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NEW TECHNOLOGY BASED FIRMS (NTBFs) IN EUROPE

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A REVIEW OF THE EMPIRICAL KNOWLEDGE AND AN ASSESSMENT OF STATISTICAL DATA ON THE ECONOMIC IMPORTANCE OF

NEW TECHNOLOGY BASED FIRMS (NTBFS) IN EUROPE

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INTRODUCTION

Interest in New Technology Based Firms (NTBFs) stems from a number of factors:

- They are thought to embody the technologies of the future and hence provide secure employment opportunities for several generations.
- In the United States NTBFs have exhibited spectacular rates of growth in employment, exports and assets.
- The geographical areas in which NTBFs are important in the United States have also exhibited major indirect job creation in the business and consumer services sectors locally.
- The quality of jobs provided in NTBFs is significantly better than those in traditional manufacturing.

The term NTBFs seems to have been coined by the Arthur D. Little Group. In 1977 they produced a path-breaking report comparing NTBFs in the United States with those in the UK and West Germany. They defined an NTBF as having the following characteristics:

- It must not have been established for more than 25 years.
- It must be a business based on potential invention or one having substantial technological risks over and above those of a normal business.
- It must have been established by a group of individuals and so must not be a subsidiary of an established company.
- It must have been established for the purpose of exploiting an invention or technological innovation.

Based upon these definitions, the Arthur D. Little study found that in the United States such businesses employed 34,000 workers and were hugely important, whereas in the UK firms of this type were very much smaller and their aggregate employment much more modest. This was even more clearly the case for West Germany.

The Arthur D. Little study made several recommendations about how the number of NTBFs in Europe could be increased and how growth in this sector could be promoted. These included:

- The provision of financial assistance to such companies.
- Changing cultural attitudes to give greater encouragement to entrepreneurs to make money out of a business.
- Changing the behavioural constraints which inhibit the willingness of Europeans to start businesses.
- Changing patent laws by giving individuals the right to exploit patents which their employers refuse or fail to exploit.

The 1980s unquestionably saw a growth in the number of new technology-based firms in Europe, but it is unclear whether this has led to any narrowing of the 'gap' between Europe and the United States. This report seeks to review these matters.

Unfortunately it is necessary to begin by highlighting the difficulties which arise in making such comparisons. The first difficulty is that of defining what is meant by a 'New Technology-Based Firm'.

In some instances it is unclear whether the word 'new' applies to the firm, or to the technology, or both. For example, Shearman and Burrell (1988) argue that the term NTBF should be restricted to refer only to new independent enterprises which are developing new industries. In their case they regard the development of the industry of medical lasers as a classic example of where NTBFs are established, since the industry is new and the firms are newly established and independent. Almost by definition they are small in numbers and in size.

This contrasts with the wider definitions, criticised by Shearman and Burrell, but which are used in this report. These can be considered as 'high tech SMEs'. Our definitions first identify a series of sectors defined as 'high tech'; these are a modified version of the UK Butchart (1987) definition which identifies sectors that have significantly higher than average expenditure on R&D as a proportion of sales or significantly greater than average proportional employment of workers who are 'qualified scientists and engineers'. The precise sectors included are shown in Part II.

Ideally a definition should also only include firms which are new (less than 10 years old) and which are independent. As will be demonstrated in the report data are rarely available in this format and we have had to relax these definitions in order to make broadly valid comparisons across EU countries.

In essence this report identifies high technology SMEs but chooses to call them NTBFs. This strategy would be rejected by Shearman and Burrell who would include a much narrower range of sectors (only 'emerging technologies') and would only include genuinely independent firms. Our definitions are based on pragmatism and data availability. We believe they are pragmatic because a substantial range of sectors can be viewed as 'new' and the firms in them have broadly similar problems, but ones which differentiate them from SMEs more generally. Secondly it is based upon data restrictions since in most countries it is not possible to isolate firms by age and ownership and make direct comparisons. Hence the SMEs definition, based on size, is the only one available to us. As the reader will increasingly realise, even these simple definitions are not easy to implement in practice.

Armed with these definitions the remainder of the report is in three Parts. Part I contains a review of the literature on issues associated with NTBFs, covering the characteristics of founders, the problems they experience and the contribution they make to the economy.

Part II then provides an extensive review of the numbers of NTBFs in the sixteen countries and the contribution which such firms have made to employment. Problems of definition and the lack of suitable data present problems here so the analysis focuses upon only the number of enterprises (or establishments) and their employment in the high tech sectors and the changes in these over the last decade or so.

Part III takes the information generated in the earlier parts and undertakes a review of the impact of public policy in this area. This is designed to provide an overview of policy, but also clear indications of new directions for policy development.

Part IV draws upon the experience in Part III to present ideas for policy consideration.

Part I

A REVIEW OF THE ISSUES

1. INTRODUCTION

This part of the report provides a review of the existing stock of knowledge on NTBFs in Europe. It draws upon sixteen country reports provided by the country experts who are the partners in this study. In this part of the report six specific issues are addressed, these are:

- The personal characteristics of NTBF founders
- NTBFs: numbers, employment and survival
- Factors facilitating or inhibiting the creation and development of NTBFs
- Responses to these constraints
- Regional concentrations of NTBFs
- The development of new products, establishments and industries

2. THE PERSONAL CHARACTERISTICS OF NTBF FOUNDERS

European studies of the founders of new technology-based firms demonstrate that, in several respects, they differ from European entrepreneurs more generally.

Table 1.1 identifies four of the personal characteristics of founders of new technology-based firms. In three respects these differ from more 'typical' entrepreneurs. The first shows that, at least in the United Kingdom, founders of new technology-based firms tend to be primarily, or even exclusively, male. Yet in the UK as a whole, currently one third of all new businesses are founded by women. The gender issue among founders of NTBFs does not appear to have been explicitly considered in founder studies other than in the UK.

The second row of Table 1.1 shows that level of educational attainment amongst founders of NTBFs is significantly higher than that of the working population as a whole, or of founders of other types of new businesses. This emerges directly from the UK and Belgian studies, but can reasonably be inferred from samples of new technology-based firms in France, Finland, Ireland and Sweden where individuals were formerly employed in institutions of higher education. For example, Olofsson et al. (1987) and Olofsson et al. (1994) identify 569 firms started by employees at Swedish Universities. In Ireland the STIAC study (1995) identifies 183 companies which have spun off from the higher education sector. Finally the studies by Mustar (1994, 1995) in France, which examine about one quarter of NTBFs established in that country between 1984 and 1991, estimates that 40% are established by scientists emerging from public research laboratories, the universities and les grandes écoles. All such individuals are likely to have educational attainments significantly above the national average.

Row 3 of the table points to slight differences in the age profile of founders of new technology-based firms compared with founders of other types of businesses. Whilst the age spectrum of NTBF founders is concentrated in a broadly similar range to that of business founders as a whole - between 30 and 50 years of age - the key difference is that founders of NTBFs are very unlikely to be young. Perhaps 15% of founders of businesses generally would be under the age of 25, but this is likely to be close to zero for founders of NTBFs, where founders require educational qualifications not normally awarded until the individual is at least in their mid 20s.

Table 1.1 The Personal Characteristics of Founder of New Technology-Based Firms

Characteristic	Comment	Studies	Country
1. Gender	• Primarily (95%) or exclusively (100%) make	Westhead & Storey (1994) and Harvey (1994)	UK
2. Education	• High Educational Attainment: 85% with degree, 48% with doctorate	Westhead & Storey (1994)	UK
	• High Education Attainment: 80% have followed higher education	Donckels (1989)	Belgium
	• High Educational Attainment: Most NTBF founders have an engineering degree	Licht et al. (1995a)	Germany
	• Innovative firms are directed by people with a very high educational background	GSRT (1995)	Greece
	• Of high tech enterprises in France are set up by university lecturers or researchers.	Mustar (1994, 1995)	France
	• Out of 15 university spin-offs had post graduate degrees	Laranja (1995)	Portugal
3. Age	• Two thirds establish business when between 30 and 50 years of age	Westhead & Storey (1994) and Harvey (1994)	UK
	• Technology-based starters are older than common starters	Donckels (1989)	Belgium
	• Founders are, on average, 37 years old	GMV Conseil (1989)	France
4. Prior work experience	• Long professional experience (12 or more years) as high level staff	Carroue & Martin (1993)	France
	• Prior experience is more likely to have been in larger firms and research centres	GMV Conseil (1989)	France
	• More likely to have worked in large (private sector) firms	Donckels (1989)	Belgium
	• No clear evidence of high tech entrepreneurs disproportionately emerging from small, medium or large firms	Westhead & Storey (1994)	UK

Row 4 of Table 1.1 identifies some aspects of the founders' prior work experience. In several respects these reflect the sampling procedures employed, so that studies of academic spin-off businesses naturally tend to identify the key importance of either universities or research laboratories. However, samples of NTBF founders drawn randomly suggest that, in both France and Belgium, founders are more likely to have previously been employed in larger, rather than smaller, enterprises. The UK study on this topic was unable to reach a clear conclusion.

3. NEW TECHNOLOGY-BASED FIRMS: NUMBERS, EMPLOYMENT AND SURVIVAL

A central reason for the interest by policy makers in new technology-based firms is their capacity to create, directly and indirectly, employment and wealth. Illustrations of this impact are drawn primarily from observations from the United States. Harvey (1994) reports that, in 1988, the aggregate revenue of 636 companies identified as having spun out of Massachusetts Institute of Technology (MIT) was almost $40bn. - an average of $62m. each. This revenue represented 33% of Massachusetts state domestic product. Roberts (1991) points out that MIT is extremely unusual, even by US standards in this respect, for two reasons. The first is that in no other local economy has a local university had anything like this major impact. The second is that, for reasons which even Roberts is unable to explain, MIT graduates are strongly represented throughout the United States amongst founders of technology-based enterprises. For example, even in Silicon Valley in California, MIT graduates were founders of businesses which provided 21% of the total employment amongst local samples of NTBFs. In no sense, therefore, can MIT be considered 'typical', even in the United States.

Nevertheless the finding that NTBFs <u>can</u> be a major source of direct and indirect employment requires a careful review of European experience in this area. Table 1.2 presents the results of studies in seven European countries. Several fairly consistent pictures emerge:

i) Compared with start ups in general, new technology-based firms exhibits <u>faster</u> average employment growth rates.

ii) Nevertheless, for young firms, the absolute growth in employment is modest. Whilst there is a range exhibited, in no country does median employment growth, ten years later, exceed twenty above its start up level. This implies that the ability of NTBFs to 'compensate' for job losses elsewhere in the EU economy is modest.

iii) If anything, the growth of firms established by 'pure' scientists defined as 'academic spin-offs' appears to be below that of technology-based enterprises established by individuals not coming out of the universities and research laboratories. An illustration of this is the finding that, in Portugal the arithmetic mean employment size of University spin off NTBFs identified by Laranja (1995) was 13 workers. This compares with the average of 18 workers identified by Fontes (1995) who examined a wider sampling frame of NTBFs.

Table 1.2 The Employment Impact of New Technology-Based Firms

Key Findings	Studies	Country
• Start ups established by university spin outs after 3 years averaged 3.3 employees	Frank et al. (1995)	Austria
• NTBFs formed by scientists between 1984 and 1988 had an average (mean) employment of 11.3 in 1988. This is a faster rate of growth than new firms generally.	Mustar (1994, 1995)	France
• Amongst younger technology-based firms with median age of 10 years in manufacturing employment was 16 workers. Firms are younger and smaller in high tech services.	SITRA (1994)	Finland
• NTBFs which are about 10 years old have about 40 employees.	Kulicke (1987)	Germany
• Firms in high technology industries grow faster than average	Nerlinger (1995)	Germany
• In a comparison of innovative and non-innovative firms, innovative firms had a greater chance of survival and grew more rapidly.	Bruederl et al. (1993)	Germany
• In the country as a whole, indigenous high technology manufacturing establishments increased in number between 1985 and 1990 by 18%. Average (mean) employment size was 36.	Cogan (1995a)	Ireland
• Mean employment of 18 workers	Fontes (1995)	Portugal
• Mean employment of 13 workers	Laranja (1995)	Portugal
• 560 university spin offs established between 1980 and 1990 had an average (mean) employment of 6.7 workers.	Olofsson et al. (1994)	Sweden
• Employment growth in NTBFs is significantly faster than in 'comparable' firms in other sectors.	Westhead & Storey (1994) and Garnsey & Cannon Brooks (1993)	UK

The clear picture which emerges is that, whilst technology-based firms do indeed exhibit somewhat faster average employment growth rates than firms in other sectors, there is little evidence in Europe of such firms exhibiting growth rates which are in any way comparable to those reported in the Massachusetts area of the United States. As Mustar (1995) says of his French sample "there are no major success stories". This may be partly because the Massachusetts area of the United States is exceptional, even by US standards, but it also probably reflects a real difference in European and US new technology-based firms. Indeed the central question running through this whole topic is why does Europe not have an MIT, and the probably linked question of why does it have no Microsoft or Apple? Frequently the blame for this is laid at the door of financial institutions which view such investments as too risky.

The irony is that the evidence shows that, on balance, technology-based firms are a lower risk. The main supportive evidence of high risk is provided by Parger (1995a), who reports Steinhöfler's (1987) finding from an Austrian study that technology-based SMEs have a higher failure rate than SMEs in general. However, the Austrian survival rates for SMEs reported by Parger are exceptionally high with

78% of start ups surviving after 6 years, which may reflect the fact that Steinhöfler studied technology based firms which recieved public assistance for the export of an innovative product[1].

Mixed evidence on risk is provided by Nerlinger (1995) for West Germany. He makes a distinction between sectors (industry and services) and macro-economic conditions. Table 1.3 taken from Nerlinger (1995) shows that the liquidation rate of businesses varies comparatively little over the 'cycle' but is consistently higher in services than in manufacturing. However, within manufacturing the evidence is that liquidation rates are marginally higher in 'high technology' sectors than for those not in technology-based industries, but lowest in the 'superior' or highest technology sectors.

Table 1.3 Annual Liquidation Rates in West Germany in Boom and Recession

	Recession I 1980-1982	Boom 1983-1990	Recession II 1991-1992
1. Superior technology-based industry	7.4%	7.6%	7.4%
2. High technology-based industry	9.5%	8.7%	9.7%
3. Not technology-based industry	8.8%	8.7%	8.6%
4. Services	12.3%	12.4%	11.8%

Source: Nerlinger (1995)

Complementary results have been obtained in the UK and France. Westhead and Storey (1994) found that the survival of high technology firms was superior to that of a random sample of UK small businesses, as did Garnsey and Cannon Brookes (1993). These UK studies contain a high proportion of services firms which, as Nerlinger shows for West Germany, have high liquidation rates. Mustar (1995) in his review of the survival of NTBFs in France 1988-94 reports

> The failure rate of high tech enterprises is much lower than that of enterprises generally .... this result ....starkly contradicts all those - directors of venture risk institutions, bankers or staff of government bodies - who label the creation of an enterprise in the innovation sector a 'deadly cocktail'.

The Italian experience reported by Malerba et al. (1995a) derives from a study by Santarelli and Sterlacchini (1994). These authors show that the annual death rate for all industrial firms in Italy over the 1985-89 period was 7.77%, but that the death rates in four of the technology-based sectors (chemicals, office machinery and computers, electrical and electronic engineering and instruments) were consistently lower than the average across all industries.

[1] Steinhöfler's (1987) study found that only 11% of the innovative projects of technology orientated start-ups showed both technical and commercial success. Interestingly, Steinhöfler found medium technology projects showed a higher success rate than high technology projects and, furthermore, the failure rate was highest amongst the firms established for the purpose of exploiting the innovative idea for which support was received.

Our interpretation of the balance of this evidence is that the impact of a firm being in a technology-based sector upon its survival is more likely to be positive than negative. It certainly is not the case that it clearly reduces the probability of survival and yet, as will be shown subsequently, there is a perception that high technology is equated to risk. In general, European financial institutions have either been consistently reluctant to finance businesses in these sectors or have retreated from these sectors following unfavourable experience.

Assuming that such institutions are not irrational, it is necessary to 'explain' this behaviour. The most plausible explanation reflects the difference between 'risk' and 'uncertainty'. In essence, financiers are prepared to fund 'risky' businesses where they can attach a clear probability of success (survival) to the portfolio. Hence, in traditional sectors where they have a clear idea of the factors influencing the survival or non-survival of firms, they feel confident about distinguishing between proposals. However, in the technology-based sectors financiers are more uncertain. They are unable to estimate the probability of success since businesses are likely to vary considerably, depending, at least in part, upon the nature of the technology employed. This uncertainty is likely to be highest where the technology is newest or the most sophisticated. Empirical support for this, in the UK at least, is provided by Westhead and Storey (1996).

4. FACTORS FACILITATING OR INHIBITING THE CREATION & DEVELOPMENT OF NTBFs

Table 1.4 selectively reviews studies of the factors which facilitate or inhibit the creation and development of NTBFs in EU countries.

Although there are differences of emphasis in the studies reviewed, which may reflect the different stages of growth of an NTBF (start up, established phase, etc.), a consistent finding relates to the key role played by external finance - such as bank loans, credit, or external equity (venture capital). The studies quite consistently report that entrepreneurs feel the growth of their businesses is 'unreasonably' restricted by lack of access to external finance.

Whilst this may be a reasonable judgement, there are several reasons why it is unwise to immediately accept these findings at face value. The first is that the studies consistently report the views of the entrepreneur, rather than the financial community, yet entrepreneurs are, in almost all contexts, more optimistic about their own business prospects than the external observer. This is the case for all entrepreneurs, not simply those founding high technology businesses (De Meza and Southey, 1996). Differences between bankers and the entrepreneur may partly reflect differences in access to information. Once the business has begun, the entrepreneur is likely to have more information about his or her business than the bank. It may also result from personality differences; the entrepreneur is often portrayed as a more 'risk loving' individual than the more 'bureaucratic' banker. However, it may also reflect the more consistently accumulated expertise of the banker in assessing risky projects referred to in Section 3. Bankers experience may lead them to the view that entrepreneurs are comparatively reluctant to 'blame' themselves for the poor performance of their business. Instead they may prefer to blame 'outsiders' - one example of which would be the banks. A key factor then is the accurate assessment of risk and return.

A second key issue is that it is necessary to distinguish between the extent to which there are differences between the entrepreneur establishing a business in the high technology sector and entrepreneurs more generally. In terms of constraints there are five reasons why, in principle, the high technology entrepreneur might expect to experience problems which are different from, and possibly additional to, those experienced by entrepreneurs in more conventional sectors;

Table 1.4 Constraints upon NTBFs at Start Up and in the 'Established' phase

Study Findings	Study	Country
• Finance, market awareness and a shortage of skilled personnel are factors emerging as constraints	Urban and Arnold (1993)	Austria
• Credibility, finance and administrative problems are key issues at start up	GMV Conseil (1989)	France
• Motivation to stay independent is important	Copin (1994)	France
• Managerial competencies and a lack of desire to grow are key competencies	Autio (1995)	Finland
• Financing problems dominate in 'growth phase' for NTBFs. Marketing and finance problems are important at start up.	Kulicke (1987)	Germany
• Rules and laws, such as 'Hochschulrecht', prevent university faculty members establishing new firms. Other barriers, such as the high cost of registering in the 'Handelsregister' exist.	Licht et al. (1995a)	Germany
• High interest rates, lack of own capital and lack of finance for investment are key problems for innovative firms.	GSRT (1995)	Greece
• Technical entrepreneurs are starved of risk capital.	Cogan and McGovern (1984)	Ireland
• They seek to supplement funds by links with large firms	Cogan (1995a)	Ireland
• Lack of knowledge of marketing and financing	Van de Meer & van Tilburg (1984)	Netherlands
• Marketing and recruitment difficulties	Laranja (1995)	Portugal
• Financial constraints	Fontes (1995)	Portugal
• Lack of planning, shortage of economic resources and lack of skilled personnel are key constraints	Martinez-Sánchez (1991,1992, 1994)	Spain
• Shortage of finance, marketing and entrepreneurial knowledge	Landstrom (1987)	Sweden
• Financial position has worsened in recent years	Olofsson et al. (1994)	Sweden
• High tech firms, per se, are not 'specially' financially constrained	Moore (1994)	UK
• The most technologically sophisticated firms are the most likely to report financial constraints	Westhead and Storey (1996)	UK

i) The high technology entrepreneur, when seeking external finance, is often seeking to cover the cost of undertaking research and development. This makes the project significantly more 'risky' as far as the bank is concerned since the product or service has not yet reached the market place and uncertainties therefore exist over whether the product/service will ever be realised. Even if a product or service does emerge, experience has often taught bankers that entrepreneurs have a tendency to under-estimate the time taken for this to reach the market. Hence, if the actual time taken exceeds that estimated, the finance sought from the bank will probably turn out to be significantly larger than that initially estimated by the entrepreneur. During this extra time period the entrepreneur may have major difficulties 'servicing' the loan.

ii) In the most technologically advanced sectors, even if there is perfect certainty that the product will come to market, and even where there is perfect certainty about the length of time this will take, the scale of demand in the market place for a totally new product is always likely to be highly uncertain. In this respect, the new or novel product or service differs fundamentally from conventional goods and services where market places are clearly identifiable and some estimate of the market share can be made with comparative ease.

iii) Technologically sophisticated sectors can be characterised by short 'windows of opportunity'. In some instances there is a 'race to patent' in which the winner takes all. For those losing that race the pay off can be nil. In other instances high technology products/services have a very short life, and only justify front-end research expenditure if either the entry of competitive products is delayed or if profit margins during the period of exploitation are high. Clearly both are high risk strategies.

iv) Although, in general, entrepreneurs with high educational qualifications are regarded by banks as lower risk entrepreneurs, financiers often have fundamental misgivings about technology-based entrepreneurs. In particular, bankers view such individuals as more interested in the scientific characteristics of the product/service, rather than in its commercial exploitation. In short, the motivation of the high-tech entrepreneur to grow the business is often questioned. Furthermore, financiers often feel that individuals with sophisticated scientific knowledge may have obtained this working in organisations - such as universities or research laboratories - where the commercial ethos is weaker than in private sector firms. Scientists may not have accumulated knowledge about the management of people in a commercial context. In short, even where financiers have no questions about the technological sophistication of the technology-based entrepreneur, they may have considerable qualms about that individuals managerial and entrepreneurial expertise. These skills or talents are likely to be considerably greater than for an entrepreneur who has spent his/her working life in the commercial sector.

v) Finally, and most importantly, the bankers ability to 'understand' the technology is also open to question. Clearly bankers will be more comfortable about making decisions about 'conventional' businesses, since they have their own experience to help them. Although bankers can seek technical advice from others on the scientific merits of a proposal, this will still leave the project relatively unattractive to the banker because unfamiliarity leads to uncertainty. These difficulties of assessment clearly rise with the increasing sophistication of the technology.

Many of these points are reflected in the findings of the studies identified in Table 1.3. The studies consistently identify problems over financing. However, it is difficult to isolate the extent to which financial problems are magnified in technology-based enterprises compared with smaller firms in general. For example, Swedish studies described by Olofsson and Stymme (1995a) refer both to shortages of finance and to a perceived absence of marketing and entrepreneurial skills. The Finnish review by Autio (1995) refers to an absence of managerial competencies amongst many science-based entrepreneurs and also to a lack of desire on their part to grow their business. The shortage of skilled personnel, referred to in the Spanish and Austrian research, is not confined to scientific personnel but also includes managerial individuals.

In some EU countries - most notably Germany - there appears to have been comparatively little finance flowing through the conventional venture capital sector to new technology-based firms throughout the 1980s and 1990s. The evidence discussed earlier in this report suggests that, at least in several countries, employment (and also sales turnover) growth is significantly faster amongst new businesses in technology-based industries than amongst new businesses more generally. It also appears that in some countries (such as France and the UK) this is combined with technology-based enterprises having lower failure rates. This implies that technology-based enterprises would appear, on balance, to be <u>better</u> propositions than those outside the technology-based industries. It also therefore questions why European financial institutions have been so wary of supporting these types of enterprises.

This wariness of financial institutions of supporting NTBFs is not characteristic of all countries in all time periods. For example, in Sweden and France, the financial institutions during the 1970s and 1980s did seem prepared to provide support to some NTBFs. Delapierre et al. (1995a) report that, in 1984, half of French risk capital institutions agreed to participate in the creation of new technology-based firms, but currently the figure is less than 10%. In 1992 less than 5% of the assets funded by risk capital institutions in France were in enterprises less than five years old, compared with 20% in the previous decade. Delapierre et al. attribute this significant change to the absence of successful investments in the NTBF sector, although it may also reflect a desire on the part of financial institutions to invest larger sums in a single package, rather than smaller sums in a large number of packages.

Supplementary explanations provided by Delapierre et al. are that the banks lack the technological expertise to test the quality of the project, and have become increasingly concerned with the avoidance of risk, even when the expected rate of return is higher. Nevertheless, it remains the case that French financial institutions cannot be accused of never having financed NTBFs.

