97.0
		5.16	92.0			12.16	96.7	96.5
		5.17	92.7[3]			12.17	97.1	97.6
		5.18	91.2			12.18	97.1	97.7
Average	91.9		91.9		83.8[4]			

[1]: Responses for a maximum of 384 innovating (I) firms.
[2]: Responses for a maximum of 163 non-innovating (NI) and 384 innovating (I) firms.
[3]: Some missing values in the original data that were not estimated by EUROSTAT, for example when the question was not asked in one or more countries. These cases are excluded from the estimates of the percent of original values since they are not used in the data analyses.
[4]: The average is 87.3 for *product* protection methods (questions with an 'a') and 80.3 for *process* protection methods (questions with a 'b').

Table B-9 Percentage of Original Unestimated Values for Important Nominal and Interval Variables for the NACE 32 Respondents: Weighted results for Innovators only

Variables (CIS question number)	CIS question	Percent
Employee number (F)	F	99.7
1992 sales	J	98.4
1992 R&D expenditures	v10d.1	*88.8*
1992 external R&D expenditures	v10d.2	**69.7**
1992 R&D Intensity	J & v10d.1	*87.4*
Engage in R&D	V10a	*84.7*
1990 sales	M	93.9
1992 export sales	L	96.2
Percent of 1992 sales due to exports	J & L	96.2
Percent change in sales between 1990 and 1992	J & M	93.7
Total innovation expenditures	v13a	**37.0**
R&D expenditures as a percentage of total innovation expenditures	v10d.2 & v13a	**35.1**
Percent R&D for product or process innovation	v10C.1 & v10C.2	*85.4*
Percentage of 1992 sales in the introductory to growth stage	v14.1 to v14.4	**73.4**
Percentage of 1992 sales from products that are unchanged to significantly changed	v15a.1 to v15a.3	*82.2*

REFERENCES

Archibugi D, Cohendet P, Kristensen A, Schaffer KA. Evaluation of the Community Innovation Survey (CIS) Phase I. CEC, EIMS Publication 11, Luxembourg, 1994.

Arundel A, van de Paal G, Soete L. *Innovation Strategies of Europe's Largest Firms.* MERIT, June 1995.

Barry A. Technical Harmonisation as a Political Project, in Locksley G, (ed) *The Single European Market and the Information and Communication Technologies,* London, Bellhaven, 1990.

CCA (Communications Companies Analysis) 1994, MDIS Publications, UK, April 1994.

CN (Communications Networks), Romtec survey, p 8, November 1994.

CWI (Communications Week International), Sirius, Montpellier, p 16, April 14, 1994a.

CWI (Communications Week International), Sirius, Montpellier, November 14, 1994b.

CWI (Communications Week International), Sirius, Montpellier, November 28, 1994c.

CWI (Communications Week International), Sirius, Montpellier, p 24, January 16, 1995a.

CWI (Communications Week International), Sirius, Montpellier, November 7, 1995b.

CI (Communications International) p 13, February 1995a.

CI (Communications International), p 48, May, 1995b.

CI (Communications International) pp 48-52, Jan. 1995c.

OECD. *Telecommunications Equipment: Changing Markets and Trade Structures,* OECD, Paris, 1991.

OECD. *Communications Outlook.* Information Computer Communications Policy, OECD, Paris, 1996.

EC (European Commission). *The European Electronics and Information Technology Industry: State of Play, Issues at Stake and Proposals for Action,* Brussels, EC - DG XIII, p 7, 1991.

EC (European Commission). *White Paper on Growth, Competitiveness, and Employment: The Challenges and Ways Forward into the 21st Century,* COM(93) 700 final, Brussels, 5 December,1993.

EC (European Commission). *Panorama of European Industry,* EC, Luxembourg, 1994.

EC (European Commission). *European Report on Science and Technology Indicators: 1994,* EC, Luxembourg, 1995.

EC (European Commission). *Green Paper on Innovation.* European Commission, Brussels, December 20, 1995.

ET (*Electronics Times*). The figures originated with Dataquest. p 1, 12 January 1995.

Eurostat. *R&D and Innovation Statistics.* Eurostat, Luxembourg, 1994.

ITU (International Telecommunications Union). STARS database, ITU, 1995.

Klevorick AK, Levin RC, Nelson RR, Winter SG. On the sources and significance of interindustry differences in technological opportunities. *Research Policy* 24:185-205, 1995.

Levin RC, Klevorick AK, Nelson RR, Winter SG. Appropriating the returns from industrial research and development. *Brookings Papers on Economic Activity*, 3:242-279, 1987.

Mansell R. *The New Telecommunications, A Political Economy of Network Evolution*, London, Sage, pp 1-45, 1993.

Miki T. *The potential of photonic networks.* IEEE Communications Magazine, pp 23-24, Dec 1994.

MDIS Publications. *Communications Companies Analysis* UK, April 1994.

Neu W, Schnöring T. The telecommunications equipment industry: recent changes in its international trade pattern, *Telecommunications Policy*, pp 25-39, March, 1989.

Pavitt K. Sectoral patterns of technical change: Towards a taxonomy and a theory. *Research Policy* 13: 343-373, 1984.

PNE (*Public Network Europe*), pp 45-47, December 1994/January 1995.

PNE (*Public Network Europe)*, p 50, March 1995a.

PNE (*Public Network Europe)*, Ovum Consultants, p 48, May 1995b.

STOA (Scientific and Technological Options Assessment). *The European Semiconductor Industry and the JESSI Initiative: Analysis of the Impact and Future Trends*, Luxembourg, February 1995, pp. 1-13.
Trajtenberg M. A penny for your quotes: patent citations and the value of innovations. *RAND Journal of Economics*, 21:172-187, 1990.

YWED (*Yearbook of World Electronics Data*), Elsevier Advanced Technology, Oxford, Volume 2, 1991.

YWED (*Yearbook of World Electronics Data*), Elsevier Advanced Technology, Oxford, Volume 1, 1994.

YWED (*Yearbook of World Electronics Data*), Elsevier Advanced Technology, Oxford, Volume 1, 1996.