Similar observations can be made about Sweden. As Olofsson and Stymne (1995a) observe, the early 1980s was a period in which there was a peak in both the number of new university spin offs and in the venture capital industry in Sweden. These events are correlated. However, during the 1980s, comparatively few university spin-offs succeeded on a major scale and by the end of the decade the venture capital community had lost interest in very early stage high technology investments. Indeed Olofsson et al. (1994), in a recent study of technology based firms, regard the lack of access to financial resources as a major current cause of concern.

Returning to Table 1.4 it is clear that whilst references to financial constraints dominate, this is by no means the only problem area to be identified. The Austrian, French, Portuguese and Swedish studies all make direct or indirect reference to the problems of marketing by a business which generally lacks credibility in the market place. This lack of credibility, combined with managerial inexperience, is characteristic of many newly established businesses. The 'additional' burden of those establishing technology-based businesses is that they are often seeking to sell an innovative product or service. The novelty of the product/service can make it particularly difficult to market, particularly when this is combined with a lack of commercial experience on the part of the owner. In some respects these constraints explain the reservations of the financial institutions in supporting NTBFs.

5. RESPONSES TO THESE CONSTRAINTS

Other than to scale-down plans and relying heavily on internally generated resources, NTBFs can respond to financial constraints in several ways. The three most common are:

a) Forge links with larger enterprises
b) Move from 'soft' to 'hard'
c) Seek venture capital

a) Forge links with larger enterprises

Given their problems in obtaining external finance, many NTBFs have sought to establish stronger links with larger companies. In some instances these are in the form of trading links, but in other instances they have led to the acquisition of the NTBF by the larger firm. Such links have benefits to larger firms, which are able to monitor developments in the novel technologies that are being developed by the NTBFs without incurring costs within their own organisation. They can also accurately assess the entrepreneurial flair and managerial skills of the individual owner of the business and determine whether acquisition of the business is likely to be beneficial.

From the viewpoint of the NTBF Cogan (1995a), in his study of five Irish NTBFs, found all had negative cash flow at least four years after start up; by the fourth year the average cumulative debts were £350,000. Not surprisingly such firms turned to supplementing their cash flows with revenues from activities unrelated to their R&D based core business. In one case, the firm obtained a product licence from the US Food and Drug Administration and found this generated sufficient interest to induce a large cash injection from a multinational pharmaceutical firm. Another Irish NTBF was highly regarded by a multinational, which paid to incorporate the NTBF's software within its own product range. Cogan notes that, in these cases, the NTBFs neither had to, nor choose to, sell equity. Even so, the sale of some equity to a larger 'partner' is a common resort of NTBFs, even though it is deemed unattractive by entrepreneurs in almost every country in the European Union.

Where it occurs, the scale of the take over process of NTBFs does seem to vary between countries. Sweden is an example of a country where take-overs of NTBFs are very frequent. There comparatively few entrepreneur-managed businesses in the technology sectors continue to be run by the entrepreneurial founder once the company has reached middle size. Olofsson and Stymne (1995a) report on a study by Steiner (1990) which investigated the whole population of manufacturing companies in the Information Technology sector. Of the 45 firms which were middle sized (defined as 50 - 499 employees), 29 were started by an entrepreneur but only 6 were still controlled by that individual. The remainder had mainly been acquired by large companies and operated either as subsidiaries or as autonomous units within a group. The interesting point however is that acquisition of the independent company seems, on balance, to have impaired rather than enhanced its performance. This finding is supported by another Swedish study, by Granstrand and Sjolander (1990), which reports similar results.

Overall, this suggests the general antipathy exhibited by new entrepreneurs to acquisition, or part acquisition, by larger enterprise has some justification. It is compatible with the findings from UK studies by Garnsey and her colleagues (Garnsey and Cannon-Brookes, 1993; Garnsey et al, 1994) which suggest that, over a 6 year period, almost one third of high technology businesses growing rapidly were acquired by larger enterprises. In the UK, evidence on the impact of acquisition does not exist specifically for small high technology firms, but the general review by Cosh and Hughes (1994) is unable to demonstrate that acquisition of smaller enterprises by the large works to the benefit of the UK economy as a whole.

b) Move from soft to hard

The Irish case studies identified by Cogan (1995a) point to the need for R&D intensive firms in their early stage to generate some cash flow. An alternative approach was articulated by Bullock (1983) who suggested that technology-based firms could only undertake R&D provided they generated cash and reinvested directly in the business. Bullock argued the generation of cash was easier, and hence the cost base lower, when the firm provided services, rather than manufactured goods. Using the terms 'soft' to reflect services and 'hard' to reflect manufacturing, Bullock argued that technology-based firms were often forced to start the business on a 'soft' basis and, only later after the cash was generated and reinvested, become 'hard'. European studies however have consistently failed to identify any clear evidence of NTBFs making this type of transition.

c) Seek Venture Capital

In principle, venture capital can provide considerable benefits to technology-based SMEs. Access to venture capital means the business owner is not required to service a loan, in the sense of repaying the loan and/or the interest on that loan. This is particularly valuable during the early years of the establishment of an NTBF since, during that time, income generated from new products is likely to be small and a requirement to service a loan could make the business uneconomic.

Instead, the injection of external equity 'strengthens' the balance sheet. The entrepreneur has the option of borrowing more should he/she wish, or cutting borrowing and using equity for financing purposes. The 'non-financial' advantages of external equity are that, in some instances, the supplier of equity also exercises a role as a source of strategic managerial advice.

The disadvantage of 'equity', however, is that ownership of the business has to be shared with an outside person or institution. Many entrepreneurs regard this as restricting their opportunities for decision taking. They also recognise that, in the event of the business being highly successful, they will have to share the 'proceeds of the sale' with another party.

The evidence presented in Table 1.5 suggests that in Europe there has been a reluctance on the part of both the venture capital institutions and NTBF owners to develop the market for venture capital for technology-based firms. The table shows that between 1988 and 1992 there was a striking difference between Europe and the United States in terms of the total value of early stage investment by the venture capital sector in technology-based industries. The upper half of the table shows that during that period the proportion of early stage investments made by the European venture capital industry in technology-based firms ranged, generally downwards, from about 20% in 1988 to 16% in 1992. There was a slight increase in the total value of investments during that time, rising from ECU 3452m to ECU 4701m.

The contrast with the United States is striking. During the same period, whilst total value of investments made by the United States venture capital industry fell from ECU 3249m to ECU 1961m, the proportion of these investments devoted to technology-based sectors rose from 60.5% to 76%. It is therefore clear that Europe and the United States are effectively the mirror image of one another in this respect.

It is difficult to disentangle cause and effect here. It may be that European owners of NTBFs are more reluctant to share equity than comparable individuals in the United States. It may also be that European financial institutions have better opportunities for investing venture capital, than in high risk start ups. It may also be that NTBF owners in Europe are perceived to be insufficiently dynamic to justify the investments that must provide rates of return acceptable to external investors. It may also reflect historical tradition. O'Shea (1995), for example, points to the fact that, after World War II, much of the technology developed by the US government was transferred into the market place, yet in later decades the US military continued to be a major purchaser of technology products. She allies this with the development of an entrepreneurial culture in US universities, to which reference has already been made. The combination of these two factors meant the creation of a 'high technology' market place, to which the suppliers of finance responded.

In short, we are not certain whether this is a supply side problem or a demand side problem. Nevertheless it is a cause for concern that there are such striking differences between the EU and the United States, particularly where the latter has a much better record of NTBFs growing rapidly and creating significant numbers of jobs. The central issue is that the comparatively small proportion of firms which create the majority of the new jobs in NTBFs in both Europe and the US are different. Those in Europe are significantly smaller and their impact significantly less.

Table 1.5 Percentage Value of Technology Investments in Europe and the US by Venture Capital Firms 1988-1992

		1988	1989	1990	1991	1992
EUROPE	Total value investments (ECU million)	3452	4271	4126	4632	4701
	Technology - % value total investments	*20.7*	*20.4*	*19.7*	*16.1*	*16.0*
USA	Total value investments (ECU million)	3249	3080	1510	1095	1961
	Technology - % value total investments	*60.5*	*67.4*	*72.8*	*80.0*	*76.0*

Source: Murray (1994)

So, does technology make a difference?

In many respects the constraints which face owners of new technology-based firms are similar to those which face entrepreneurs in general. At start up their managerial skills are untested, and the businesses' credibility in the market place is low. In some respects, indeed, the technology-based entrepreneur may have advantages over the 'typical' entrepreneur, particularly in terms of high educational attainment. On the other hand the high tech entrepreneur has disadvantages which we have referred to above, such as uncertainties over delivery of a product, market size and in the lack of market credibility where, for example, customers require a guarantee that supplementary parts and spares will be provided. It is therefore the case that the financing of technology-based firms presents special problems, over and above those of financing of small businesses in general. It is less obvious that the technology-based founder will always be at a disadvantage compared with small firms in general.

The empirical evidence on this is taken from two studies in the United Kingdom (see Table 1.4). In essence, the Moore's (1994) study is unable to demonstrate that technology-based firms are more likely to report the lack of finance as a serious constraint on growth than 'comparable' firms outside the technology-based sectors. Moore shows that younger firms are more likely to report serious constraints, and that manufacturing firms are more likely to report constraints than service firms. However he finds that high technology manufacturing firms are no more likely to report serious constraints than businesses in the 'conventional' manufacturing sector. He finds that whether a firm innovates or not is unrelated to whether it experienced problems in seeking finance. These results clearly conflict with those of a sample of high technology firms examined by Westhead and Storey (1996) who show that, within this group, those firms which were more innovative, in the sense of undertaking more R&D and having more qualified scientists and engineers, were more likely to report financial constraints than the less innovative firms.

6. REGIONAL CONCENTRATIONS OF NTBFs

This section examines the evidence for any geographical clustering of new technology-based firms in European Union countries. This a key policy issues since the presence of external scale economies is argued to be a major factor underlying the success of NTBFs in the United States. The two best known examples of geographical clustering are the so-called 'Route 128' around Boston in Massachusetts and the 'Silicon Valley' in California. The nature of these external scale economies are that private costs to the firm are lowered by being located in these areas for two prime reasons. The first is that information, a key ingredient to the success of an NTBF, is more easily and hence more cheaply accessed. This information is provided by easy interaction with local universities, in which the NTBF owner may previously have been employed. The owner knows whom to contact in the university and hence access costs are lower. This does not, of course mean, that all, or even most, of the technology based small firms in the locality will have close relations with the local university. Instead, it suggests that such relations are more likely than in other locations.

The second reason is that many NTBFs sell their products/services to other firms in the locality. The local market place is strengthened because of the presence of purchasers of output, but it is also enhanced because of easier access to supplies, both of product/services and also of skilled labour in the form of PhDs emerging from the local university.

In short, the huge concentration of universities and government research laboratories, and in particular the dominant role played by MIT, are often argued to be the key influence upon the growth of 'Route 128' which may be considered the 'ring road' around Boston.

We have investigated the extent to which there is significant regional clustering of technology-based enterprises in EU countries. Although the matter is extremely complex, Table 1.6 presents some simple statements from major countries.

Table 1.6 Regional Concentrations of NTBFs

Country	
Austria	Concentration in (and around) Vienna, Graz and Upper Styria: research centres, universities and enterprises in same industry.
Belgium	Regional initiatives in the Flemish and Walloon regions and in Brussels have sought to stimulate technically-based small firms. No evidence of regional distribution of such firms.
Denmark	Clear concentration around Copenhagen and the other university cities of Aahus, Aalborg and Odense.
Finland	Studies of NTBFs on Science Parks naturally mirror university locations but the SITRA (1994) study suggests NTBFs are distributed geographically in a similar way to firms as a whole in Finland.
France	Ile de France and Mediterranean area contain most NTBFs, although this also reflects the distribution of enterprises throughout France.
Germany	Universities, transport, qualified personnel and place of residence of founder are key factors influencing regional NTBF patterns. The old metropolitan areas - Munich, Karlsruhe, Stuttgart, Cologne, Aachen, Hamburg have NTBF concentrations. Munich is particularly important with Siemens as a large tech employer and the existence of the Max Planck, Fraunhofer-Gesellschaft Institutes.
Greece	High concentration in Athens & Thessaloniki: also some presence in Crete. There may be a slight move away from Athens in recent times.
Ireland	No geographical concentration in NTBFs, other than in the distribution of universities from which they were launched.
Italy	No clear geographical concentration, though Pisa is starting to emerge as a strong centre. Academic links are weak in Italy and so the absence of concentration around Universities is not surprising.
Netherlands	University of Twente pays attention to start ups. More than 200 have been established in the locality.
Portugal	Some industrial districts - Aveiro, Leiria and Setubal concentrate on IT and are component suppliers. Parks are being established in many areas.
Spain	Madrid and Catalonia contain more technologically intensive firms whereas the Basque and Valencia regions are more traditional. Science Parks are seeking to reduce this imbalance. Within Aragon (a peripheral region) Zaragossa is dominant, but in Seville there is a cluster of suppliers active in advanced aeronautics.
Sweden	Large metropolitan areas such as Stockholm and Gothenburg exhibit NTBF concentrations. University spin offs are sectorally concentrated within for example Uppsala and Umea specialising in medical and biotechnology.
UK	NTBFs are geographically concentrated in 'sun-rise' belt running from Cambridge to Oxford and along 'M4 corridor'. This is attributed to the presence of universities and (former) government research laboratories. These are not regarded in Britain as urban areas.

Our interpretation is that significant geographical clusters of NTBFs in Europe probably occur only in Germany and the United Kingdom. There is some small scale clustering in Denmark, Portugal and Sweden, but in most countries it is difficult to distinguish the geographical distribution of NTBFs from that of enterprises as a whole.

The evidence of clustering in Germany is that NTBFs appear disproportionately clustered in all the major urban centres. However, the evidence appears to be show that Munich has a particularly high degree of clustering, even by German standards. This is attributed by commentators to the key role played by Siemens, both as a purchaser of products and services and as a source of new 'spin off' companies. The presence in the locality of international institutes such as Max Planck and the Fraunhofer-Gesellschaft is also deemed a major influence.

In the United Kingdom the pattern is rather different. Here the evidence is that clusters of NTBFs occur away from the main urban conurbations. Instead, they are concentrated in an arc, known as the 'sunrise belt' running from Cambridge to Oxford and along the 'M4 corridor'. This concentration is attributed to the role of the UK's two leading universities - Oxford and Cambridge - in providing highly educated scientists who, possibly whilst continuing their university research, commercialise their findings in companies which they establish locally. A second major source of 'spin out' has been individuals from research laboratories - many of which were formerly government-owned - again seeking to commercialise their scientific discoveries. In both instances the entrepreneurs are seeking to continue living in the area in which they worked and therefore establish their businesses locally.

The key role which universities can play in stimulating the growth of NTBFs emerges quite consistently from several of the country reviews. In part this may reflect 'sampling bias' since researchers know that easily-accessed concentrations of technology-based firms will be found on science parks established next to the local university. As Autio (1995) points out, sampling NTBFs on science parks points to considerable concentrations around universities, whereas a random sample of NTBFs throughout the whole of the country fails to exhibit such clear clusters. Nevertheless, with this proviso in mind, concentrations around universities are apparent in both Sweden and Denmark. It is also the case that, in the Netherlands, the University of Twente has been the source for more than 200 NTBFs. Equally, in Austria, the Styria province exhibits concentrations in Graz and Upper Styria as well as Vienna, where research centres and universities concentrate.

Probably the most notable exception to these statements is Italy. Here there appears to be almost no evidence of geographical clusters of NTBFs, even in university cities - with the modest exception of Pisa where a centre is starting to emerge. In the case of Italy this is attributed to the very weak links between academia and local enterprise.

In Spain and Portugal there is some evidence of geographical concentrations; the urban districts of Madrid and Catalonia exhibit some concentration, whereas some of the small industrial districts in Portugal such as Aveiro and Leiria and Setubal contain small scale concentrations of firms specialising in information technology. However, in both Spain and Portugal, science parks established in recent years have sought to extend the concentration of NTBFs over wider areas of the country and also enhance links between research institutions and the commercial sector.

7. THE DEVELOPMENT OF NEW PRODUCTS, ESTABLISHMENTS AND INDUSTRIES

This section examines the role of new technology-based firms in innovation, in developing new industries and their links with other enterprises. Over the last 20 years there has been an increasing recognition that smaller enterprises play a key role in innovation. Acs and Audretsch (1990) in the United States, and Pavitt et al. (1987) in the UK, have both demonstrated that smaller enterprises are a disproportionate source of key new innovations. Recently this evidence has been challenged by Harrison (1994) of the United States and by Tether (1996a, 1996b; Tether et al., 1996) for the UK. Nevertheless, even despite these recent criticisms, it remains probable that case that small firms contribute 'at least their share' of innovations.

However, as Rothwell and Zegveld (1982) reported a number of years ago, large and small firms do not work in isolation. In their assessment of the development of the computer industry in the United States, Rothwell and Zegveld note that it was scientists from the large Bell Laboratories founding their own enterprises which constituted the genesis of that industry. Even so, it was not simply in their role in the provision of scientifically skilled labour that large firms played a key role. They also were, and continue to be, important as customers, as suppliers of finance, as partners in collaborative agreements, particularly in the marketing area or as partners in joint ventures.

In the United Kingdom, Beesley and Rothwell (1987) examined 100 innovative SMEs. They found 84 had a significant link with larger firms in at least one of the following areas: contracted-out R & D, joint R&D ventures, marketing or manufacturing relationships. It is therefore the concept of partnership, between small and large firms, with mutual benefits for both, which is the consistently emerging theme of this section. Large firms can provide markets, capital and personnel. In the UK, for example, Monck et al. (1987) found that 37% of founders of technology-based firms came from the large firm sector. This is almost identical to the 32% which Kulicke (1987) discovered for Germany.

The nature of these linkages between small and large firms emerge from several interesting reviews from Belgium, Sweden and Italy. In Belgium, the Ghent University-based Plant Genetic Systems established joint ventures with Japan Tobacco and Clause (France) (Segers, 1993). It also established a research and development relationship in bio-pharmaceuticals with Corvas in the United States, and has a co-marketing and licensing agreement with Hilleshög in Sweden.

It is not surprising to find that, in the technology sectors, links between large and small firms in Italy are strongly developed, given the Italian tradition of industrial districts and collaboration in manufacturing more generally. As Malerba et al. (1995a) report, large firms are more likely to innovate than small firms because large firms undertake the majority of research and development activities. However, drawing upon the work of Esposito and Raffer (1990) who examine 32 small firms in Southern Italy involved in the high technology sectors, Malerba et al. confirm that large firms not only seek to obtain inputs from small sub-contractors but assist them before and during the partnership. The small firm is not simply a supplier of components but is also an important actor in the network of high-tech firms. Both parties gain from this relationship, the small firm obtaining markets and expertise, but the larger firm obtains access to technologies to which it might otherwise have been denied.

However it would be misleading to focus exclusively upon the 'success stories' in this context. Olofsson and Stymne (1995a) report Lundgren (1991) who reviews the evolution of the new industry of Digital Image Processing (DIP). In many respects this is the story of an industry which, whilst based on science, failed to take off commercially. It can be considered to be the 'flip side' of the computer industry. D.I.P. is a technological system combining the technologies of computing, electronics and telecommunications. D.I.P. technology includes techniques for receiving visual information, recording that information as images and interpreting the images. For example, echoes from ultrasonic waves passing through soft body tissue can be recorded in digital form on electronic medium and then be shown as pictures on a monitor and analysed by computer programme to detect abnormalities.

The industry can be traced back to the early 1960s when scientists at Sweden's Royal Institute of Technology set out to develop a machine for reading spectral recordings into a computer. By the early 1970s this had lead to several research ventures in Sweden, most notably associated with the new University in Linkoping. Funding for these developments came primarily from public sources, although Saab also became interested. The development work was closely associated with one individual, Professor Abrahamsson, but his death lead to a lull in activity. However, in 1979 the Swedish National Board for Technological Development initiated a five year special programme for the development of the industry providing major incentives for scientists to become entrepreneurs. Several new groups were formed in the Linkoping area with their academic connections retained. Since 1976 image processing equipment has been sold on a commercial basis, and by 1985 Swedish organisations had developed at least ten technologically-sophisticated image processing computer systems. However, whilst they were technologically-sophisticated, the results were commercially disappointing. Most of the new technology-based companies failed, or were absorbed by other, sometimes foreign-owned, companies. This probably reflects stronger emphasis on research in the Swedish businesses, rather than giving priority to the needs of the customer. It may also be because each laboratory saw its own solution as universally applicable and was reluctant to tailor solutions to specific client needs; and it may have reflected a reluctance to collaborate with other businesses. Only two of the larger established firms ultimately became successful, and the experience may have lead to a subsequent reluctance on the part of major Swedish companies to pursue the commercialisation of these areas of research.

Whilst collaboration between firms of different sizes is clearly not a guarantee of success, the results from several European countries - such as France, Ireland and Spain - indicate that, on balance, collaboration is not only beneficial but that it has enhanced the access of small firms to EU funding in recent years. For example, a study in France by Mustar (1994) found that from a sample of 100 NTBFs, 54 co-operate formally in research with French firms and 31 co-operate with firms elsewhere in the European Union. Most importantly he finds the collaborators perform better than the non-collaborators in the sense of being larger, more export orientated and less dependent on a few customers. In Ireland, Cogan (1995a) found that amongst academic spin off companies, EU research programmes were the instrument used by virtually all academic entrepreneurs to demonstrate the quality of their research and to provide it with international credibility. A key problem in Ireland and elsewhere is that the technology-based sectors are frequently dominated by large multinational enterprises. This is also true for Spain and the presence of large multinationals is thought to have acted as a significant barrier to the establishment of NTBFs in sectors such as micro electronics and telecommunications. The Spanish experience has been that, whilst it is uneconomic to seek to compete directly with multinationals, within computer services and electrical or electronic instrumentation there are niches which it is possible for local enterprises to exploit, often with the encouragement of larger firms. Furthermore in Spain, some large firms have been an effective providers of support in the form of skilled personnel, finance and marketing for example, for the indigenous technology sector.

The overall European experience is that NTBFs, where they are successful in developing new products and new industries, rarely achieve this without collaboration, in some form, with larger, generally private sector, organisations. This section has only discussed marketing and technological co-operation with large enterprises - it has not discussed financing which is left till later. However collaboration is certainly not a sufficient condition for the achievement of success. The example of the Swedish digital image processing industry demonstrate the importance of a clear commercial focus on the part of the smaller enterprises, combined with a major commitment by large organisations.

Part II

AN ANALYSIS OF THE STATISTICAL EVIDENCE ON THE ROLE OF SMALLER FIRMS IN THE DEVELOPMENT OF EUROPE'S HIGH TECHNOLOGY SECTORS

1. INTRODUCTION

This part of the report discusses the role of New Technology Based Firms in Europe using national census data. Unfortunately information on the age of businesses is not generally available and so data on the changing contribution of small, medium-sized and micro units[1] to Europe's high technology sectors during the 1980s is utilised.

The nature of the data examined will be discussed below, but the contribution of small, medium-sized and micro units to the high technology sectors will be assessed in two ways:

- in terms of the absolute number of units in the high technology sectors and particularly how this has changed over time.
- in terms of the contribution of these smaller units to employment in the high technology sectors and how this has changed over time.

The contributions of small, medium-sized and micro units to the high technology sectors are monitored both in relation to the contribution of large units to these sectors and by referenced to the contribution of smaller units to other economic activities, particularly by reference to their contribution to manufacturing activities as a whole.

The report will highlight differences and similarities between countries and sectors in the development of high technology activities.

The structure of this part of the report is as follows:

- Section 2 introduces the framework through which the changing structure of the high technology sectors will be examined.
- Section 3 discusses the statistical data utilised in this part of the report.

[1] These are establishments or enterprises with less than 500 employees. A more complete definition of micro, small, medium-sized and large units is presented in Section 3 of this part of the Report.

- Section 4 assesses developments within the aggregated high technology manufacturing sectors of European countries and compares these developments with changes in the entire manufacturing sectors of European countries.
- Section 5 examines developments in four specific high technology manufacturing sectors:
  - Section 5a: The Pharmaceuticals Sector (NACE-70: 257)
  - Section 5b: The Office Equipment and Computers Sector (NACE-70: 330)
  - Section 5c: The Electronics Sector (NACE-70: 34)
  - Section 5d: The Instruments Sector (NACE-70: 37)
- Section 6 assesses developments in the aggregated high technology service sectors of European countries.
- Section 7 examines developments in three specific high technology service sectors:
  - Section 7a: Computer Services (NACE-70: 8392)
  - Section 7b: Research and Development Services (NACE-70: 940)
  - Section 7c: Technical Services (NACE-70: 837)
- Section 8 analyses the development of the high technology sectors on a country by country basis.
- Section 9 provides a summary and some conclusions.

2. A FRAMEWORK FOR ANALYSING THE EVOLUTION OF INDUSTRIES

This section presents the framework through which we will analyse the evolution of high technology activities in European countries, both in terms of the change in the number of units active in these activities and in terms of the change in these sectors' employment.

<u>Background: An *A Priori* Model of Industrial Evolution</u>

In general, industries might be expected to follow an evolutionary path over time. A standard evolutionary path is displayed in Figure 2.1.

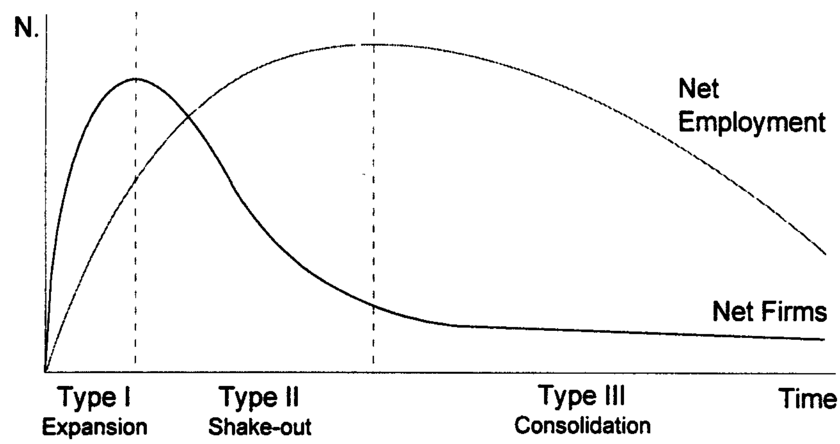
In the early phase of an industry, there is net entry, both in terms of the number of firms (or establishments) in the industry, and in terms of the industry's employment. We call this phase 'Phase I - Expansion' and industries in this phase are described as Type I industries.

After a while, the number of exits will at first equal, and then exceed, the number of firms entering the industry; through a process of 'shake-out' there is net exit in terms of the number of firms in the industry. However, employment in the industry continues to rise, and becomes more concentrated within the remaining firms in the industry. We call this period phase 'Phase II - Shake-out', and industries in this phase are described as Type II industries.

After a time, an industry will stabilise and then contract in terms of its total employment. When the industry starts to contract in terms of employment it enters 'Phase III - Consolidation'. We describe industries in this phase as Type III industries. Note that in phase III the number of firms active in the industry will continue to decline, but more gradually than in phase II.

Figure 2.1

An *A Priori* Model of Industrial Evolution



This then is the basic *a priori* model. There is, however, a fourth type of industry, Type IV. Type IV industries arise when industries contract in terms of employment but expand in terms of the number of firms active in the industry. Type IV industries do not appear to comply with this standard *a priori* model of industrial evolution, but, as we shall see, their existence in the high technology sectors of Europe is quite common. We shall provide some explanation for the existence of Type IV industries later in the report.

<u>The Analysis of High Technology Sectors in European Countries</u>

In this report, we do not analyse the development of individual industries over long periods of time, instead we assess the development of various high technology industries in Europe over a period of about 10 years from around 1980 to around 1990, making comparisons between industries and between countries.

Figure 2.2 presents the basic framework used in this analysis. This is a two variable graph where the x-axis measures change in terms of the number of units active in the sector and the y-axis measures change in terms of employment in the sector. As we shall show, this framework relates to the *a priori* model of industrial evolution discussed above.

The framework developed for this analysis can be used to compare industrial change between countries and between sectors. For, in an analysis of industries, point '*a*' in Figure 2.2 would represent an industry in which both the number of units and the industry's employment has increased - this is a Type I industry. Point '*b*' represents an industry in which the number of units has decreased but in which employment has increased - this is a Type II industry. Point '*c*' represents an industry in which both the number of units and the industry's employment have decreased - this is a Type III industry. And point '*d*' represents an industry in which the number of units has increased but the industry's employment has decreased - this is a Type IV industry.

Figure 2.2

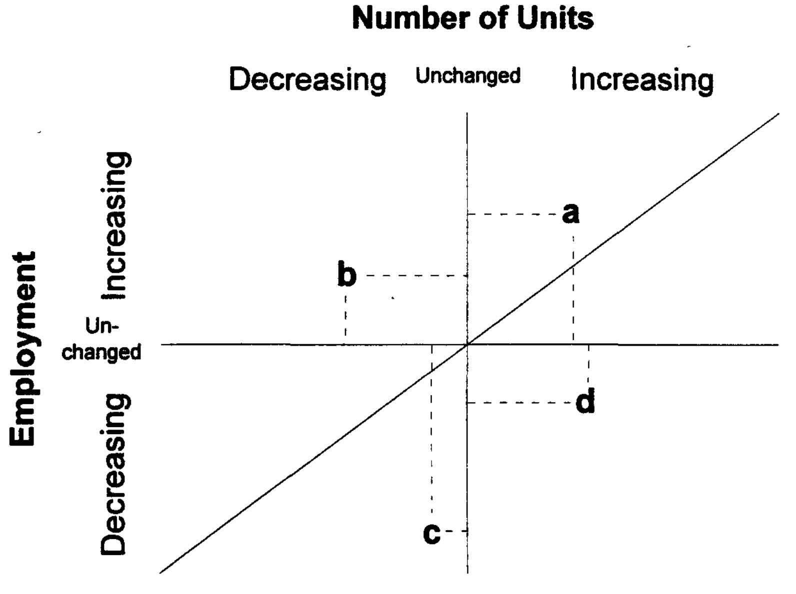


Figure 2.2 also shows the diagonal line along which the change (increase or decrease) in the number of units equals the change in employment. Along this line, the average unit's employment remains unchanged. At the points above this line, such as '*a*' and '*b*', the change in employment exceeds the change in the number of units, therefore employment in the average unit has increased and the industry is evolving towards larger units (cf. 'Phase II - Shake-out' of industrial evolution and Type II industries). At points below this line, such as '*c*' and '*d*', the change in the number of units exceeds the change in employment, therefore, employment in the average unit has decreased and the industry is evolving towards smaller units (cf. Type IV industries)[2].

Thus, the information on the graph can be used to classify industries into the four types identified in relation to the evolution of industries and shown in Figure 2.1. These are:

[2] The distance from the diagonal line indicates the rate of change of employment in the average unit, such that greater perpendicular distance of point *b* to the diagonal in comparison with the distance of point *a* to the diagonal shows that the proportional increase in average unit employment was greater in *b* than in *a* and therefore industry *b* was moving towards larger units more rapidly than industry *a*. By contrast, the points *c* and *d* are equidistant to the diagonal, which shows that at both these points (and at all other points between them) mean unit employment decreased at the same rate.

Type I: Both the number of units and employment have increased. This can be sub-divided into:

Type Ia: Employment increased more rapidly than the number of units, average unit size increased.

Type Ib: Employment increased less rapidly than the number of units, average unit size decreased.

Type II: The number of units decreased, but employment increased. Average unit size increased.

Type III: Both the number of units and employment decreased. This can be sub-divided into:

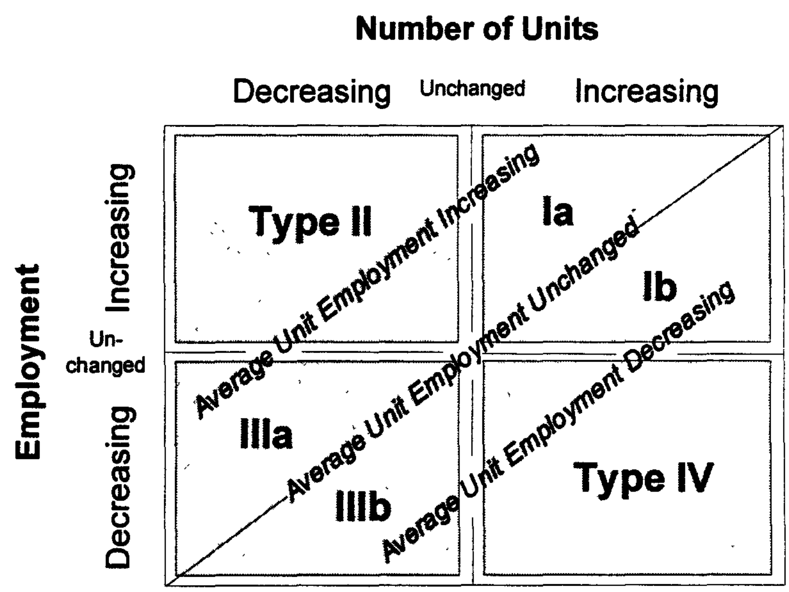
Type IIIa: Employment decreased less rapidly than the number of units, average unit size increased.

Type IIIb: Employment decreased more rapidly than the number of units, average unit size decreased.

Type IV The number of units increased, but employment decreased. Average unit size decreased.

Figure 2.3 shows the position of these Types on the framework introduced in Figure 2.2.

Figure 2.3

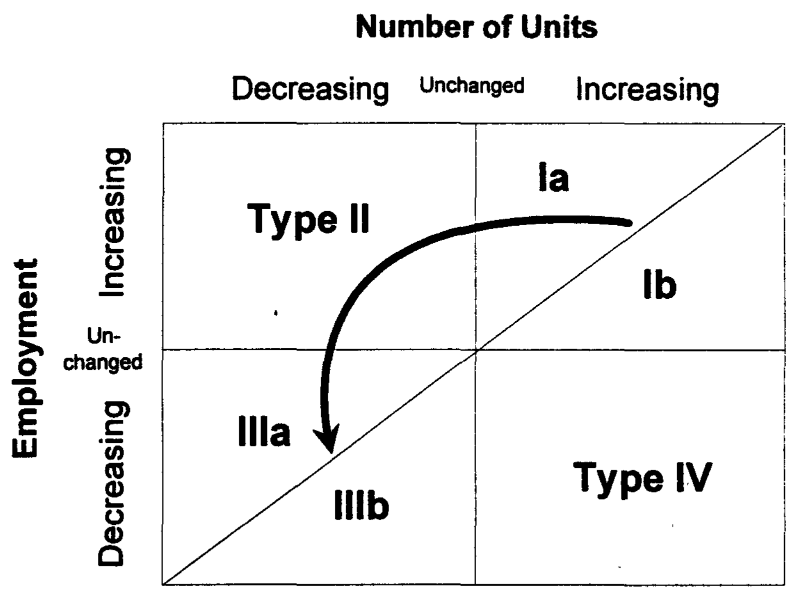


The Evolution of Industries over Time

According to the *a priori* model of industrial evolution, a 'new' industry would appear as a Type I industry, and then, as it matures, move around in an anti-clockwise direction to become first a Type II industry and then a Type III industry. There is no *a priori* reason for the emergence of Type IV industries. Figure 2.4 translates the model of industrial evolution onto the framework developed in Figures 2.2 and 2.3. The thick black line indicates the suggested evolutionary path of industries over time.

Although this model relates to the evolution of industries, from new to mature, over time, in the analysis which follows, we assess changes to high technology rather than specifically 'new' industries. High technology industries are those that are investing proportionally more heavily on scientific and technological resources or activities (Butchart, 1987) than industries in general. Whilst such industries need not be new, we would expect them to be expanding, at least in terms of employment and possibly also in terms of the number of active units. Thus, new high technology industries should be Type I, whilst those in a later phase of development might be expected to be Type II. *A priori*, we would not expect them to be either Types III or IV.

Figure 2.4



<u>A Further Refinement - the Inclusion and Exclusion of Micro Units</u>

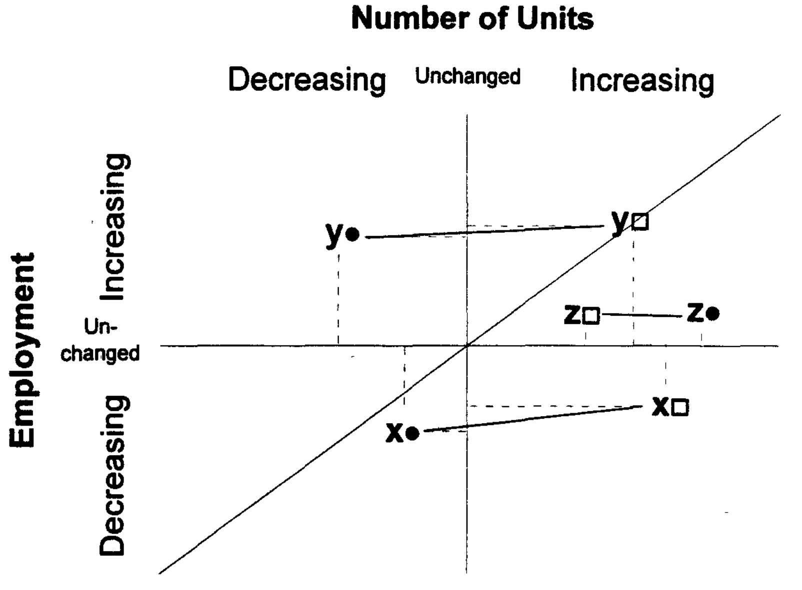
Before discussing the data and undertaking the analysis, we introduce one further refinement to the framework introduced above. This concerns the inclusion and exclusion of micro units from the analysis.

It is a fact that in all industries micro units dominate in terms of the number of units, but, in manufacturing in particular, larger units normally dominate employment, with micro units providing a marginal contribution to employment. The inclusion or exclusion of the micro units from the analysis can therefore make a difference to the position of an industry within the framework.

For example, in Figure 2.5, the point *x*□ represents the position of industry '*x*' with the micro units included in the analysis, whilst *x*● represents the position of the same industry with the micro units excluded. The graph shows that with the micro units included (*x*□), the number of units increased, but employment decreased. Without the micro units (*x*●), both the number of units and employment decreased.

From this, it can be concluded that there was an increase in the number of micro units in the industry, whilst the number of non-micro units declined. Whether or not the micro units were included, the industry's average unit size in terms of employment decreased[3].

Figure 2.5



A second pair of points, *y* □ (which includes the micro units) and *y*● (which excludes the micro units), both show employment increasing in industry '*y*', but when the micro units are included *y*□ shows the number of units also increased, and at the same rate as employment increased so the average unit's employment remained unchanged. Without the micro units, *y*● shows the number of units declined and thus in industry '*y*' the average non-micro unit's employment increased.

In general, the relative position of the symbol which includes the micro units (□), to the symbol which excludes the micro units (●), can be interpreted according to certain rules:

- When □ is to the **right** of ●, the participation of micro units has grown more rapidly (or decreased more slowly) than the participation of non-micro (small, medium, large) units.
- When □ is to the **left** of ●, the participation of micro units has grown less rapidly (or decreased more rapidly) than the participation of non-micro units (see z□ and z● in Figure 2.5).
- When □ is to the **above** of ●, employment in micro units has increased more rapidly (or decreased less rapidly) than employment has increased (or decreased) in non-micro units.
- When □ is to the **below** of ●, employment in micro units has increased less rapidly (or decreased more rapidly) than employment has increased (or decreased) in non-micro units.

[3] Whilst this might have be expected to follow from the increase in the number of units with the inclusion of micro units it does not necessarily follow amongst the residual non-micro units. The point *x*● shows that the mean unit size also decreased when the analysis was restricted to small, medium sized and large units.

3. THE DATA

The data used in the analysis below was collected from national sources that include the number of units operating in a variety of 'high technology' sectors. Units are defined as either establishments or firms/enterprises, depending on the level at which national statistics are collected and made available.

The sectors identified as being 'high technology' were those identified by Butchart (1987) (Table 2.1). Data were gathered for these sectors according the NACE 70 classification, NACE Revision 1/NACE 1992 or the national classification, depending on the coding used by national data sources.

Table 2.1 High Technology Industry Codes Classified by NACE 70

High Technology Manufacturing	
Synthetic Rubber & Plastics	251.0
Pharmaceutical Products	257.0
Office Machinery	330.1
Electronic Data Processing Equipment	330.2
Basic Electrical Equipment	342.0
Telegraph and Telephone Equipment	344.1
Electrical Instruments and Control Systems	344.2
Radio and Electronic Capital Goods	344.3
Components other than Active Components	344.4
Active Components and Electronic Sub-Assemblies	345.3
Aerospace Equipment	364.0
Measuring Checking and Precision Instruments	371.0
Medical and Surgical Equipment and Orthopaedic Appliances	372.0
Optical Precision Instruments	373.2
Photographic and Cinematographic Equipment	373.3
High Technology Services	
Telecommunications	790.2
Architectural and Engineering Activities and related Technical Activities	837.0
Technical Testing and Analysis	837.0
Professional and Technical Services not elsewhere specified	837.0
Computer Services	839.2
Research and Development in Natural Sciences and Engineering	940.0

Data on the number of units were collected according to a size classification of micro, small, medium-sized and large units. Where, in general:

- Micro units are those with: 0 - 9, 1 - 9, 0 - 19 or 1 - 19 employees, according to national definitions.
- Small units are those with 10 - 99 or 20 - 99 employees, depending on the definition of micro units.
- Medium-sized units are those with 100 - 499 employees

- Large units are those with 500 or more employees.

Note, however, that:

- In some smaller countries (Denmark, Greece, Ireland, Luxembourg, Norway) there is no medium sized category and all units with more than 100 employees are categorised as being large.
- France and Greece were unable to provide data on the number of micro units or their employment and, for the UK, the enterprise level data does not allow a distinction to be made between small and micro enterprises (the smallest categorisation is of enterprises with less than 100 employees).

Data on the employment of these units was also collected, divided according to the size classification of micro, small and medium sized, and large units.

Table 2.2 Data Provided by Country

Country	Units	Year A	Year B	Micro	Notes
Austria	Establishments	1981	1991	1-9	
Belgium	Establishments	1980	1990	1-9	
Denmark	Establishments	1983	1992	1-19	
Finland	Firms	1986	1993	0-9	
France	Firms	1982	1992	(1-19)	No data on micro units is available
Germany	Establishments	1980	1990	1-9	The data relates to West Germany only[4]
Greece	Establishments	1980	1992	(1-19)	Manufacturing: No data on micro units
Greece	Establishments	1978	1988	1-19	Services: includes data on micro units
Ireland	Establishments	1980	1990	1-9	
Italy	Enterprises	1981	1991	1-19	
Lux.	Enterprises	1984	1990	0-9	
Neths.	Firms	1983	1990	0-9	
Norway	Firms	1980	1990	1-19	
Portugal	Establishments	1982	1989	0-19	
Spain	Establishments	1982	1992	0-19	
Sweden	Firms	1984	1993	0-9	
UK (a)	Enterprises	1980	1990	*na*	1-99 employees the smallest category
UK (b)	Establishments	1985	1994	1-9	

These data were requested for two years, the first, Year A, around 1980, the second, Year B, around 1990. For most countries, Year A data were provided for a year between 1980 and 1983 and Year B data for a year between 1989 and 1992. However, due to data availability considerations, there were

[4] The German data is derived from the social security database which registers all establishments with at least one employee. This source therefore excludes establishments with no employees, which are important in the service sectors.

some exceptions. For Finland, data were provided for the years 1986 and 1993, for Sweden 1984 and 1993, for Luxembourg 1984 and 1990, and for the UK[5] at the establishment level 1985 and 1994. Greek service sector data were for were for 1978 and 1988.

Table 2.3 Notes on the Data provided on High Technology Sectors

		AM	AA
Austria	11 manufacturing sectors, plus some service sector data.	✓	✓
Belgium	10 manufacturing sectors, plus 4 service sectors	✓	✓
Denmark	3 aggregate manufacturing sectors, plus 2 service sectors	✓	✓
Finland*	10 manufacturing sectors, plus 8 services sectors	×	✓
France	20 manufacturing sectors. No comparable service sector data	✓	×
Germany	5 aggregated manufacturing sectors, plus 4 aggregated service sectors.	✓	✓
Greece	12 manufacturing sectors, plus 5 service sectors.	✓	×
Ireland	8 manuf. sectors. No comparable service sectors. Employment estimates	✓	×
Italy	12 manufacturing sectors, plus 5 service sectors	✓	✓
Lux.	2 aggregated manufacturing sectors, plus 5 services sectors	×	✓
Neths.	9 manufacturing sectors, 4 service sectors. Employment is estimated	✓	✓
Norway	5 manufacturing sectors. 1980 employment estimated. No service sectors	✓	×
Portugal	6 manufacturing sectors. No service sectors	×	×
Spain	18 manufacturing sectors. No service sectors	✓	×
Sweden	9 manufacturing sectors, 5 service sectors.	✓	✓
UK (a)	10 manufacturing sectors. No service sectors	✓	×
UK (b)	15 manufacturing sectors, 4 service sectors with no size classification	✓	✓

AM Data provided on All Manufacturing Activities

AA Data provided on All Activities - i.e., includes both manufacturing and services.

* In the case of Finland, data on All Industrial Activities was provided, but not data on All Manufacturing Activities.

Thus data for Denmark, Sweden and the UK at the establishment level, cover 9 year periods, whilst that for Greek manufacturing sector covers a 12 year period. To make these data more comparable with that provided by other countries they have been adjusted, using a linear correction, to a 10 year period. In the cases of Finland, the Netherlands and Portugal, the data cover 7 year periods, whilst that for Luxembourg covers a 6 years period. No correction has been made to these data because these periods were considered insufficiently close to a ten year period to permit a linear correction.

Sectoral coverage also varied between countries. For the manufacturing sectors, some countries were able to provide detailed statistics classified at the four digit level (or equivalent) whilst other countries

[5] Data was also gathered at the enterprise level for the UK for the years 1980 and 1990.

were only above to provide more aggregated data. Coverage of the service sectors is much less complete than coverage of manufacturing, as many countries were unable to supply suitable data[6].

In addition, for comparative purposes, data on the number, size distribution and employment of all manufacturing units and, when available, the same for all service activities and all activities combined, were also collected. Tables 2.2 and 2.3 summarise the data that was made available for this analysis from national sources.

It must be stressed that the lack of homogeneity in the data sources used, as well as the differences in the level (establishments or enterprises), timing (the different periods studied) and detail (the amount of sectoral disaggregation) of the data analysed for each country, makes strict comparisons impossible. However, the data does allow indicative comparisons between sectors and countries.

4. DEVELOPMENTS IN HIGH TECHNOLOGY MANUFACTURING (in Comparison with Developments in All Manufacturing Activities)

Having discussed the data, we now examine the development of the aggregate high technology manufacturing sector (AHTMS) in European countries, within the framework introduced earlier. This framework permits an assessment of the changing contribution of small, medium-sized and micro units to this sector in the various European countries.

The aggregate high technology manufacturing sector (AHTMS) is defined as the combined sum of the data on the various individual high technology manufacturing sectors provided from national statistical sources. The 'sector' as examined here is not, therefore, entirely homogeneous in definition. However, whilst this analysis will not provide exact comparisons between countries, it does permit a general examination of similarities and differences between countries.

Background

Before proceeding to the framework analysis, it is useful to provide some background details on the features and trends within the AHTMS:

- In most European countries, high technology manufacturing units generally account for less than 10% of all manufacturing units and in some countries (Austria, Belgium, Greece and Spain) they account for less than 5% of all manufacturing units.

[6] These countries include France, Ireland, Norway, and Spain. For the UK, some data on services was collected at the establishment level but is not available at the enterprise level nor is the establishment data divisible into a size classification.

- Generally these units account for a larger share of manufacturing employment (usually between 10 and 20% of manufacturing employment).
- Thus, high technology manufacturing industries tend to be dominated by larger units.
- Across Europe, the general trend is that large scale units (LSEs - those with more than 500 employees[7]) generally account for over half of all employment in the AHTMS, but in Italy (48%) and the UK (at the establishment level) (45%) their share is slightly less than half the total. Only Spain stands apart, there 49% of high technology manufacturing employment is in medium sized (100-499 employees) rather than large units.
- In most European countries, the average employment of both high technology manufacturing and all manufacturing units have declined, but, on average, high technology manufacturing sector units still employ about twice as many people manufacturing units in all sectors.

The Evolution of the Aggregate High Technology Manufacturing Sector in European Countries

Figure 2.6 applies the framework introduced earlier to the data on the aggregate high technology manufacturing sectors (AHTMS) of the various European countries. The figure is shown first without annotation, then shown again with the addition of country labels.

It is immediately apparent that, over the period of analysis, in most countries the AHTMS was either Type I[8] or Type IV[9]. Thus, in terms of the number of units, only in Portugal, Spain and Sweden was there a reduction in the number of units active in the AHTMS. In Spain and Sweden this reduction was caused by a decline in the number of micro units in the sector, for the number of non-micro units active in the AHTMS increased in both these countries. Only for Greece and Portugal does the data indicate that the number of non-micro units in the AHTMS decreased. The data for Greece are not wholly reliable[10].

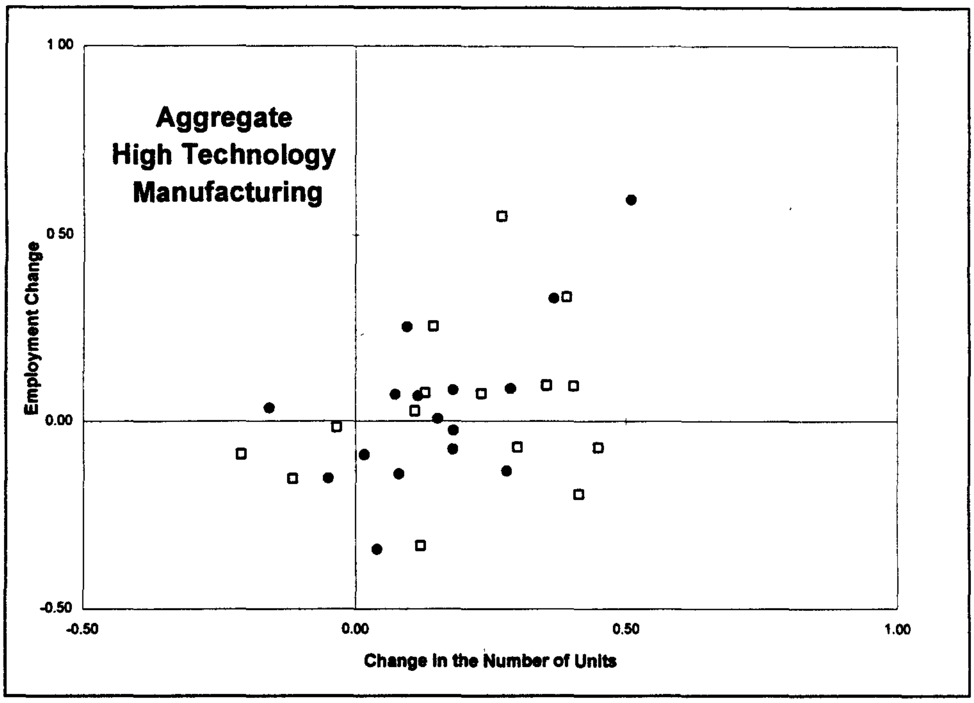
Although most countries experienced increases in the number of units active in the aggregate high technology sector, the rate of increase varied widely between countries, increasing most rapidly in Italy (+57% between 1981 and 1991), the UK (+51% at the enterprise level between 1980 and 1990), the Netherlands (+50% between 1983 and 1990) and Ireland (+48% between 1980 and 1990). In France, excluding the micro enterprises, the number of active high technology manufacturing sector enterprises increased by 32%.

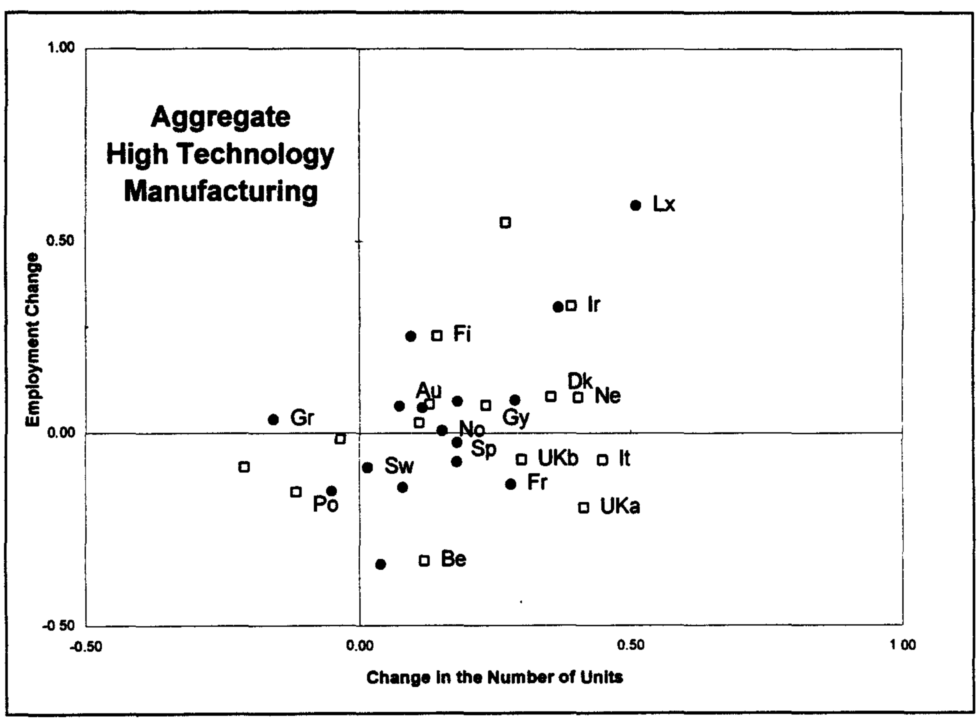
As noted above, in contrast to the near universal trend of an increase in the number of active units, there was not a general trend towards greater employment in the aggregate high technology

[7] Except for Greece, Ireland and Norway where large units are those with more than 100 employees.
[8] Austria, Denmark, Finland, West Germany, Ireland, Luxembourg the Netherlands and Norway.
[9] Belgium, France, Italy and the UK.
[10] The Greek data is not truly cross-sectional. Individual firms that grow (or contract) out of their original size band are not reclassified into their 'new' size band.

manufacturing sector: whilst employment in the sector increased in some countries[11], in others it declined[12].

Figure 2.6





Amongst those countries in which the absolute level of employment in the aggregate high technology manufacturing sector increased, the rate of increase varied widely between 73% and 3%[13]. And there

[11] Austria, Denmark, Finland, West Germany, Luxembourg, Ireland, Norway and, excluding the micro units, Greece.
[12] Belgium, Italy, Portugal, Spain, Sweden, the UK and, excluding the micro units, France.

was also a wide variation in the rate of contraction amongst countries in which the absolute level of employment in the aggregate high technology manufacturing sector declined, with the rate varying between -28% and -2%[14].

The combination of these trends meant that in most countries, the average high technology manufacturing unit's employment declined. In Belgium, Denmark, France, Italy, the Netherlands, and the UK, the rate of contraction was greater than in Austria, West Germany, Ireland, Norway and Portugal, but in Finland, Luxembourg and Sweden, the average employment of high technology manufacturing units increased. In general, the trend in the AHTMS was that micro and small-medium sized units increased in number, and so increased their employment, whilst large units declined in number and cut their employment.

The Evolution of All Manufacturing Activities in European Countries

Above, we showed that the aggregate high technology manufacturing sector of most European countries were either Type I or Type IV industries. We now compare the position of these high technology industries with the position of all manufacturing activities in the various European countries.

Figure 2.7 shows the position in the framework of all manufacturing activities in the various European countries. It is apparent that, with two exceptions[15], the aggregate all manufacturing sector (AMS) in European countries was either Type III[16] or Type IV[17]. Thus, the aggregate manufacturing sector (AMS) stands in marked contrast to the aggregate high technology manufacturing sector. The former being either Type III or Type IV; the latter being either Type I or Type IV.

Thus, for both the aggregate high technology manufacturing sector (AHTMS) and the aggregate manufacturing sector (AMS), the data reveals that industries have not evolved wholly as expected on the basis of the *a priori* model introduced earlier. That model suggested the high technology sectors should be either Type I or Type II, whilst the whole manufacturing sector should be Type II or Type III.

In both cases this expectation was only partially fulfilled. In some countries the aggregate high technology manufacturing sector was Type I, and in some countries the aggregate manufacturing sector was Type IV, but for both aggregate high technology manufacturing, and manufacturing as a whole, there were countries in which these sectors were Type IV, the classification unexplained by the *a priori* model.

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[13] Luxembourg (+73%, 1984-1990), Ireland (+39%, 1980-1990), Finland (+29%, 1986-1993), Denmark (+10%, 1983-1992), The Netherlands (+10%, 1983-1990), Austria (+8%, 1981-1991), West Germany (+8%, 1980-1990), Greece (ex-micro, +4%, 1980-1992), Norway (+3%, 1980-1990).

[14] Belgium (-28%, 1980-1990), the UK (-18% 1980-1990), Portugal (-14%, 1982-1989), France (ex-micro units, -13%, 1982-1992), Sweden (-8%, 1984-1993), Italy (-7%, 1981-1991), Spain (-2%, 1982-1992).

[15] Denmark and The Netherlands.

[16] Austria, Greece, Ireland, Italy, Norway, Spain and Sweden.

[17] Belgium, West Germany, Finland, France and the UK.

The emergence of Type IV industries is explained empirically by an increase in the number of micro units but a decrease in the number of large units. As large units dominate employment, especially in the high technology sectors, the increase in the number of micro units fails to compensate for the employment lost from the decline in number of large units and there is a decline overall employment.

Figure 2.7

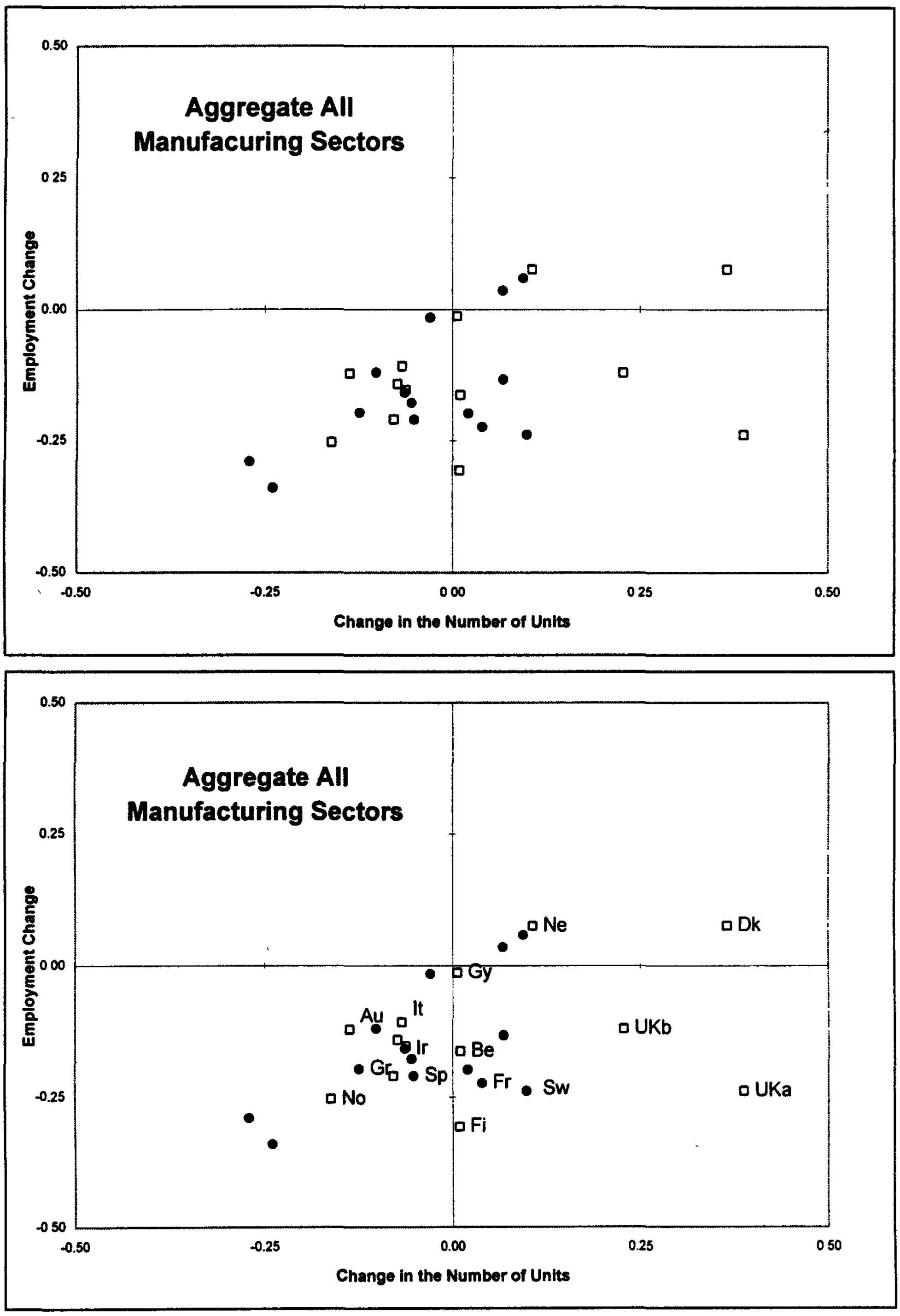


Table 2.4 shows this trend held for both the AHTMS and the AMS in many European countries, the primary difference between the two being that in the AHTMS the trend was for small and medium

sized units to increase in number and employment whilst in the AMS the trend was for small and medium sized units to decline in number and employment.

Table 2.4 Trends in the Size Distribution of High Tech. and All Manufacturing Activities

On balance, the trend is for ...	The Aggregate High Tech. Manuf. Sector	The Aggregate All Manufacturing Sector*
The NUMBER of MICRO units to...	INCREASE	(NO TREND)
	↑11, =0, ↓3	↑6, =0, ↓6
EMPLOYMENT in MICRO units to...	INCREASE	INCREASE
	↑12, =0, ↓2	↑9, =0, ↓3
The NUMBER of SMALL & MEDIUM sized units to ...	INCREASE	DECREASE
	↑14, =0, ↓2	↑6, =0, ↓8
EMPLOYMENT in SMALL & MEDIUM sized units to ...	INCREASE	DECREASE
	↑14, =0, ↓2	↑5, =0, ↓9
The NUMBER of LARGE units to...	(NO TREND)	DECREASE
	↑7, =2, ↓7	↑2, =0, ↓12
EMPLOYMENT in LARGE units to...	(NO TREND)	DECREASE
	↑8, =0, ↓8	↑2, =0, ↓12
No Data	Micro 2, Non-Micro 0	Micro 4, Non-Micro 2

* For Finland, All Industrial Activities, not All Manufacturing Activities are considered.

In this, and subsequent tables in this part of the report, the count next to the arrows indicates the number of countries in which the number of units or employment increased (↑), did not change (=), and declined (↓) respectively.

These empirical facts do not, however, explain the phenomenon, so below we discuss some of the reasons that might be behind the emergence of Type IV industries.

- Information Technologies, Reduced Transaction Costs & Increased Outsourcing/Subcontracting: One explanation for the increase in number of small units within industries that are contracting in overall employment is the argument that in recent years large firms have been increasingly focused on their core competencies. This has meant that they have shut down or sold off many of their peripheral activities and now contract out areas of production that were formally undertaken in-house. This trend has been, to a large extent, facilitated by the information technologies revolution, which has lowered transaction costs and has increased the attraction of out-sourcing relative to in-house production (Brynjolfsson et al., 1994). It should, however, also be noted that this argument suggests these new small sub-contracting firms are dominated by their large principals and are economically marginal.

- Redundancy Push New Firms following the Contraction of Major Companies: With the contraction of large firms within high technology industries, many well qualified managers and technologists are released onto the labour market. Some of these individuals may start their own companies, perhaps out of a desire for economic independence, but perhaps also because of an inability to find work elsewhere within large established companies in contracting industries. These newly formed companies may operate in specialist niche markets and be highly profitable, but they may also be economically marginal sub-contractors which are dependent on the large established companies in the industry.

- Major Innovations: A third argument is that a major innovation, or set of innovations may present opportunities for new and small firms which the established large firms in the industry are unable of exploit. The classic example of this is the introduction of personal computers by new firms in the US which broke the hegemony of the established, mainframe dominated, computer makers. The emergence of biotechnology from within the pharmaceuticals sector is another example. Note, however, that major innovations do not always disrupt an industry; sometimes the established firms within the industry successfully adopt the innovation and continue to dominate the industry.

From the above, it is important to note that the emergence of Type IV industries, both within the high technology sectors and within manufacturing as a whole, may well have more to do with 'negative factors', especially the downsizing of large companies[18], than it has to with 'positive factors' such as the emergence of highly innovative smaller firms.

5. ANALYSIS OF FOUR SPECIFIC MANUFACTURING SECTORS

Having examined developments in the aggregate high technology manufacturing sector, we now briefly examine the evolution of four specific high technology manufacturing sectors. This analysis illustrates the differences which exist between industries in the evolution of high technology industries.

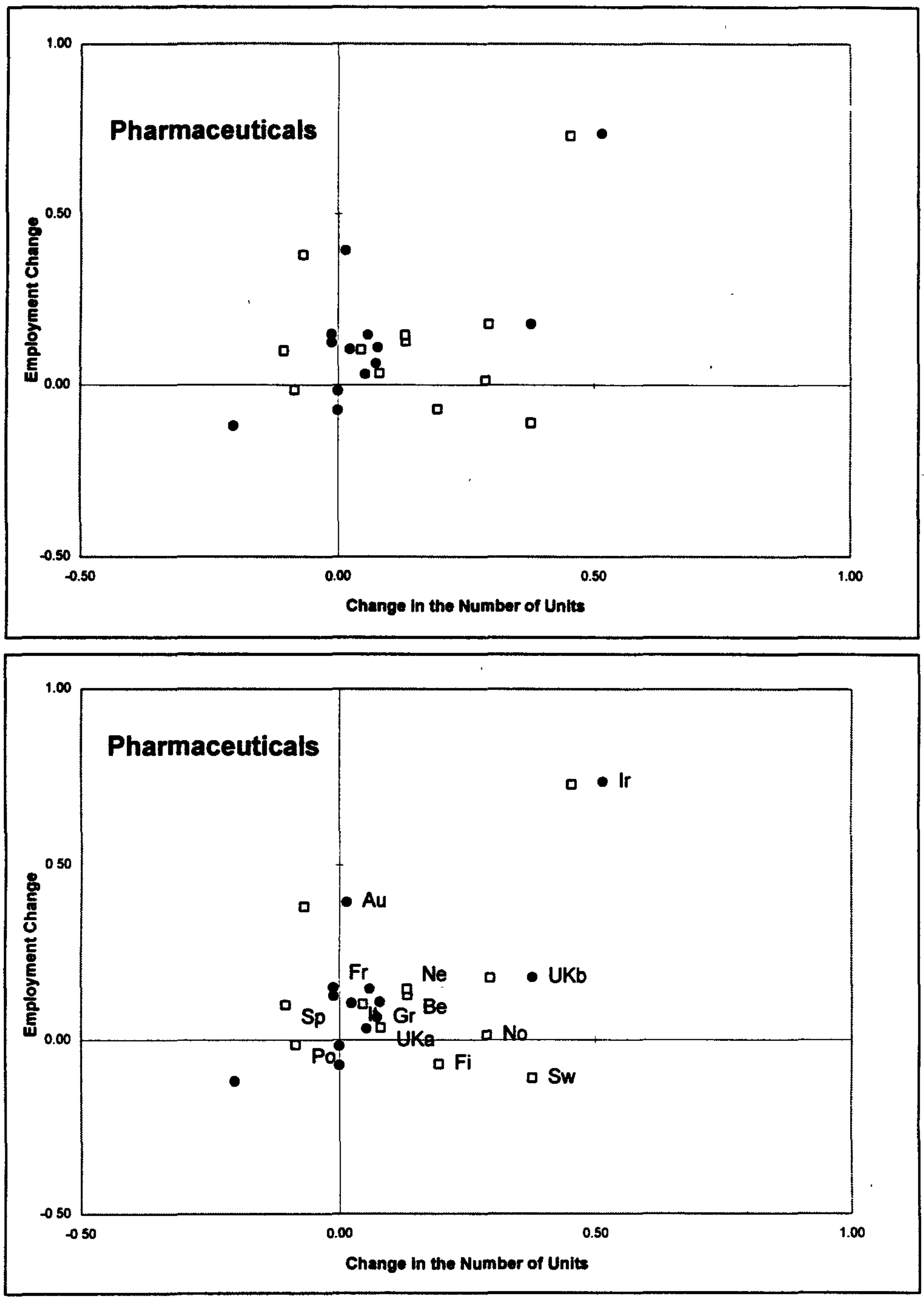
The industries which are examined are pharmaceuticals (NACE 70: 257), office equipment and computers (NACE 70: 330), electronics (NACE 70: 34) and instrumentation (NACE 70: 37). These industries have been chosen because they reflect different technological families and because of the different opportunities they present for new technology based firms.

Specifically, pharmaceuticals is 'science based' (Pavitt, 1984) and has traditionally been the preserve of large if not giant firms, but the recent emergence of biotechnology has provided new opportunities

[18] We consider the down-sizing of large companies to be a negative factor in terms of its impact on employment in the economy as a whole. Of course, within the individual firms, it may be considered necessary for efficiency and even survival.

for NTBFs. The office equipment and computer manufacturing sector, and the electronics sector, although also 'science based' and traditionally dominated by large firms, have seen tremendous growth and change over the last twenty years. These sectors have been centres of innovation and have provided many opportunities for new technology based firms. The instruments sector by contrast has traditionally been the preserve of small and medium sized, specialist supplier, firms (Pavitt, 1984).

Figure 2.8



5a. PHARMACEUTICALS[19]

In the majority of countries, the pharmaceuticals sector is dominated, in terms of employment, by large scale units[20], but medium sized units dominate the sector in both Austria and Spain and small units dominate in Greece. The importance of the pharmaceuticals sector in Europe varies from around 1% of manufacturing employment in Austria and Norway, to over 2% in France and over 3% in Ireland, but in most EU counties the sector accounts for around 1.5% of manufacturing employment.

In most countries the pharmaceuticals sector was Type I during the 1980s, but in both Austria and Spain, the sector was Type II (micro units included - □). This was also the case, with the micro units excluded, in Belgium and France.

Finland, Portugal and Sweden were the most exceptional countries. Finland and Sweden both experienced an increase in the number of pharmaceuticals firms (including the micro units - □), but a decrease in the sector's employment, thus making their pharmaceuticals sectors Type IV. In Portugal, the sector was Type III with the micro units included, and Type IV with the micro units excluded..

In general, with the exceptions of Ireland, Norway, Sweden and the UK, the change in the number of active units in the pharmaceuticals sector has been relatively small, which is probably a reflection of the high barriers to entry in the sector.

Table 2.5 Trends in the Pharmaceuticals Sector

On balance, the trend is for ...	Micro Units	Small-Medium Sized Units	Large Units	All Units, Incl. Micro	All Excl. Micro Units
The NUMBER of units to..	INCREASE ↑7, =1, ↓2	INCREASE ↑7, =3, ↓2	INCREASE ↑6, =2, ↓4	INCREASE ↑8, =0, ↓3	INCREASE ↑9, =2, ↓3
EMPLOYMENT to...	INCREASE ↑6, =2, ↓2	INCREASE ↑7, =1, ↓4	INCREASE ↑9, =0, ↓3	INCREASE ↑7, =1, ↓3	INCREASE ↑10, =1, ↓3
The AVERAGE UNIT'S EMPLOYMENT to ..				INCREASE ↑6, =1, ↓4	INCREASE ↑8, =1, ↓5
No Data	6	4	4	5	2

[19] Data on the pharmaceuticals sector was available in almost all countries, with West Germany and Luxembourg the two exceptions. For Germany, data on the pharmaceuticals sector are available from another source. However, the use of multiple sources is likely to lead to at least as much confusion as understanding. For this reason the data were not used.
[20] This is the case with Belgium, Finland, France, Ireland, Italy, the Netherlands, Norway, Sweden and the UK

5b. THE MANUFACTURE OF OFFICE EQUIPMENT AND COMPUTERS[21]

The office equipment and computing sector has been the focus of tremendous growth and innovation over the last twenty years, but despite this the office equipment and computer manufacturing sector remains fairly small in most European countries. In some, such as Austria, Belgium, Spain and the Netherlands, it accounts for less than half of one percent of all manufacturing employment. In others it is larger, accounting for around 1% of manufacturing employment in several countries, about 1.5% in France, Sweden and the UK, and an outstanding 4% in Ireland.

Although the office equipment and computer manufacturing sector is often thought of as a sector which attracts many new companies, across Europe, it tends to be dominated by large units[22]. Only in Austria, Belgium and Spain is the sector dominated by medium sized units, and in no country do small or micro units dominate.

However, the average size of manufacturing units in this sector has declined rapidly in most European countries. For example, in France, excluding the micro enterprises, the mean employment of office equipment and computer enterprises declined from over 1,000 in 1982 to about 350 in 1992, whilst in the UK, the average employment of enterprises in this sector fell from about 200 in 1980 to about 50 in 1990. This is indicative of the high degree of entry into this industry over the last decade[23], a period over which the level of net entry in terms of the number of units has been much greater than the level of net entry in terms of employment, which also increased in most countries[24].

Table 2.6 Trends in the Office Equipment and Computing Sector

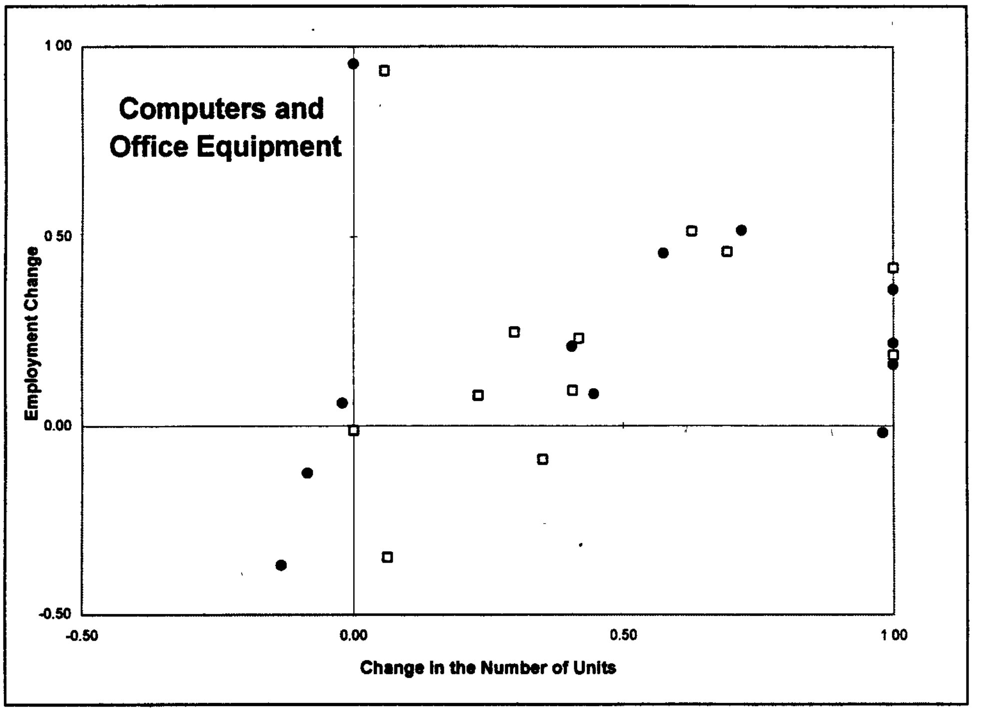
On balance, the trend is for ...	Micro Units	Small-Medium Sized Units	Large Units	All Units, Incl. Micro	All Excl. Micro Units
The NUMBER of units to..	INCREASE ↑9, =0, ↓2	INCREASE ↑8, =0, ↓4	INCREASE ↑9, =1, ↓2	INCREASE ↑8, =0, ↓3	INCREASE ↑9, =0, ↓3
EMPLOYMENT to...	INCREASE ↑11, =0, ↓0	INCREASE ↑9, = 0, ↓3	INCREASE ↑6, =0, ↓5*	INCREASE ↑10, =1, ↓0	INCREASE ↑8, =1, ↓3
The AVERAGE UNIT'S EMPLOYMENT to ..				DECREASE ↑1, =1, ↓9	DECREASE ↑2, =0, ↓10
No Data	5	4	4	5	4

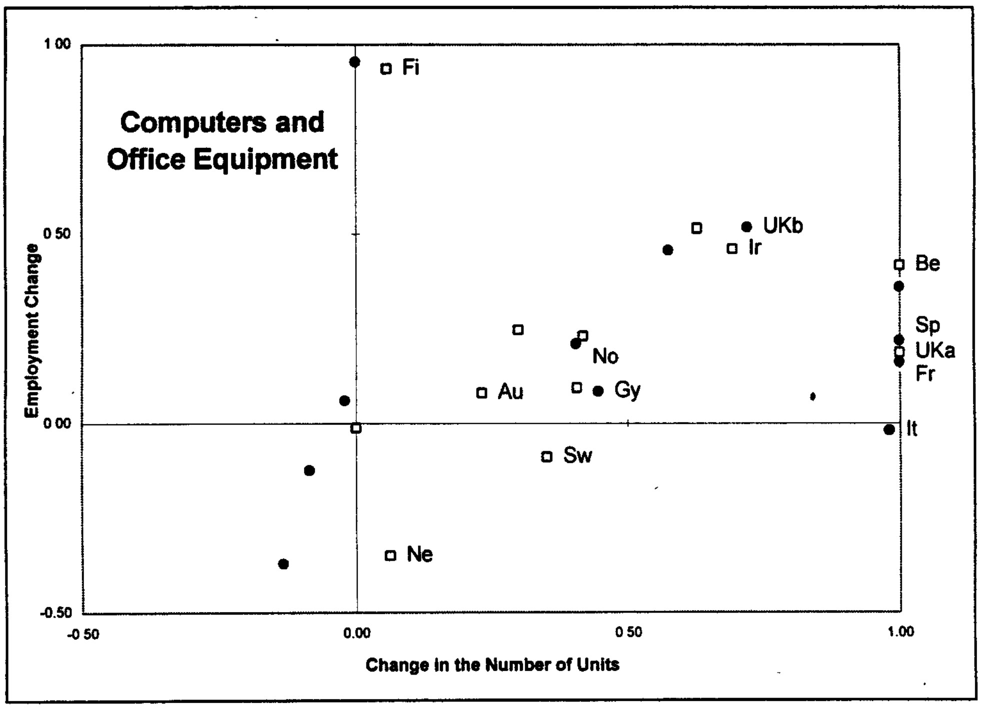
* For the UK, at the enterprise level there was a decrease, at the establishment level an increase,

[21] Data on the office equipment and computers sector was available in all countries except Denmark, Greece, Luxembourg and Portugal.
[22] This is the case in Finland, France, West Germany, Ireland, Italy, the Netherlands, Norway, Sweden and the UK.
[23] The sector expanded in terms of the number of active units in all countries except Italy.
[24] The exceptions being Italy, the Netherlands and Sweden.

Thus, as expected, in most countries the office equipment and computers sector was Type I in the 1980s. Only Italy (Type IV), Sweden (□ Type IV; ● Type III) and the Netherlands (□ Type IV; ● Type III) defy the trend.

Figure 2.9





5c. ELECTRONICS[25]

The electronics 'sector' as examined here is the combination of the individual three or four digit electronic sectors gathered from national data sources. The exact coverage therefore varies between countries, but broad comparisons can be made.

These 'electronics sectors' generally account for between 3 and 12% of manufacturing employment; that is, between a third and two thirds of all high technology manufacturing employment. These sector are dominated by large units, which have over half the sector's employment in all countries except Greece, Italy, Spain and the UK at the establishment level. In Italy and the UK (establishment level), large units have the largest share of electronics employment (over 40%), whilst in Spain medium sized units dominate employment with 47%. In Greece, no size classification dominates the sector.

Across Europe, the electronics sector was mainly Type I[26] or Type IV[27], but there were exceptions: Portugal, Spain and Sweden (□) were all Type III, as were Austria, Belgium and Greece when the micro units were excluded. Finland (□) was Type II (Figure 2.10).

Thus, in most countries, there was an increase in the number of units in the sector, whether or not micro units are included, but in most countries there was also a net reduction in employment, again, whether or not the micro units were included. Thus, in all countries except Austria, Finland, Greece (●) and Sweden (□), the average employment of units in the electronics sector has declined. This reduction was most extreme in the UK at the enterprise level, where the average employment of enterprises in the electronic sector was cut in half, from 130 in 1980 to 60 in 1990.

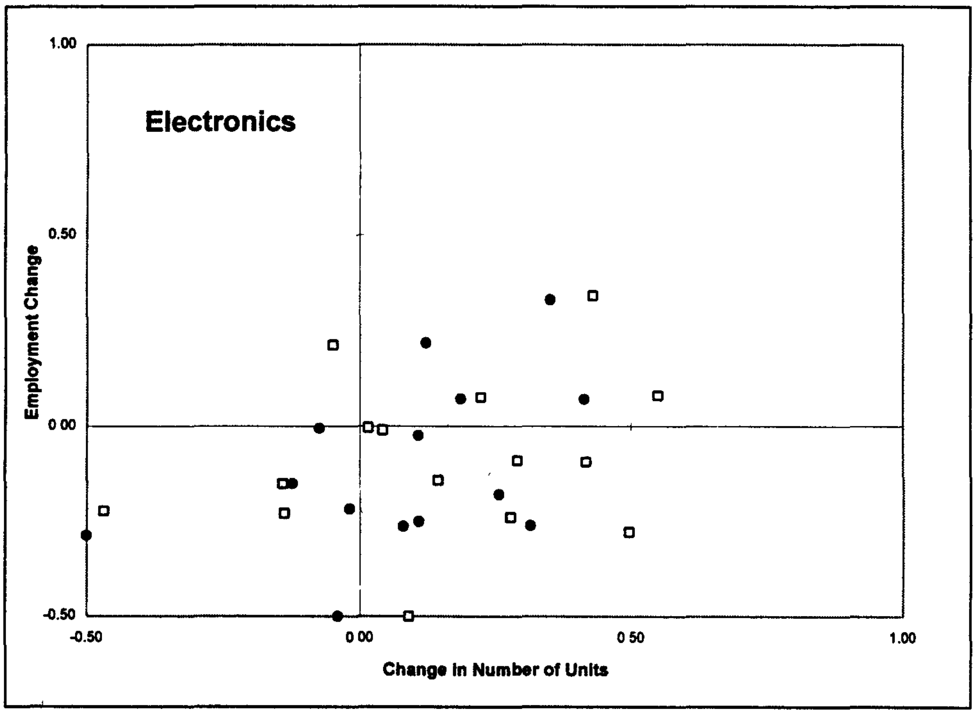
Table 2.7 Trends in the Electronics Sector

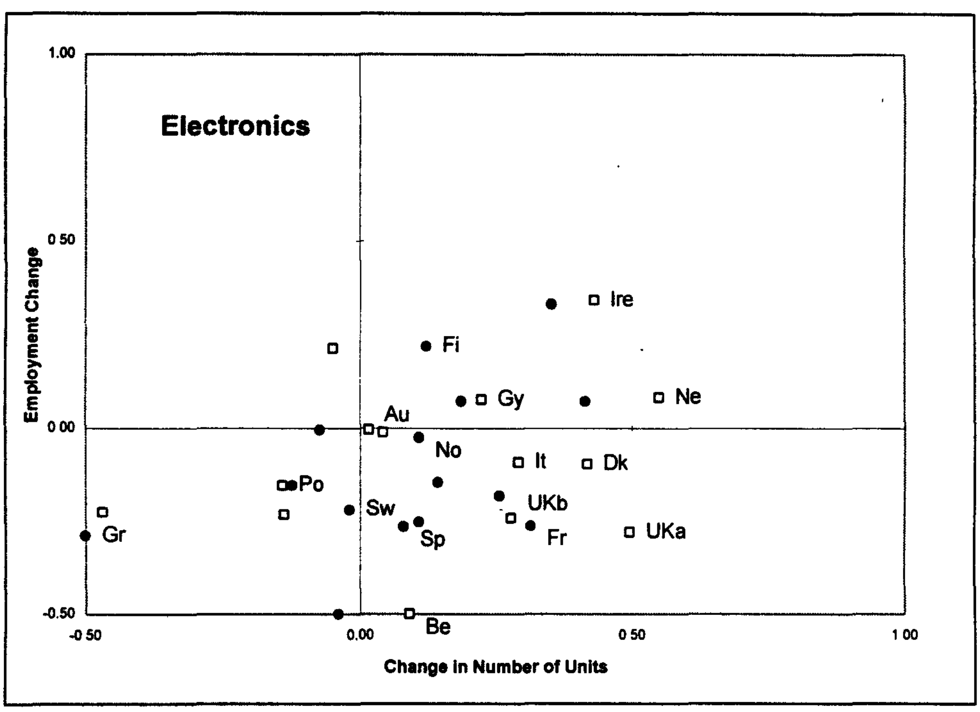
On balance, the trend is for...	Micro Units	Small-Medium Sized Units	Large Units	All Units, Incl. Micro	All Excl. Micro Units
The NUMBER of units to..	INCREASE ↑8, =1, ↓4	INCREASE ↑11, =0, ↓3	DECREASE ↑4, =2, ↓8	INCREASE ↑9, =0, ↓4	INCREASE ↑10, =0, ↓5
EMPLOYMENT to...	INCREASE ↑11, =0, ↓2	INCREASE ↑12, =0, ↓2	DECREASE ↑4, =0, ↓10	DECREASE ↑4, =1, ↓8	DECREASE ↑4, =1, ↓10
The trend is for the AVERAGE UNIT'S EMPLOYMENT to ..				DECREASE ↑2, =0, ↓11	DECREASE ↑3, =0, ↓12
No Data	3	2	2	3	1

[25] Data on the electronics sector was available in all countries except Luxembourg.
[26] Germany, Ireland, The Netherlands and, excluding the micro units, Finland.
[27] Austria, Belgium, Denmark, Italy, Norway, the UK and, excluding the micro units, France and Spain.

Table 2.7 shows that the general trend in the electronics sector was for the number of micro and small-medium sized units to increase, and for these to increase their employment, whilst the number of large units fell, reducing their employment, and the employment of the sector as a whole. Note that this contrasts with the pharmaceuticals and office equipment & computer manufacturing sectors, in which the general trend was for growth in all units size classifications.

Figure 2.10





5d. INSTRUMENTATION[28]

Like the electronics sector, the instruments sector as defined here varies between countries because it is formed by the combination of data under the individual 'instruments' classifications gathered from national sources. Thus defined, the instruments sector typically accounts for about 2% of manufacturing employment in European countries[29], but for less than 1% of all manufacturing employment in Austria, Belgium, Greece, Norway and Spain and, at the other extreme, around 4% of manufacturing employment in Ireland. Unlike the pharmaceuticals, electronics and office equipment & computer manufacturing sectors, the instrumentation sector is dominated by smaller units[30], although, with the exception of Italy, the dominance tends not to be by micro but by small[31], medium-sized[32] or small and medium-sized[33] units.

Figure 2.11 shows that, in all European countries except Greece and Portugal, the instruments sector was Type I[34] or Type IV[35] during the 1980s, the majority being Type I. In most European countries, the average employment of units in the sector declined, most steeply in Austria where the average employment of instruments sector establishments fell from 15 in 1981 to 9 in 1991, or, excluding the micro units, from 80 to 32. Only in Finland, Portugal, Sweden, Greece (●) and Ireland (□) did average unit size increase.

Table 2.8 Trends in the Instruments Sector

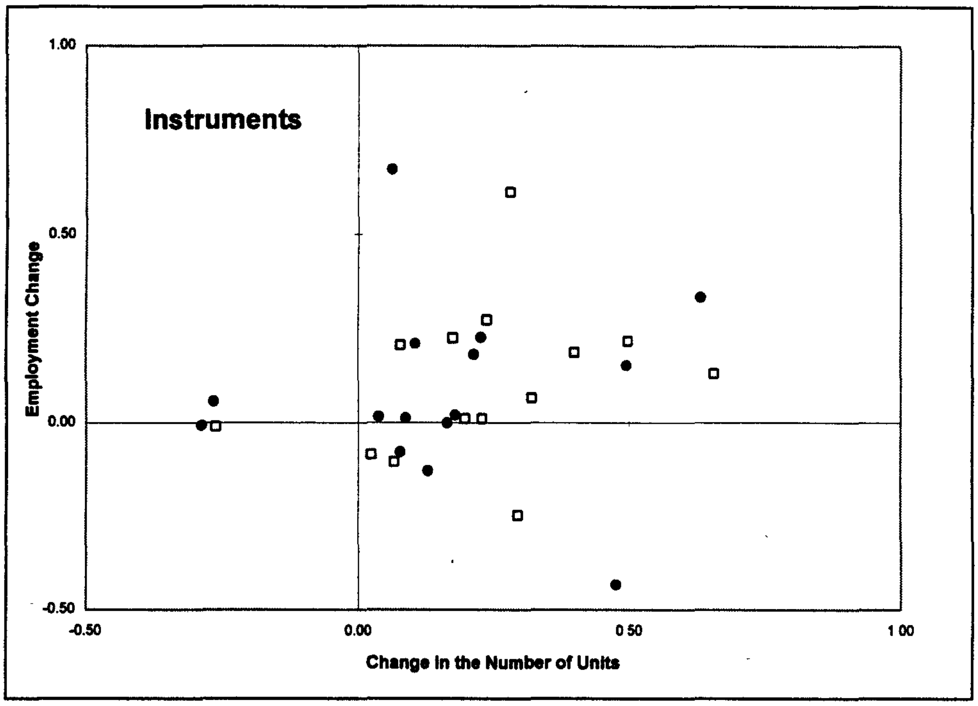
On balance, the trend is for...	Micro Units	Small-Medium Sized Units	Large Units	All Units, Incl. Micro	All Excl. Micro Units
The NUMBER of units to..	INCREASE ↑12, =0, ↓1	INCREASE ↑12, =1, ↓1	DECREASE ↑5, =1, ↓8	INCREASE ↑12, =0, ↓1	INCREASE ↑11, =0, ↓2
EMPLOYMENT to...	INCREASE ↑11, =0, ↓2	INCREASE ↑9, =0, ↓5	DECREASE ↑5, =0, ↓9	INCREASE ↑9, =1, ↓3	INCREASE ↑10, =2, ↓3
The trend is for the AVERAGE UNIT'S EMPLOYMENT to ..				DECREASE ↑5, =0, ↓8	DECREASE ↑4, =1, ↓10
No Data	3	2	2	3	1

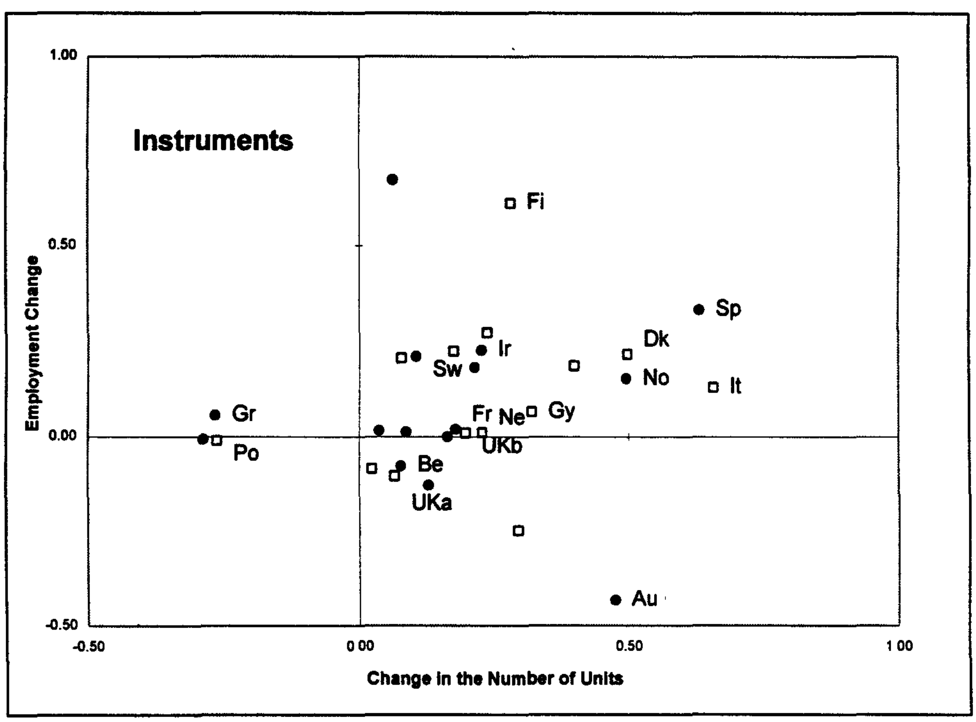
Table 2.8 shows that the general trend in the instruments sector was similar to the electronics sector: the number of micro and small-medium sized units increased, and increased their employment, whilst the number of large units fell and reduced their employment, but in this case the contraction of large

[28] Data on the instruments manufacturing sector was provided for all countries except Luxembourg.
[29] For example, Denmark, Finland, France, West Germany, Italy, the Netherlands, Sweden and the UK
[30] An exception is Denmark, where the sector is dominated by large (100+ employee) establishments.
[31] Greece, the Netherlands, Norway and the UK at the establishment level.
[32] Belgium, Finland, and France.
[33] Austria, Spain and the UK at the enterprise level.
[34] Denmark, Finland, West Germany, Ireland, Italy, Norway, Spain and Sweden, but only marginally in France, the Netherlands and the UK at the establishment level.
[35] Austria, Belgium, and the UK at the enterprise level.

units did not reduce the employment of the sector as a whole. Thus the instruments sector also contrasts with the pharmaceuticals and office equipment & computer manufacturing sectors, in which growth was generally in all size classifications.

Figure 2.11





6. THE AGGREGATE HIGH TECHNOLOGY SERVICE SECTOR

The data gathered on the high technology service sectors was much less comprehensive than for the manufacturing sector, with many countries unable to provide any data.

Nevertheless, amongst countries that provided data[36], there was a universal trend that the aggregate number of units in high technology service sector activities increased, and the aggregate employment of high technology services increased. Thus universally, the aggregate high technology service sector (AHTSS) in European countries was Type I in the 1980s.

7. THE DEVELOPMENT OF THREE SPECIFIC HIGH TECHNOLOGY SERVICE SECTORS

The aggregate high technology service sector is composed of four activities: telecommunications, computer services, research and development services and technical services. The first of these is dominated by large units, usually the national telecommunications company. Although there has been some entry into this sector in terms of the number of units, we concentrate on the other three sectors as these are more relevant to the new technology based firms phenomenon.

Because, unlike the manufacturing sectors, employment in these sectors tends to be dominated by micro and small units, separate analysis is not undertaken with the micro units excluded. Furthermore, because relatively few data points are available, only one annotated figure per sector is presented.

7a. COMPUTER SERVICES[37]

Computer services have been a centre of dramatic growth over the 1980s and, in all countries that provided data, the sector was Type I, growing rapidly in terms of the number of active units and in terms of the sector's employment.

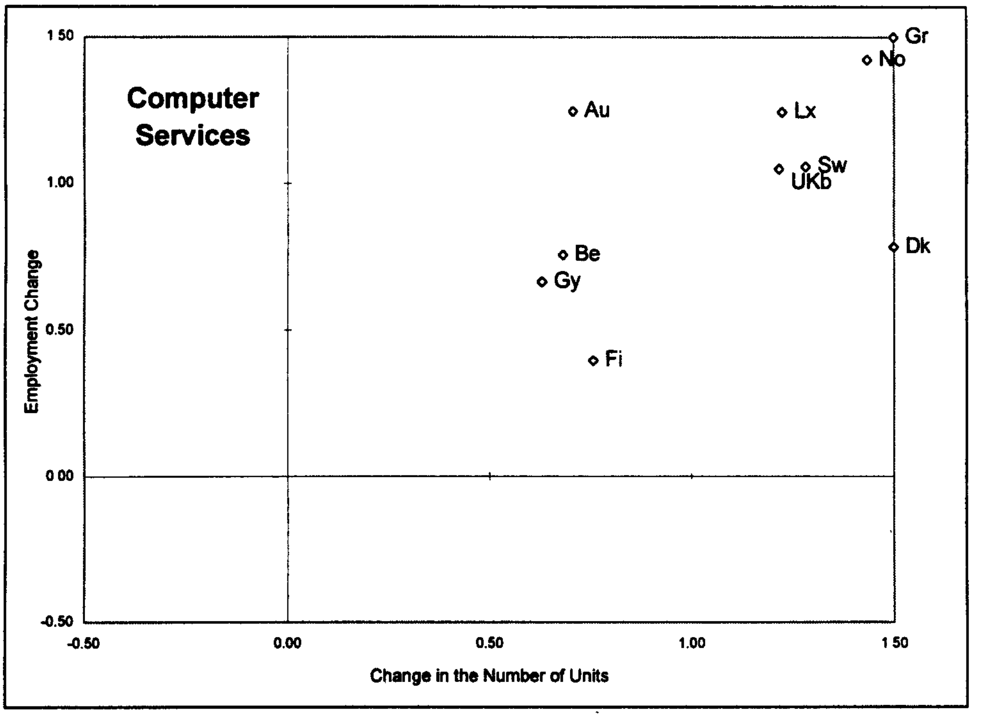
By the beginning of the 1990s, computer services generally accounted for about 1% of all employment in European countries; in the early 1980s their share was generally less than half of one percent. The sector is dominated by smaller units, with small, medium-sized and/or micro units providing the great majority of the employment in the sector. However, growth over the last decade has generally been 'across the board', with micro, small-medium sized, and large units all increasing their number and

[36] Some high tech. service sector data were provided for all countries except France, Ireland, Norway, Portugal and Spain

[37] Data on the computer service sector for Denmark, Finland, Luxembourg, the Netherlands, Sweden and, the establishment level, the UK. Data was also provided on the 'information technology' sector for West Germany, which includes telecommunications with the computer services, and the data provided from Austria and Belgium also includes other business services and is not confined to computer services.

their employment. The average unit size increased in Austria, decreased in Denmark, Finland, Sweden and the UK, and remained constant in Belgium, West Germany, Luxembourg and Norway.

Figure 2.12



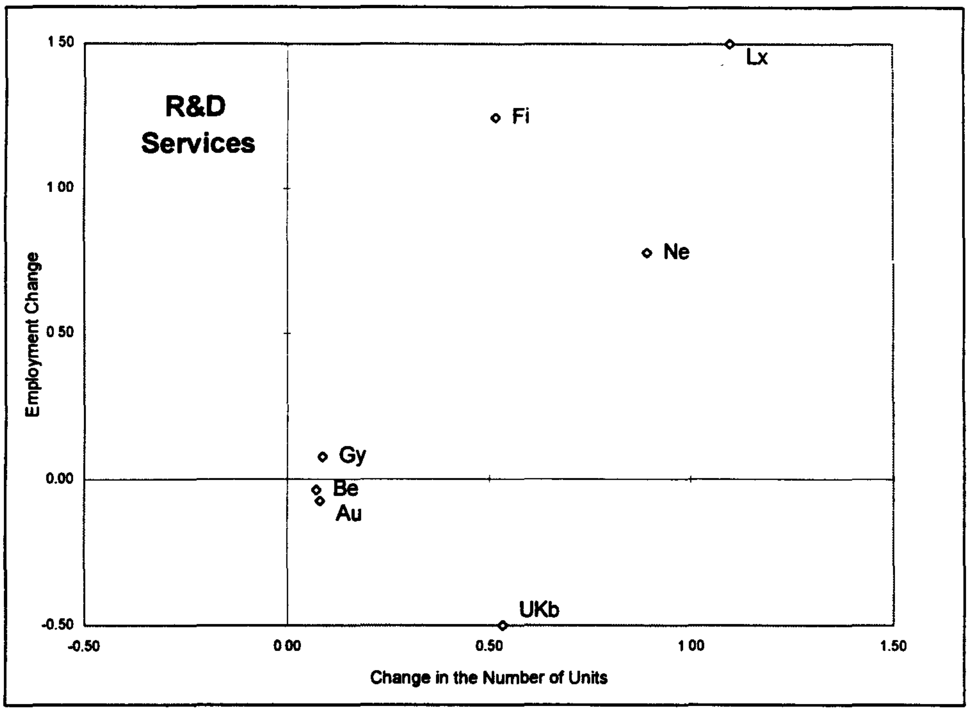
7b. RESEARCH AND DEVELOPMENT[38]

Across Europe, the number of units active in the provision of research and development services increased in all countries which provided data, but there was a division between those countries in which R&D employment increased[39] and those countries in which R&D employment decreased[40]. Thus the R&D sector was either Type I or Type IV during the 1980s.

It is notable that those countries in which R&D employment increased are generally those in which there was employment growth in the aggregate high technology manufacturing sector[41], whilst two of the three countries to experience a contraction of their aggregate high technology manufacturing sectors also experienced a contraction of their R&D employment[42]. This demonstrates the close link between high technology manufacturing, especially in large units, and R&D employment. Only Austria and Italy defy this trend; in Austria employment in the aggregate high technology manufacturing sector increased, but employment in R&D decreased, whilst in Italy the trends were exactly the opposite.

[38] Data on the research and development units was provided for Austria, Belgium, Finland, West Germany, Italy, Luxembourg, the Netherlands and, at the establishment level, the UK.
[39] Finland, West Germany, Italy, Luxembourg and the Netherlands
[40] Austria, Belgium and the UK
[41] West Germany, Finland, Luxembourg and the Netherlands.
[42] Belgium and the UK.

Figure 2.13



In all the countries in which R&D employment increased, growth was generally across all units size classifications, and there was no clear pattern with regard to the change in average unit employment. In most countries a much greater share of R&D employment is in larger units than is typical in service sectors generally, or in other high technology service sectors, such as computer or technical services.

7c. TECHNICAL SERVICES[43]

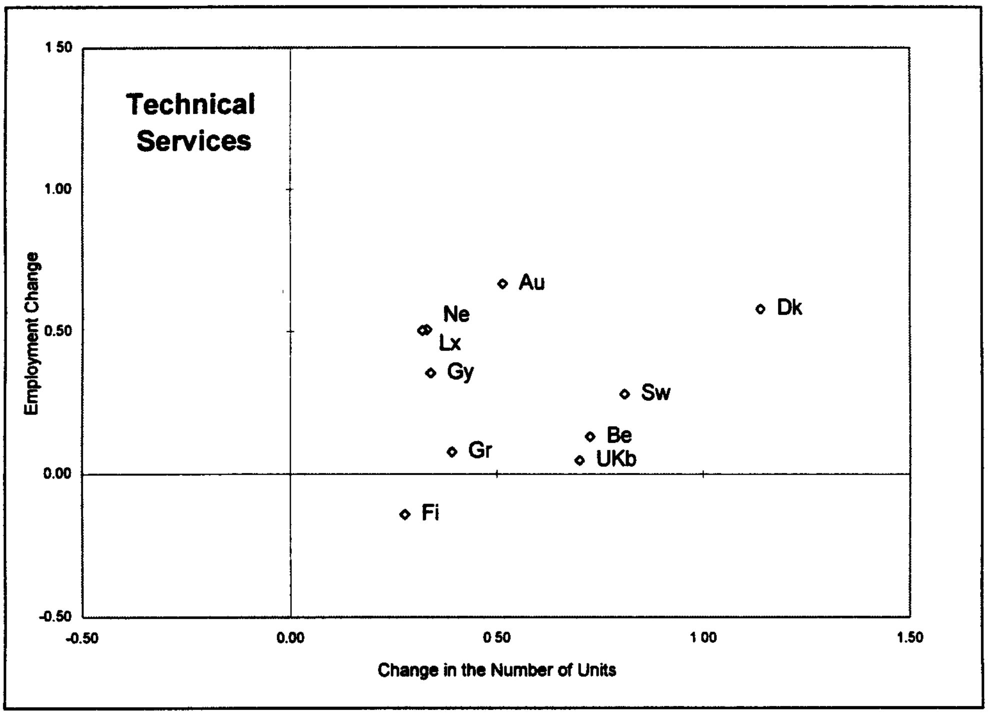
Amongst the countries that provided data, the universal trend was for an increase in the number of units active in the provision of technical services. Furthermore, with the single exception of Finland, employment in the sector also increased. Thus, in all countries except Finland, technical services was a Type I sector, whilst it was Type IV in Finland.

Technical services are generally dominated by small and/or micro units, and in all countries except Denmark[44] these provide well over half the employment in the sector. With regard to average unit size, there was a general trend towards smaller units, with the number of units growing more rapidly than employment in Belgium, Denmark, Greece, Italy, Sweden and the UK, but average units size remained static in West Germany, and increased in Austria, Luxembourg and the Netherlands.

[43] Data on various technical services were provided for all countries except France, Ireland, Norway, Portugal and Spain.
[44] Where they account for 45% of the sectors employment.

In all the countries that provided data, there was an increase in the number of micro units in the technical services sector, and in all these countries these micro units increased their employment. In seven out of ten countries, the number of small-medium units increased, as did their employment, whilst in only five countries did the number of large units (and their employment) increase, with the number of large units in technical services (and their employment) declining in four other countries, and remaining stable in the last.

Figure 2.14



8. AN ANALYSIS OF THE DEVELOPMENT OF THE HIGH TECHNOLOGY SECTORS ON A COUNTRY BY COUNTRY BASIS

We now assess the development of the various high technology industries in individual European countries. We do this in two ways. First there will be a general discussion of the similarities and differences between countries, and second, the development of the high technology sectors in each country is assessed through the graphs presented on the following pages. To these graphs, we have attached a brief commentary for each country. This report does not discuss the development of the various high technology sectors in each country in great detail.

From the analysis undertaken above, we know there were differences between sectors in their position on the Framework for Analysis, but were there also differences between countries? Did the high technology sectors in some countries behave as the *a priori* model suggests, whilst in others the sectors defied the model's expectation? We now assess this question.

The figures which follow show the differences between countries in the evolution of the high technology sectors. At one extreme, there is West Germany where the high technology sectors were all Type I, exactly as the *a priori* model predicted. At the other extreme, there is the UK (at the enterprise level between 1980 and 1990) where almost all the high technology manufacturing sectors were Type IV. Although the high technology service sectors are not shown for the UK at the enterprise level, and these would have been Type I (with the exception of R&D), there is a clear difference between the UK and West Germany in the development of the high technology sectors.

In the UK, there has been an evolution towards smaller units through an increased number of units but a contraction in the number and employment of large units, whilst in West Germany, large units in these sectors continue to expand. Generally in West Germany there was been an increase in the number of units active in the high technology sectors, with small and micro units entering the various sectors, this has not been associated with a contraction of large units and employment loss from these as has clearly been the case in the UK[45].

It is important to remember at this point, that the emergence of a large number of smaller units, especially in Type IV as opposed to Type I industries, may have more to do with 'negative factors' than it has to do with 'positive factors'.

Most other countries lie between the extremes of West Germany and the UK. Austria, Denmark, Finland, Ireland, Luxembourg, The Netherlands and Norway were all similar to West Germany in that their aggregate high technology manufacturing sectors were Type I, and the majority of the component high technology manufacturing sectors were Type I. Belgium and France were closer to the UK in that their aggregate high technology manufacturing sector were Type IV, and many of their component high technology manufacturing sectors were also Type IV. Italy lies between the two groups.

The distribution of high technology activities in three other countries deserve note. Portugal, Spain and Sweden were unusual in that their aggregate high technology manufacturing sectors were Type III. For all three countries, this was true with the micro units are included in the analysis - that is, the number of units active in high technology manufacturing has decreased, as has employment in high technology manufacturing sectors. However, in Spain and Sweden, the number of non-micro units has increased and, excluding the micro units, the aggregate high technology manufacturing sector is Type IV. In Portugal, the number of non-micro units has decreased, so with high technology manufacturing sectors remained Type III when the micro units were excluded.

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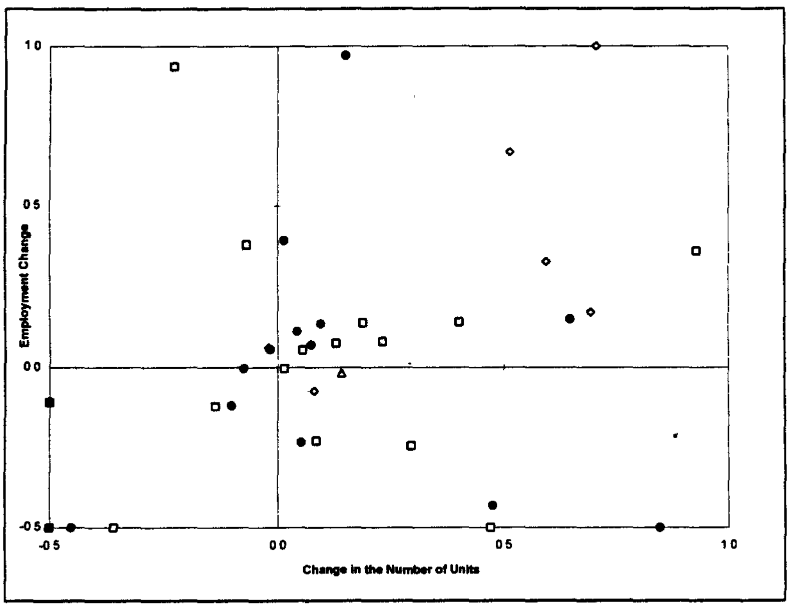
[45] It should be noted that the timing of the analysis is more favourable to West Germany than to the UK. Manufacturing industry as a whole in the UK was severely affected by the recession in the early 1980s, and the effects of this are found in the analysis of the UK data. West German industry was, on the other hand, hit by the recession which occurred in the early 1990s after the reunification of Germany. The analysis of the German data does not include that period, during which some of the industries became Type III or Type IV. However, it is unlikely that all of the difference between Germany and the UK is explained by the timing of the analysis.

Figures 2.15

Notes on Symbology and the Dispersion of Industries

In the graphs of the following pages, manufacturing sectors which include the micro units are identified by the symbol □, manufacturing sectors which exclude the micro units are identified by the symbol ●, service sectors (which include micro units) are identified by diamonds, and all activities by triangles. Note also that the graphs which follow use a standard set-up, but that the dispersion of industries varies widely between countries. This is partially a reflection of the different sizes of the countries analysed and partially a reflection of the level of aggregation at which data was provided. Generally, the smaller the country and/or the more disaggregated the data, the greater the expected dispersion of industries, because, within each industry, relatively small absolute changes in the number of units and/or employment will have a greater relative impact on the position of that industry than in large countries or in highly aggregated industrial sectors.

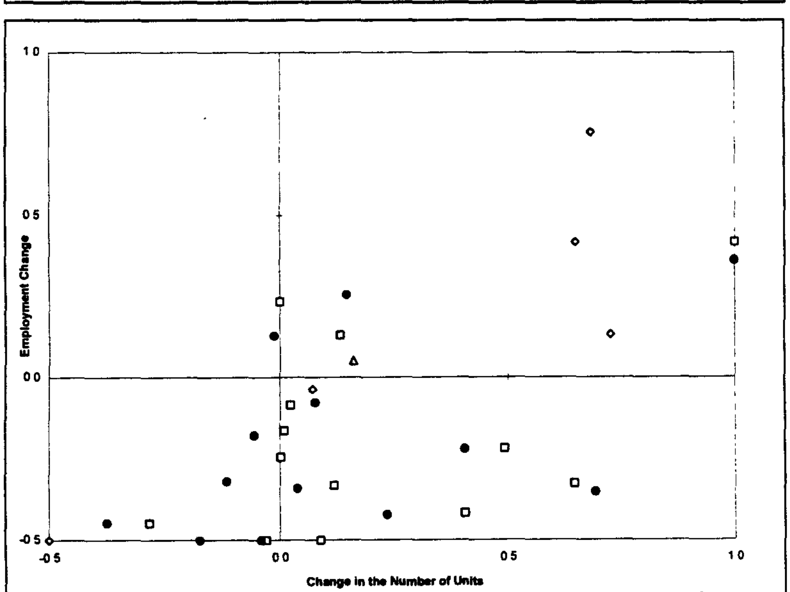


Austria

- Establishments 1981 & 1991

Although dispersed, the high technology sectors in Austria were mainly Type I. This was true of the AHTMS and for all the service sectors apart from R&D (Type IV).

In most sectors, with the micro units included, average unit size fell, but excluding the micro units, average units size remained little changed

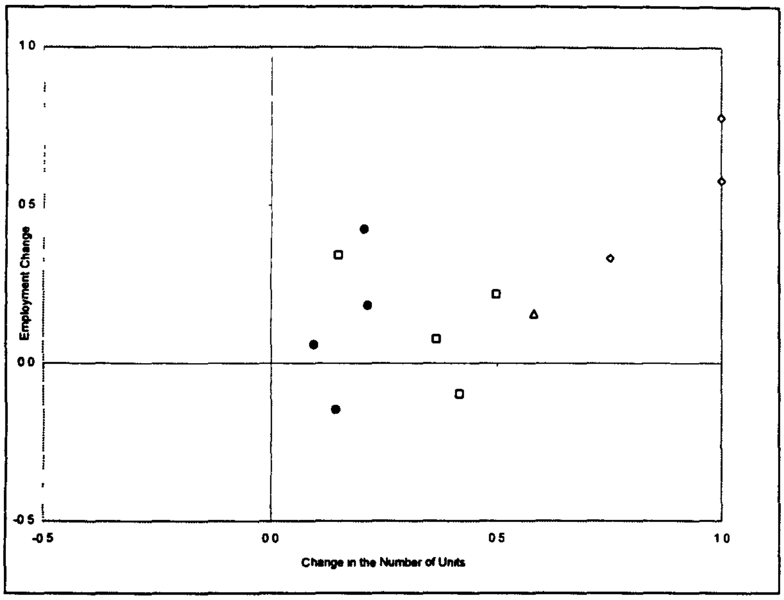


Belgium

- Establishments, 1980 & 1990

Most high technology manufacturing sectors in Belgium were Type IV. This was true of the AHTMS, Electronics and Instruments. The service sectors were mainly Type I.

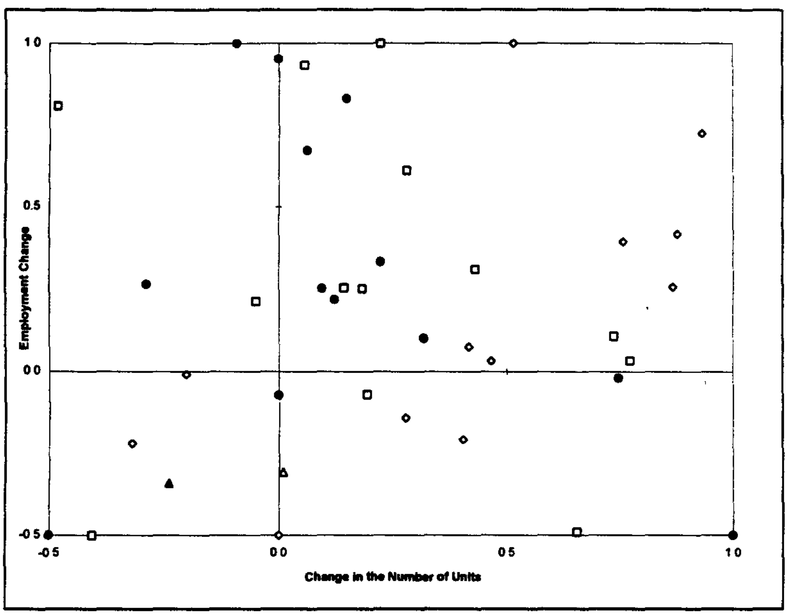
In almost all sectors, whether the micro units are included or not, the average employment of units fell.



Denmark

- Establishments 1983 & 1992

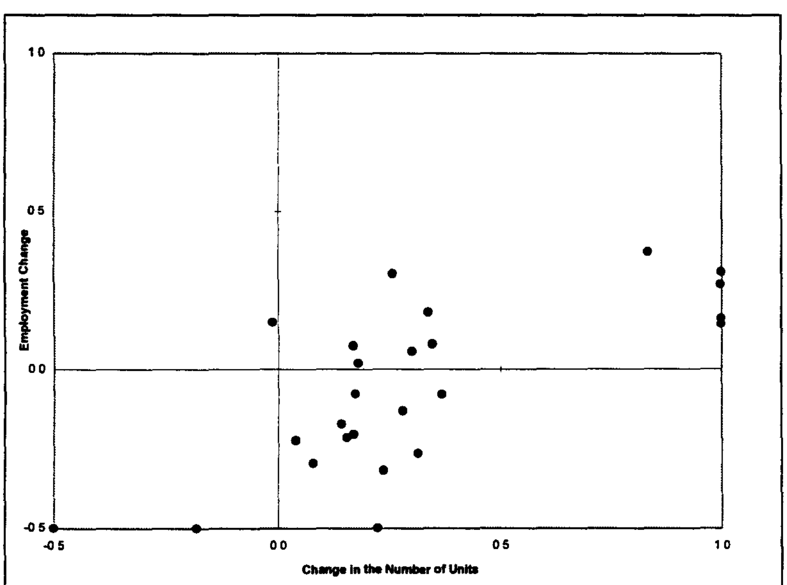
In Denmark as elsewhere, the high technology service sectors were Type I in the 1980s. But in Denmark, most of the high tech. manufacturing sectors were also Type I - both the number of units and employment increased. Only the electronics sector was not Type I. This was Type IV - the number of units increased, but employment fell.



Finland

- Firms, 1986 & 1993

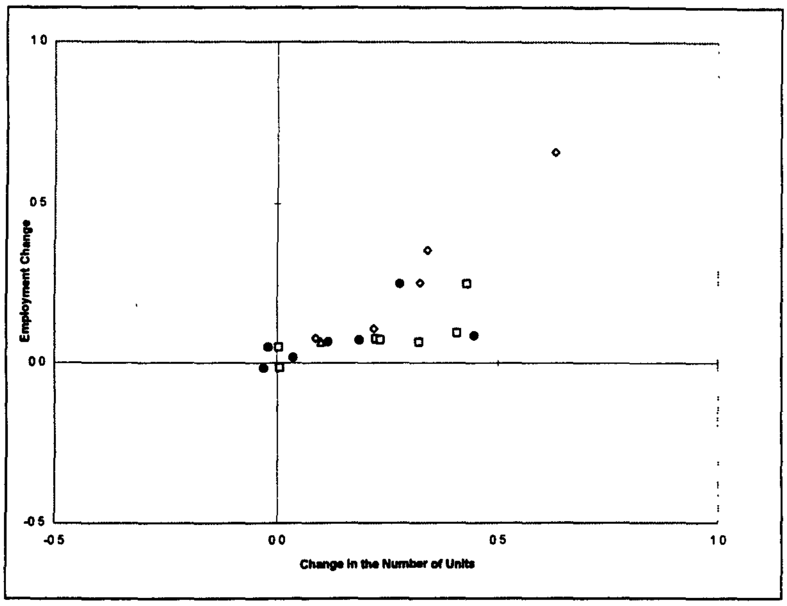
Although widely dispersed, the high technology sectors in Finland were mainly Type I. This was true of the AHTMS and for all the services except Technical Services (Type IV). With the micro units included, there was no trend in average unit size, with these excluded, average unit size increased in most manufacturing sectors.



France

- Firms, 1982 & 1992

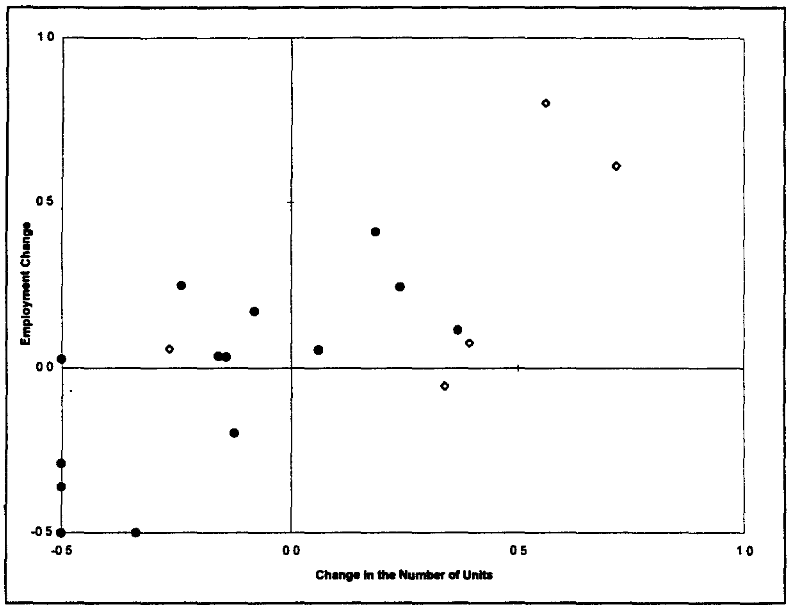
The French data is confined to manufacturing and there is no data on micro units. Most sectors were either Type I (office equipment & computers, instruments) or Type IV. (AHTMS, electronics). In only three sectors, did the number of units decline. In almost all sectors, average firm size declined.



West Germany

- Establishments, 1980 & 1990

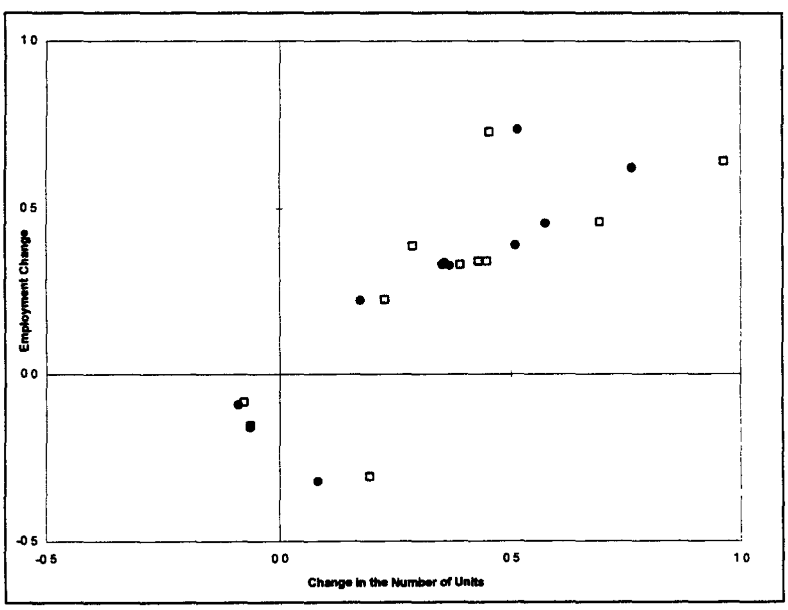
Type I industries prevail amongst the high technology sectors of Germany All except chemicals have grown in terms of the number of units and their employment, whilst all manufacturing has contracted slightly. In most high tech. sectors, growth in terms of units has been greater than employment growth. Thus, average unit size has declined.



Greece

- Manufacturing Plants, '80 & '92
- Service Establishments, '78, '88

The Greek data are not derived from proper cross sections of industry and are therefore unreliable in this analysis. However, the data show the high technology manufacturing sectors in Greece to be Types I, II and III, whilst the high tech. service sectors are mainly Type I.

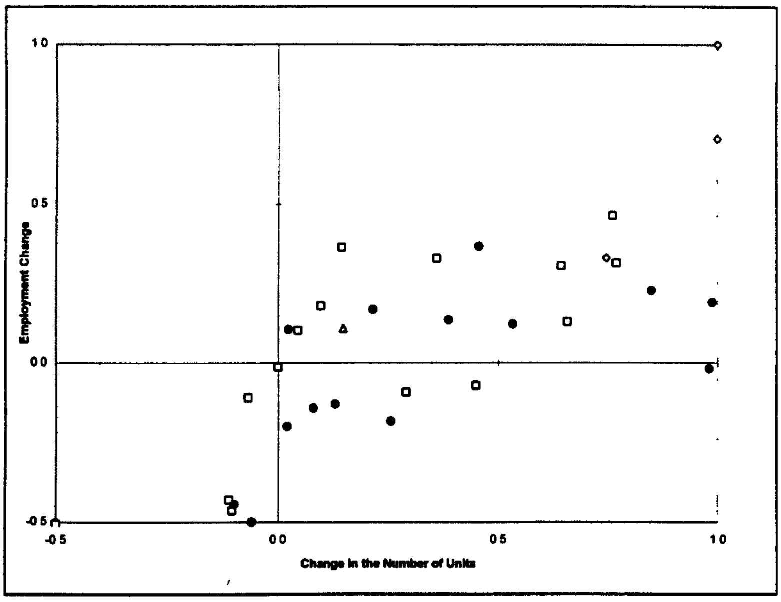


Ireland

- Establishments, 1980 & 1990

The Irish data only covers manufacturing, but shows almost all the high technology sectors were Type I. All manufacturing sectors combined were Type III.

Ireland appears unusual in that, whether or not the micro's are included, in most sectors, average unit size declined only marginally.

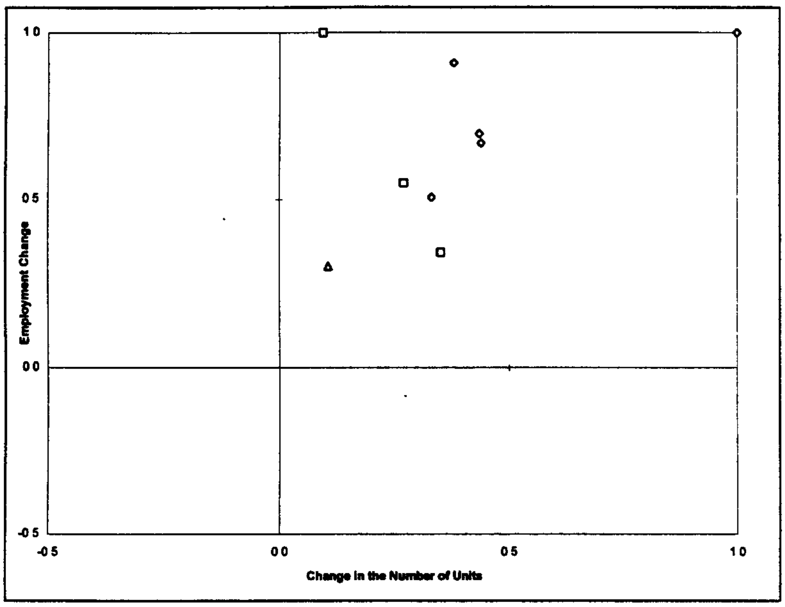


Italy

- Enterprises, 1981 & 1991

Most high technology sectors in Italy were Type I (Pharmaceuticals, Instruments and high tech services) or Type IV (AHTMS, Office Equip. & Computers, Electronics).

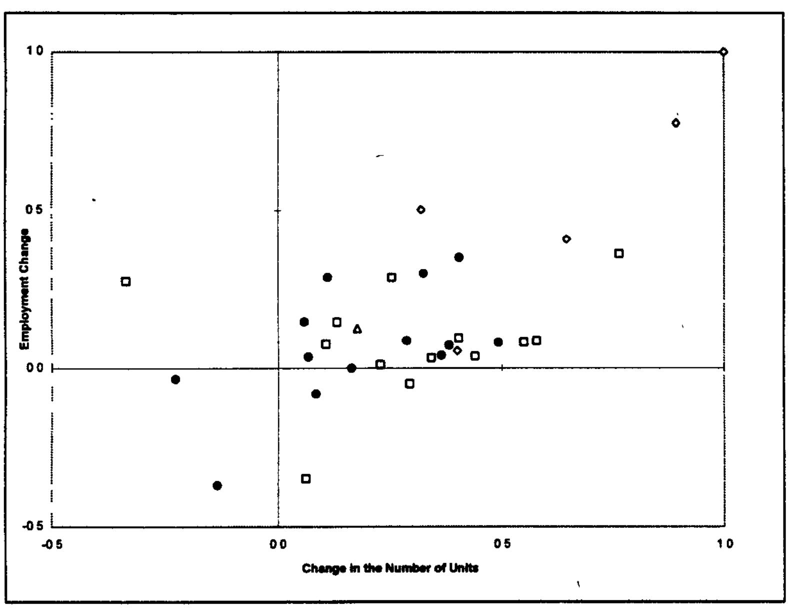
Average unit size declined in most sectors. This is especially so when the micro units are excluded.



Luxembourg

- Enterprises, 1984 & 1990

In Luxembourg, all the high technology sectors were Type I, and in most of these sectors employment growth has exceeded the growth in the number of units, so in most sectors, average unit size has increased.

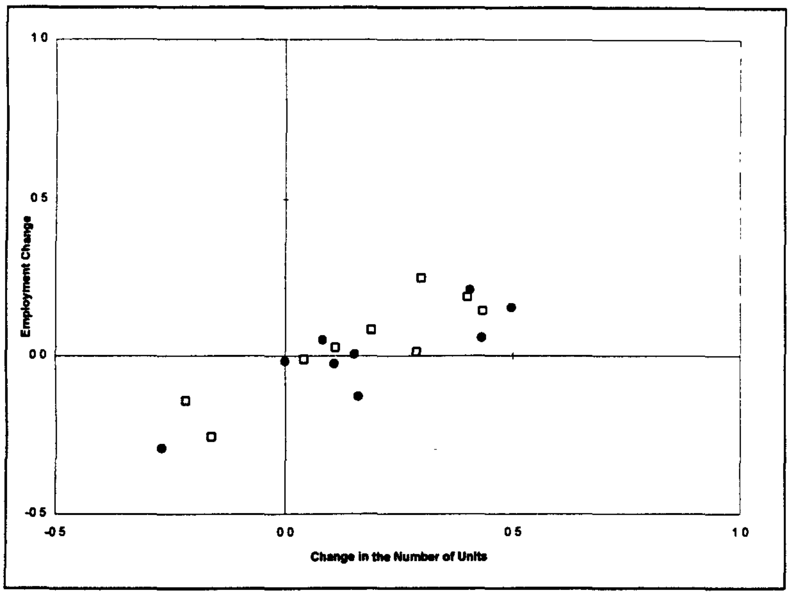


The Netherlands

- Firms, 1983 & 1990

In the Netherlands, the high technology services sectors were all Type I and the manufacturing sectors were predominantly Type I (the Office Equipment and Computer manufacture being a notable exception).

In most sectors, average unit employment declined.

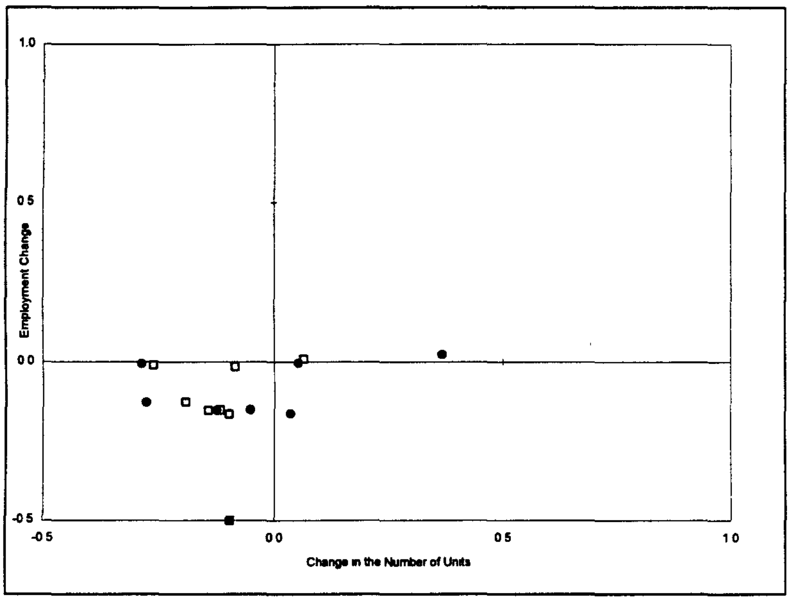


Norway

- Firms, 1980 & 1990

The Norwegian data relate only to manufacturing, but show most of the high technology sectors were Type I (although. Electronics was Type IV). This contrasts with all manufacturing which was Type III.

In almost all the sectors, average unit employment declined.

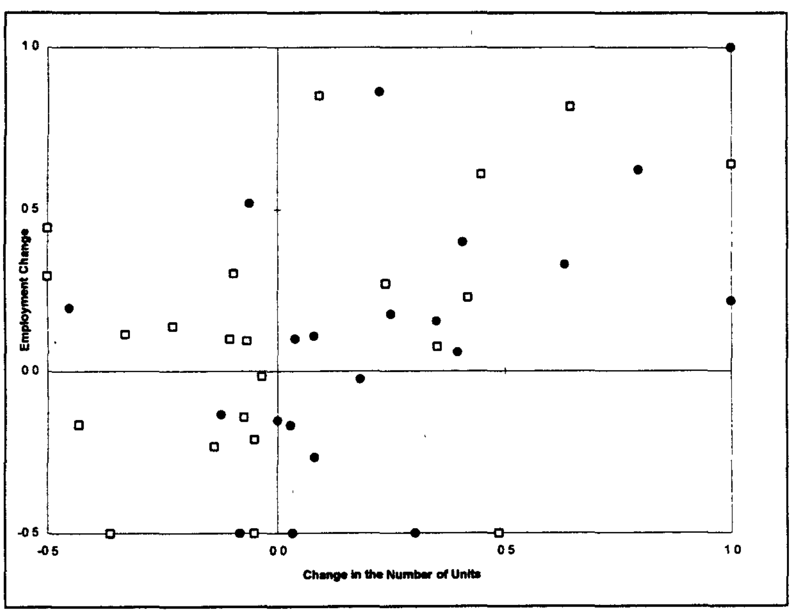


Portugal

- Establishments 1982 & 1989

In Portugal, most of the high technology manufacturing sectors have been Type III during the 1980s. Portugal, like Spain and Sweden, is unusual in this respect.

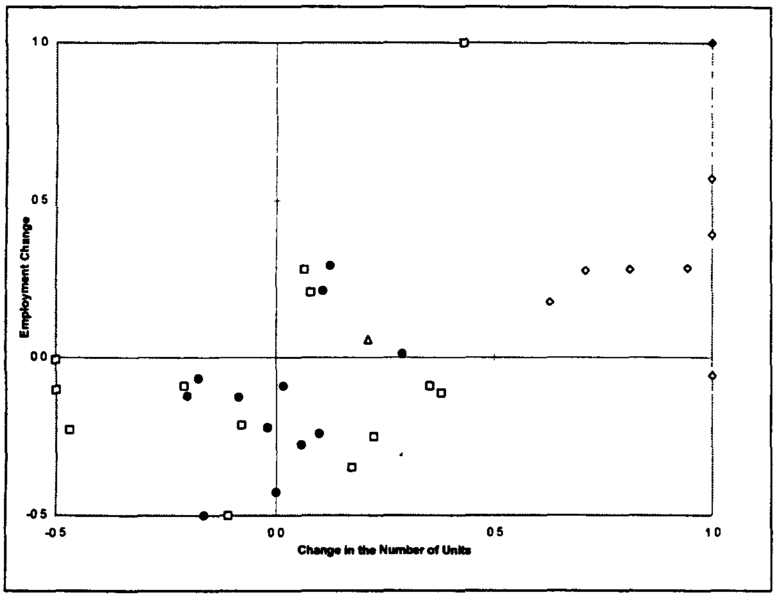
However, unlike Spain and Sweden the high technology industries were remained Type III when the micro units were excluded.



Spain

- Establishments, 1982 & 1992

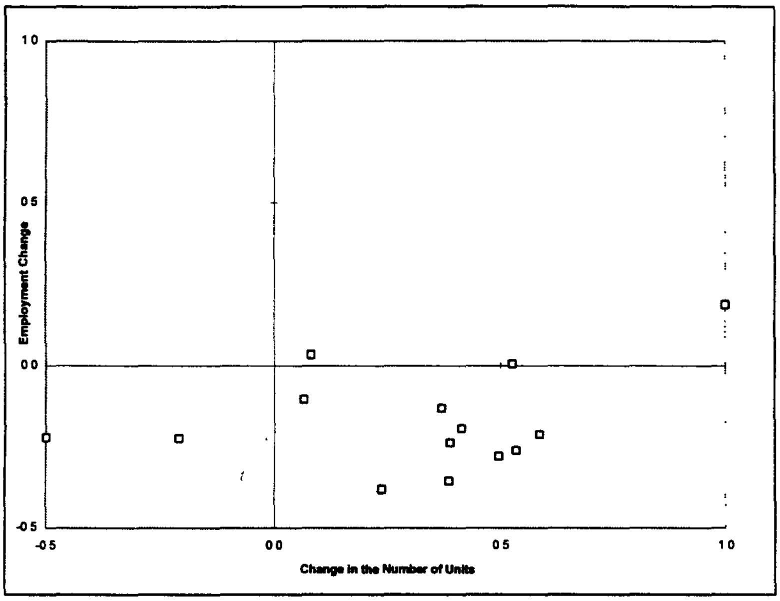
The data for Spain only relate to manufacturing. Spain is unusual in that there were many Type II and Type III high technology manufacturing sectors - that is, sectors in which the number of active units declined. There were however, also several Type I sectors and, when the micro units are removed, some Type IV sectors.



Sweden

- Firms, 1984 & 1993

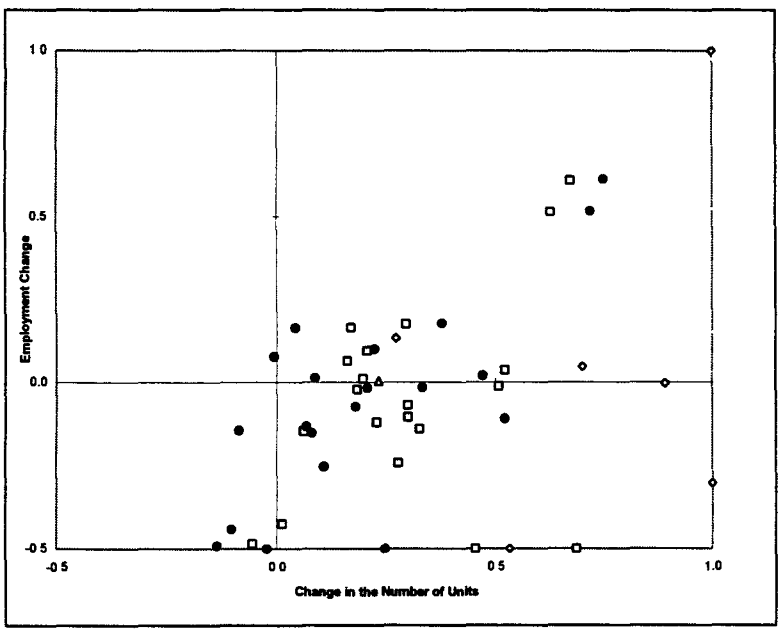
In Sweden, the high technology service sectors were mainly Type I, but the high tech. manufacturing sectors were predominantly Types III or IV. Sweden is unusual in having experienced a net reduction in the number of manufacturing units in its aggregate high technology manufacturing sector as well as in the manufacturing sector as a whole.



UKa

- Enterprises, 1980 & 1990

The UK enterprise data are restricted to manufacturing. They show that between 1980 and 1990 employment in almost all the high technology manufacturing sectors declined, but that the number of enterprises in these sectors increased. In the UK, most high technology manufacturing sectors were therefore Type IV: the average employment of units fell.



UKb

- Establishments, 1985 & 1994

Between 1985 and 1994, however, the establishment level data for the UK shows most of the high technology manufacturing sectors were either Type I or Type IV. This shows how timing can affect the analysis, but, as for enterprises between 1980 and 1990, the AHTMS was Type IV and in almost all the sectors average unit size declined.

9. SUMMARY AND CONCLUSIONS

In this section, we draw out some of the main findings from the analysis in this part of the report.

The High Technology Manufacturing Sectors of Europe

- In Europe, high technology manufacturing units generally account for less than 10% of all manufacturing units.
- Generally these units account for a larger share of manufacturing employment (usually between 10 and 20% of manufacturing employment).
- Thus, high technology manufacturing industries tend to be dominated by larger units.
- Across Europe, the general trend is that large scale units generally account for over half of all employment in the aggregate high technology manufacturing sector.
- In most European countries, the average employment of both high technology manufacturing and all manufacturing units have declined, but, on average, high technology manufacturing sector units still employ about twice as many people as the manufacturing units in all sectors.
- In most European countries the aggregate high technology manufacturing sector was either Type I or Type IV. That is, in almost all the European countries, the number of units active in the aggregate high technology manufacturing sector increased, but whilst in some the employment of the sector also increased (Type I), in others the employment of the sector decreased (Type IV).
- In general, the trend in the aggregate high technology manufacturing sector was that micro and small-medium sized units increased in number, and so increased their total employment, whilst large units declined in number and cut their employment.

Comparison with Developments in All Manufacturing Activities

- In marked contrast to the aggregate high technology manufacturing sector, the aggregate manufacturing sector in most European countries was either Type III or Type IV. That is, in almost all countries total employment in manufacturing declined, but countries were divided between those in which the total number of manufacturing units also declined (Type III) and those in which the total number of manufacturing units increased (Type IV).

- There are various reasons for the emergence of Type IV industries, both within the manufacturing sector as a whole and within the specific high technology sectors. It is important to note that the emergence of Type IV industries may well have more to do with 'negative factors', especially the down-sizing of large companies, than it has to with 'positive factors' such as the emergence of highly innovative smaller firms.

Differences between High Technology Manufacturing Industries - Analysis of Specific Sectors

- The analysis showed that different industries have evolved in different ways.

- In most countries the **pharmaceuticals sector** was Type I during the 1980s. In general, the change in the number of active units in the pharmaceuticals sector has been relatively small, which is probably a reflection of the high barriers to entry in the sector.

- Although the **office equipment and computer manufacturing sector** is often thought of as a sector which attracts many new companies, across Europe, it tends to be dominated by large units. However, the average size of manufacturing units in this sector has declined rapidly in most European countries, which reflects the large amount of entry into the sector by smaller firms over the last decade. In most European countries, the sector was Type I during the 1980s

- Across Europe, the **electronics sector** was mainly Type I or Type IV. Thus, in most countries, there was an increase in the number of units in the electronics sector, but a reduction in the sector's employment

- The general trend in the electronics sector was for the number of micro and small-medium sized units to increase, and for these to increase their employment, whilst the number of large units fell, reducing their employment, and the employment of the sector as a whole. This contrasts with the pharmaceuticals and office equipment & computer manufacturing sectors, in which the general trend was for growth in all units size classifications.

- Unlike the pharmaceuticals, electronics and office equipment & computer manufacturing sectors, the **instrumentation sector** is dominated by smaller units. In all European countries except Greece, the instruments sector was Type I or Type IV during the 1980s, the majority being Type I.

- In most European countries, the average employment of units in the sector declined as the general trend in the instruments sector was similar to the electronics sector: the number of micro and small-medium sized units increased, and increased their employment, whilst the number of large units fell and reduced their employment, but in this case the contraction of large units did not reduce the employment of the sector as a whole.

The High Technology Service Sectors - Analysis of Specific Sectors

- Amongst the countries that were able to provide data, there was a universal trend that the aggregate number of units in high technology service sector activities increased, and the aggregate employment of high technology services increased. Thus universally, the aggregate high technology service sector (AHTSS) in European countries was Type I in the 1980s.

- The **computer services sector** is dominated by smaller units, with small, medium-sized and/or micro units providing the great majority of the employment in the sector. However, growth over the last decade has generally been 'across the board', with micro, small-medium sized, and large units all increasing their number and their employment.

- Across Europe, the number of units active in the provision of **research and development services** increased in all countries which provided data, but there was a division between those countries in which R&D employment increased and those countries in which R&D employment decreased. Thus the R&D sector was either Type I or Type IV during the 1980s. This is closely linked to the general development of high technology manufacturing in the countries concerned.

- **Technical services** are generally dominated by small and/or micro units, and in all countries which provided data these units provide well over half the employment in the sector. Amongst the countries for which data was provided, the universal trend was for an increase in the number of units active in the provision of these services, and in all countries except of Finland, employment in the sector also increased. Thus, in all these countries except Finland, technical services was a Type I sector, whilst it was Type IV in Finland.

Differences between Countries

- There were notable differences between countries in the evolution of the high technology sectors. At one extreme, there was West Germany where the high technology sectors were all Type I. At the other extreme, there was the UK (at the enterprise level between 1980 and 1990) where almost all the high technology manufacturing sectors were Type IV[46].

[46] Note again that the timing of the analysis may be particularly fortuitous for West Germany. Further research by ZEW, the German partner in this study, has shown that in the early 1990s many of the high technology sectors became Type III or Type IV. This may be a short term recessionary effect. Overall, the German position may not be quite as outstanding as the analysis above appears to suggests, but it is likely that, like its neighbours: Austria, Denmark and the Netherlands, the German position can be considered superior (in terms of Type I industries vis a vis Type IV industries) to that of other countries, such as the UK.

- In the UK, there has been an evolution towards smaller units through an increased number of units but a contraction in the number and employment of large units, whilst in West Germany, large units in the high technology sectors continue to expand. Generally in West Germany there has been an increase in the number of units active in the high technology sectors, with small and micro units entering the various sectors, this has not been at the associated with a contraction of large units and employment loss from these as has clearly been the case in the UK.

- It is important to remember that the emergence of a large number of smaller firms in a Type IV industry may well be the consequence of 'negative' rather than 'positive' factors.

- Most other countries lie between the extremes of West Germany and the UK, but Portugal, Spain[47] Sweden and were unusual in that their aggregate high technology manufacturing sectors were Type III - that is, in these countries the number of units active in high technology manufacturing and high technology employment both decreased.

[47] The position of Spanish and Portuguese industries is probably partially explained by the entry of these countries into the European Community in 1986. This exposed Iberian industry to greater competition from other European countries and led to a period of rationalisation within industries in these countries.

Part III

PUBLIC POLICY MEASURES

1. INTRODUCTION

This part of the report seeks to draw upon the literature review undertaken in Part I and the statistical data assembled in Part II. It identifies five policy areas and provides a synthesis of the policy developments in EU countries and an assessment of effectiveness. The policy areas examined are:

- Science Parks
- The Supply of PhDs in Science and Technology
- Relationships between NTBFs and Universities/Research Institutions
- Direct Financial Support to NTBFs by National Governments
- The Impact of Technological Advisory Services on NTBFs

Although they are considered independently they clearly part of an interdependent 'system'. For example, the supply of PhDs is likely to be a factor influencing the growth of firms on Science Parks. Equally, the role of government in providing financial support and advisory services influences both NTBFs and universities. For these reasons we conclude with an overview of this whole policy area.

2. SCIENCE PARKS

The development of Science Parks in Europe clearly received its early impetus from United States experience. As an illustration, there is a clear link between observing the early success of a Science Park at Stanford, California and its replication in Cambridge, UK.

There is, however, a considerable time lag between the establishment of the Stanford Park in the 1950s, the establishment of the Cambridge Science Park and Sophia Antipolis in France in the late 1960s, and the growth in Science Parks in the rest of Europe. In many European countries it was not until the 1980s and 1990s that significant numbers of science parks were established.

Science Parks are defined in the UK as property-based initiatives having formal and operational links with a university. They are designed by the UK Science Park Association to encourage the formation and development of knowledge-based businesses. They provide a management function designed to ensure the transfer of technology and business skills between the businesses on the Park and the local university or research centre. The rationale underlying the development of Science Parks is that they can play the following roles:

i) To enable academics at the local university to commercialise their research ideas in a convenient location.

ii) To provide accommodation for existing well-established (possibly large multinational) businesses wishing to locate near, or on, a university campus so as to facilitate research links with individuals or department within the main university.

iii) To provide high quality prestigious accommodation for existing/established (small) businesses which are using and developing sophisticated technologies. The aim is to enable them to obtain the benefits of close association with the university, other similar businesses on site and the managerial services provided by the Park staff.

At a European level, however, it is difficult to be confident that a consistent definition of Science Parks has been employed in each Member State.[1] Table 3.1 provides some indication of the numbers of Parks in EU countries. It also provides an indication of the numbers of firms located on those Parks and employment in the firms.

The definitional problems emerge immediately since the largest number of Science Parks are found in France, Germany and the United Kingdom. The UK definition is however 'tighter' than that of Technopoles in France or Business and Technology Centres (BTCs) in Germany. Pett (1994) notes that many of the BTCs do not focus exclusively upon research or science based firms. Instead, they may be considered as property-based initiatives designed to encourage local economic development, but not exclusively or even primarily utilising the science base of the local university. Similar considerations apply in France. In other instances, however, both France and Germany have innovation and technology centres and more conventionally defined Science Parks. The figures in Table 3.1 include a substantial number of initiatives which may not be regarded as Science Parks in other studies.

Table 3.1 clearly demonstrates that it is in France that Science Parks exist on the largest scale. Development began in Sophia Antipolis in 1969 and this park now has more than 1000 companies employing 16,200 workers. As will be shown shortly, France is the only European country to have

[1] It is also important to note that the definition of a Science Park employed is much less relevant for a non-Campus University. For example, in Austria, universities are frequently not centralised in a single location but are instead often widely distributed around their respective cities

Science Parks on a scale comparable with the United States. Currently employment in French Science Parks is more than double that of all other EU countries combined.

In Europe, the United Kingdom has the longest-established tradition of Science Parks. However, at the start of the 1980s the only operational Parks were in Cambridge and Heriot Watt University in Scotland. Yet, by 1993, Science Parks were attached to virtually every UK university and the UK Science Park Association estimated there were almost 1200 firms on these Parks providing employment for almost 20,000 workers. Arithmetic mean employment size of Science Park firms was therefore about 16 workers.

Amongst the Scandinavian countries, Finnish and Swedish Science Parks are important. Currently there are 13 Science Parks in Sweden with 500 firms and 8,000 employees. This also averages about 16 employees per business. In Finland there are currently nine Parks, with a tenth about to be established. The total employment in Science Park businesses in Finland in similar to that in Sweden. In Denmark there are only five Parks and these are smaller scale operations.

The Benelux countries have well-established Science Parks, with seven Parks in the Netherlands and eight in Belgium. Although the Belgian Parks appear to have significantly fewer firms than the Dutch, their average firm size is very much larger, reflecting the greater role played by multinationals, which are often foreign-owned, and the more modest role played by NTBFs.

Table 3.1 Science Parks in the European Union

Country	Year	Number of Parks	Number of Firms	Number of Employees
Austria	1993	28 Innovation Centres	350 Tech. Based Firms 45 Research Institutes	2800 employees
Belgium	1988	8 Science Parks	68 Firms	4000 employees
Denmark	1995	5 Parks	180 Firms	1025 employees
Finland	1994	9 Parks	800 Firms	8000 employees
France	1995	35 Parks*	7160 Firms	145,834 employees
Germany	1992	124 Technology Centres		
Greece	1995	4 Parks	41 Firms*	690 employees
Ireland	1993	1 Park	90 Firms	2400 employees
Italy	1993	15 Science Parks	No reliable data	No reliable data
Luxembourg		No Parks		
Netherlands	1993	7 Science Parks	280 firms	3000 employees
Portugal	1995	4 Parks		
Spain	1995	15 Science Parks	311 Firms	8307 employees
Sweden		13 Science Parks	500 Firms	8000 employees
UK	1995	46 Science Parks	1250 Firms	23,229 employees

* Greek and French data are taken from 'World-wide Research and Science Park Director 1995/6'. In the case of Greece, data on employment is provided by only 41 out of 55 firms. In the case of France data are provided by 35 out of 51 Parks. It is probably reasonable, however, to assume the non-providers of data are likely to be newly established, and hence small, Parks.

In Italy there are 15 Science Parks, many of which are only recently established. It has not been possible to obtain reliable data on the number of firms in these Parks and their employment. Indeed several of the 'Parks' might not satisfy fully the definition of a Science Park discussed earlier.

Similar comments apply to Spain, where there are also about 15 Parks which accommodate about 260 businesses. The interesting characteristic of the Spanish Parks is that many initially began by seeking to attract the research laboratories of large multinational corporations, but in recent years there has been a shift towards the attraction of indigenous technology-based enterprises.

In many countries the establishment of Science Parks has occurred through a partnership between regional and national governments, universities and regional and local private sector interest groups. Amongst European countries, however, there are clear differences in tradition which have influenced the development of the Parks. For example, Parks are funded primarily by the private sector in Denmark, whereas in Italy, the interface between universities, research associations and industry is particularly weak. Malerba et al. (1995b) report work by Sterlacchini which shows that Italy has the lowest proportion of university research that is financed by the private sector (2.6% in 1989). This compares with 4.6 in France, 7.4 in the UK, 5.9 in Sweden, 7.0 in Germany and 7.3 in Ireland.

In many respects these percentages also reflect the scale of importance of Science Parks in European countries - such that countries like Sweden and the UK, where a comparatively high proportion of university research has traditionally been funded by the private sector, have a more 'advanced' Science Park movement than Italy or Spain. As ever, there are exceptions - such as Denmark, where Parks are primarily privately funded, yet where the numbers are small.

Science Parks have a number of roles, only one of which is to stimulate the growth and development of indigenous new technology-based firms. Their objectives are long term and so the extent to which the objectives are met can only be examined over a long period of time. Westhead and Storey (1994), in their UK study, found that:

i) New technology-based firms have higher (employment) growth rates and lower failure rates than UK small businesses as a whole.
ii) NTBFs on Science Parks have identical closure rates to NTBFs elsewhere.
iii) NTBFs on Science Parks have (very marginally) higher growth rates than NTBFs located elsewhere.

Westhead and Storey conclude that a Science Park location does not significantly influence the growth and survival of an NTBF, but the existence of a Science Park is likely to stimulate the formation of

NTBFs which would not otherwise have been established and constitutes an 'economic' magnet for the clustering of technology-based firms which enhances local economic development.

Broadly similar findings emerge from studies in the Netherlands by Bartels and Wolff (1993) and van Tilburg and Vorstman (1994). The former finds the growth rates of firms in business incubators/Science Parks does not differ significantly from comparable firms elsewhere, whereas the latter confirm that such firms have a comparatively low rate of business failure.

Since the concept of a Science Park was originally developed in the United States, it is valuable to compare developments in Europe with those in America. The top half of Table 3.2 shows that the six largest Parks in the United States are significantly larger, and generally have an average firm size which is very much higher, than in the European Parks which are shown in the lower half of the table.

Table 3.2 Science Parks in Europe and the United States

Park	Date Established	Number of Firms	Employment	Average Firm Size
Stanford Research Park, USA	1951	162	26,000	160
Research Triangle Park of North Carolina, USA	1959	71	34,000	479
Charlecote University Research Park, USA	1968	29	12,000	414
Metro Tech., USA	1986	18	14,000	778
Irvine Spectrum, USA	1978	2,000	32,000	16
Louisiana Biomedical and Development Park, USA	1991	20	15,000	750
Sophia Antipolis, France	1969	1,034	16,200	16
Cambridge, England	1970	72	3,600	50
Tetrapole, Grenoble, Iserc, France	1972	600	12,000	20
Nancy Brabois Innovation, France	1977	250	15,000	60
Villeneuve D'Ascq Technopole	1986	2,497	22,259	9

Amongst the European Parks, four of the largest of which are in France, none would rank in the top six in the United States in terms of employment per firm. Average employment per firm in all the US Parks except Irvine Spectrum exceeds 100 workers, whereas in Europe only Cambridge and Nancy amongst the very large Parks, has an average employment per firm of 50 or more.

This implies that, in Europe, only France has a Science Park movement which compares in scale with the developments in the United States.

<u>In Conclusion</u>

Science Parks in many European countries are a comparatively new development, so it is premature to judge their effectiveness. With the exception of France, it is clear that Science Parks have clearly made only a modest direct contribution to employment and their contribution to technology transfer has been difficult to estimate.

It is also clear that the average employment in a Science Park firm is between 10 and 20 workers and that there are no instances of European Parks housing firms which have achieved the employment size of those in the larger United States' Parks.

European Parks currently do not seem to be spawning rapidly growing indigenous science-based enterprises. Nevertheless, it is clear that, at a local level, a Science Park is a much valued and prestigious location for new firms in Europe. The central policy question is why European science-based firms appear unable to achieve the growth rates achieved by comparable US businesses. The remainder of this part of the report will discuss influences on this, such as the supply of labour, links with universities and the provision of finance and information.

3. THE SUPPLY OF PhDs IN SCIENCE AND TECHNOLOGY

The proportion of founders of new technology-based firms that have a science or technology based PhD has increased strikingly in recent years. For example, Westhead and Storey (1994) in their study of the founders of high technology firms located on and off Science Parks in the UK, found a significant increase in this proportion over a six year period. In 1986 52% of founders of Science Park firms had a higher degree and this rose to 62% in 1992. Amongst the 'off Park' firms the proportion of founders with a higher degree rose from 16% to 32% over the six year period.

In part this reflects the increasing supply of such individuals. Nevertheless, it also reflects the technological imperatives, since only individuals who have studied at the highest academic level have sufficient understanding both of the technology itself and the associated market opportunities. Quite simply, those who wish to exploit 'leading edge' technology have, themselves, to be at the leading edge. Since, by definition, that leading edge is always moving forward, enterprises which are exploiting that technology require individuals with the highest academic qualifications to exercise the entrepreneurial function.

In making these statements a number of provisos have to be identified. The first is that it does not imply that <u>only</u> individuals with science-based PhDs will be owners of new technology-based firms. It is quite possible that a team of individuals, combining both technical and managerial skills, will own such businesses. Nevertheless, as the technology becomes more sophisticated, NTBFs are less likely to come into existence without someone in the senior management team having highly sophisticated technical knowledge. In the future the most successful NTBFs are likely to be lead and owned by such individuals, although, conversely, this does not imply that having an owner with a PhD is a guarantee of success.

The second proviso is that it does not imply that all, or even a sizeable proportion, of those individuals with science-based PhDs will ultimately seek to become owners of an NTBF. Not surprisingly when questioned on this topic, the vast majority of scientists in universities and research institutions emphasised their wish to continue with their science, rather than seeking to directly commercialise their expertise. It is also the case that many universities, even if they have not actively discouraged entrepreneurship amongst the scientific community, have rarely facilitated the commercialisation of research. Changing the 'entrepreneurial culture' in European universities is likely to be a lengthy task.

The third proviso is that in many small, and less prosperous EU countries, those educated to the highest level (i.e. PhD) often recognise that better employment opportunities - either in science or elsewhere - are found abroad. For example, the Irish experience reported by Cogan (1995b) is that 43% of those who graduated with a PhD between 1984 and 1988 were no longer resident in Ireland at the beginning of 1994. This figure was significantly higher for those with natural science degrees. Hence even the establishment of science-based PhD programmes is no guarantee of an increase in the future supply of potential NTBF founders in the host country.

Fourthly, it assumes a broad comparability in the scientific expertise recognised by the PhD award in the different EU countries. We are not clear about the validity of this assumption, but, in general, we believe it to be plausible.

Despite these reservations, it is the case that the formation of NTBFs is increasingly likely to require the presence of an individual with the highest possible academic qualifications. The extent to which those individuals are available within an economy is likely to be a major, but certainly not the only, factor influencing potential supply of NTBFs in the future. It is important to emphasise that there will be an expected time lag of about a decade between the individual obtaining a doctorate and subsequently starting a firm, assuming that individuals complete their doctorates about the age of 27 and primarily start their businesses in their mid thirties. This 'time lag' has to be taken into account in policy-making.

For all these reasons it is important to examine the total number of individuals currently completing PhDs in science and technology and to examine the extent of any changes which have occurred in these numbers over the last decade or so. Unfortunately EUROSTAT data does not distinguish between those taking higher degrees and those taking first degrees, so EUROSTAT data are not usable in this context. These data also do not usefully distinguish between subject areas. We have therefore sought to assemble, for the first time, some EU data on this topic. The basic data is shown in Table 3.3.

Prior to any interpretation of the table it is appropriate to point to differences in tradition between EU countries which render statistical comparisons imperfect. For example, the Scandinavian countries have a tradition of awarding a licentiate. In Finland and Sweden this is a less demanding dissertation, but in those countries PhDs are also awarded for the more advanced studies. However, in Denmark, until 1987, all dissertation awards were called licentiate. Only following the educational reforms of that year were PhDs awarded.

Career patterns of individuals also differ significantly between countries. For example, in Austria doctorates at technical universities are usually pursued by people seeking academic careers, rather than by those with the intention of starting a business. It is this reason, combined with the high educational level of technical school at the secondary level, which explains why about one third of Austrian entrepreneurs in science parks come from this background rather than having a PhD. Similar but different considerations apply in France. Here there is a tradition of a dual education system between universities on the one hand and engineering schools on the other. The latter have been providers of much of the senior managerial talent in French industry, whereas the former have supplied PhDs. The experience in Finland is rather different. There Autio and Ahola (1996) show that only 54% of those with a PhD awarded in the previous twenty years, and working in 1992, were in Education and Research. Almost a quarter were in Health Care, 9% were in Public Administration and 8% in Manufacturing and Services (the private sector).

Third, European countries vary considerably in their 'tradition' of studying abroad. For example, Portugal, Greece and Italy have always encouraged doctoral students to study abroad, whereas in the UK this is much more unusual. Hence, Table 3.3, which identifies degrees awarded by country, is likely to overestimate the importance of PhDs in the population in the UK - if migrants return home - and underestimate their importance in Italy, Portugal and Greece.

Despite these difficulties over interpretation, two fairly clear conclusions emerge. The first is that, in comparing the first two columns of the table, it is clear that, in most EU countries, there has been (at least) a doubling in the number of doctorates awarded in science and technology during the last ten years. This is likely to be a factor influencing positively the number of NTBFs formations in the next decade or so.

Table 3.3 Completed Doctorates In Science/Technology/Maths

Country	In the 1980s	Current	Working Age Population (15-64 '000)	PhDs in Science & Technology per 100,000 pop'n	Comment
Austria	169 in 1980/81	478 in 1991	5,419	0.09	
Denmark	139 in 1988	353 in 1994	3,512	0.10	
Finland	120 in 1985	260 in 1993	3,408	0.08	
France	4905 in 1990	6050 in 1993	37,898	0.16	
Germany (Incl.)	5656 in 1988	7505 in 1992	55,764 (44,474)	0.13 (0.13)	
Greece	109 in 1985	163 in 1993	7,048	0.02	In 1990 the number of PhDs was 233
Ireland		273 in 1991	2,268	0.12	
Italy	741 in 1983	1426 in 1994	39,361	0.04	
Netherlands	841 in 1990	1067 in 1994	10,548	0.10	
Portugal		375 approx.	6,679	0.06	Estimate - 350 to 400 per year in 1994-97
Spain		1700 in 1993/4	26,702	0.06	
Sweden	312 in 1985/86	571 in 1993/4	5,586	0.10	
UK		6,500 in 1993	38,673	0.17	

Notes: Doctorates exclude Medical Doctors
The German Working Age population figure includes the New Germany
Source: Working Age Population derived from 'Employment in Europe', 1995
PhDs from study partners

Secondly the table shows that there are also some notable differences between EU countries in the number of PhDs awarded, when this is normalised by the working population (column 4). The United Kingdom and France have the highest proportion with awards. A number of countries (Sweden, Ireland, Denmark and Netherlands) follow with very similar rates. These rates are twice as high as those in countries such as Italy and Spain, and these, in turn, are twice as high as that in Greece, although here the choice of 1993 disadvantages that country since there was a major fall in PhDs awarded, compared with two years previously.

In Conclusion

During the next decade or so it is increasingly likely that the only founders of NTBFs will be those individuals who have served a PhD 'apprenticeship' in a science-based subject.

Our findings are that, in almost all EU countries there has been a doubling of the number of such individuals graduating in the last decade, but that there are major differences in the relative numbers of such individuals graduating. The countries with the highest proportions of the workforce graduating with a science-based PhD are France and the UK.

If the number of such individuals is a key influence on the 'supply' of high technology entrepreneurs then the extent to which these are converted into business founders during the subsequent decade will depend upon out-migration, employment opportunities and the extent to which they are made aware of the opportunities for commercialising their research.

Our judgement is that the rise in PhDs in science will coincide with declining, or at best stable, employment opportunities in academic life for which PhDs have trained in the past. Policy therefore has to be directed towards facilitating the 'entrepreneurial option' amongst such individuals. This is particularly important for less developed economies where many PhDs have been trained elsewhere and who are therefore likely to be very willing to leave their native country with the associated losses.

4. RELATIONSHIPS BETWEEN NTBFs AND UNIVERSITIES/RESEARCH INSTITUTIONS

A key development in most EU economies is that the relationships between industry and the research/academic world have become progressively stronger in the last twenty years. This has occurred for a number of reasons: firstly, universities have considerable technical expertise which, if harnessed by the commercial sector, could enhance significantly the latter's competitive position. Secondly, universities and publicly funded research institutions, require increasingly expensive equipment, facilities and personnel. At a time when governments in all countries face funding pressures, the option of seeking funding for such research from the private sector is an attractive option since it releases public monies which can be devoted to other activities. Strengthening the 'market links' between the private sector and universities is also often justified on the grounds of making research more 'relevant' to the 'needs' of the market place.

Not surprisingly these developments have often been resisted strongly by those undertaking research in universities. They argue that the research 'consumers' (the private sector) tend to have a much more short-term view of research outputs than the scientists themselves. This can lead to an undue emphasis upon short term applied work, rather than on fundamental research.

In some European countries these developments have progressed faster than in others. The concern with ensuring commercial users have an opportunity to influence the research agenda of university scientists is characteristic of a number of the Scandinavian countries. It also has a long tradition in Germany and Austria, and in recent years has become more important in Spain and the Netherlands. Italy however, with some significant exceptions, appears to have been the most reluctant of the major EU countries to embrace this development.

Whilst there has been, in some instances, a rather grudging acceptance of the need to ensure that research programmes can demonstrate relevance, it remains the case that, where links between universities and the private sector are established, they tend to be with large rather than smaller firms. For example, Malerba et al. (1995b), in their review of Italian developments, note that the strongest industrial links in Italy with universities occur in the pharmaceuticals sector where average firm size is very large. A survey of technological co-operation amongst Austrian firms also emphasises this point, finding that about 8% of firms with less than 200 employees collaborated with universities, compared with 34% of those with more than 200 employees.

There are a number of reasons for this: firstly, the majority of SMEs do not conduct research themselves and therefore have comparatively little 'in common' with research scientists in universities. Secondly, from the universities' perspective, linkages and research co-operation with SMEs is significantly less 'prestigious' than working with world famous multinationals. Thirdly, since the costs of establishing these relationships are broadly invariant with the value of the contract, it is clearly more cost-effective for universities to seek links with large enterprises - which are able to offer larger contracts - than with SMEs.

For these reasons SMEs, in general, are not the natural focus of attention of universities. The new technology-based firm, in some countries, may be an important exception. Here the owner is likely to have an academic background, or indeed may even be a current or former employee of the university.[2] The competitive position of the NTBF is also likely to be significantly enhanced by having access to leading-edge research, so linkages can be established at comparatively low costs to both parties. Furthermore, the university scientists themselves may derive greater personal satisfaction from working with a small company at an early stage in its development, where they know the owner, than providing research input to a (faceless) multinational. Finally, the key role which SMEs play in many local economies mean that universities feel an obligation to assist this group.

These reasons serve to explain why most universities in countries such as Austria, Denmark, Finland, Ireland and the United Kingdom have industrial liaison officers whose function is to ease the process of technology transfer between the university and businesses in their locality. In most of these cases the officer responsible has a specific remit to focus upon smaller enterprises. Similar arrangements were in place in the Netherlands where 'Transfer Points' have been established.

Some illustrations of important developments in this field are:

[2] This is certainly not the case in all EU countries. For example in the Netherlands the proportion of students studying science is significantly below other EU countries, meaning that the supply of science-based entrepreneurs is likely to be impaired, (De Lind van Wijngaarden 1994).

i) The Extension Centre of the Technological University of Vienna: this has about 20 employees and its objectives are knowledge and technology transfer, scientific information, training for enterprises and international affairs. An agreement between the Centre and the Economic Chamber of Vienna offers subsidised access to the research potential of the university - about 1200 scientists in 106 institutes. Each year it organises six presentations by the Institutes, ten information meetings about special scientific areas and one technology transfer conference. At the same time it helps university teachers to use their research and development results commercially by co-operating with firms.

ii) The University of Aalborg has a formal programme for the distribution of knowledge from the university's research directly to firms. Stimulated by the affiliated programmes of Stanford University, it is one of seven European Union universities which have scientific knowledge distribution networks between the university and private firms. The programme has succeeded in strengthening both the university and local firms. For example it has been able to build on and improve formal and informal networks around the university in important areas such as mobile communication techniques.

iii) In Spain the office for the transfer of research results (OTRI) provides access to data bases of knowledge, identifies of results generated by research groups, assists with the transfer of these results to companies, participates in the negotiation of research contracts, provides technical assistance and assistance with patents and licensing. It also provides information about European Research and Development programmes and collaborates in the interchange of research personnel with companies. The mission of ORTI under the newly developed PACT1 is to strengthen the interface between the science, technology and industrial sectors through the interchange of personnel, co-operative technological projects and subsidies for the creation of technology transfer centres in specialised technologies.

Another key role which universities can play is to bring to the raise the awareness of students - particularly those with higher degrees - of the opportunities to start their own businesses. In some instances these may be established as spin off companies from the university and in Sweden in the 1980s the universities of Chalmers (Gothenburg) and Linkoping were highly successful in this respect. In Ireland, Cogan (1995b) reports work by Kinsella and McBrierty who identified the existence of 183 campus companies responsible for employing almost 2,000 people and generating 75 patents. This figure has been disputed as an overestimate, because some of the companies are dormant, and a figure of 60 companies may be more realistic. Nevertheless, both these examples illustrate that, perhaps, particularly in smaller countries, university spin-off companies can play an important role.

A further role for the universities is to seek to enhance technological links between SMEs and themselves. Illustrations of these types of schemes are found in several countries. The following two are illustrative. At the University of Twente in the Netherlands a support scheme called Temporary Entrepreneurial Places (TEPs) is financed by the Ministry of Economic Affairs. These places enable personnel and students at the university wanting to start their own enterprise on the Science Park to work at the university on a half time basis. Facilities at the university are placed at their disposal in addition to a mentor and an interest free loan of 15,000 ECUs.

In the United Kingdom, the Shell Technology Enterprise Programme (STEP) has been in operation for almost 10 years. In this programme, second year undergraduates during their summer vacation undertake a project in a local SME. Its purposes are primarily to make the undergraduate more aware of employment opportunities in SMEs, and to make the SME more aware of the value of graduates, in the context of the student undertaking a commercial project. Evaluation of this programme suggests that students who participate in it are significantly more likely, upon graduation, to obtain employment, although this is rarely in a small firm.

Despite these developments, it would be misleading to suggest there has been a fundamental shift in entrepreneurialism in the universities of Europe. Academics continue to be judged primarily on the quality of their publications and the combining of an entrepreneurial and an academic career is possible only for the most hardy of individuals. Even schemes such as Transfer Points in the Netherlands were ultimately unable to change the 'culture' of universities; their weakness was emphasising insufficiently the requirements of the customers - SMEs.

In Conclusion

There is evidence that there has been a major shift in the last 15 years in almost EU economies towards ensuring stronger links are established between research institutions and the commercial sector. These links tend to be strongest between universities and larger, rather than smaller, firms. Nevertheless, there is considerable interest in most countries in enhancing the links between universities and SMEs. Partly these involve dismantling the barriers which universities have traditionally established which prevent academics from establishing their own businesses. Universities are also now bringing to their students' attention the opportunities for self employment and new business formation. In their outreach activities, many universities have an Industrial Liaison Officer, who has a specific remit to strengthen links with SMEs by encouraging them to work with the (generally scientific) departments in the university. Nevertheless, it is almost inevitable that, if the prime objective of outreach activities is to generate income for the university, then the prime links are likely to remain with larger, rather than smaller, enterprises. Partly for these reasons it is easy to exaggerate the strength of links between SMEs and universities. In most instances these links are not given a high priority within the institution, although it is also clear that changes are afoot.

5. DIRECT FINANCIAL SUPPORT TO NTBFs BY NATIONAL GOVERNMENTS

In reviewing the support received by new technology-based firms from governments an initial distinction is made between support provided in direct financial terms - such as loans, grants, guarantees, tax relief etc., and indirect support provided in the form of advisory services, access to information etc. This section examines the direct financial assistance provided by national governments. Indirect assistance is reviewed in Section 6.

In some EU countries - such as Belgium, Germany and Spain - most forms of industrial assistance are provided at a local (regional) level as well as by national governments. For example, the Lander in Germany provide financial support to NTBFs which, in monetary terms, exceeds the value of national government schemes.

In other countries such as France, the Netherlands and the UK and, whilst there is some regional delivery of assistance, policy is primarily delivered through national government schemes. This section, given the space constraints, focuses exclusively on national policies. It also does not seek to provide a review of supra-natural schemes, such as those of the EU, which are delivered at a national or regional level.

The broad characteristics of the direct financial support available to NTBFs by national governments is shown in Table 3.4. For each of the 16 countries a key distinction is made between national government support policies which focus <u>exclusively</u> and <u>explicitly</u> upon NTBFs. These are shown on the left hand side of the table. They are compared with policies where NTBFs are only one component of the population of SMEs or larger enterprises which are supported by direct financial support. These are shown on the right hand side of Table 3.4.

Only three countries currently have financial support schemes targeted exclusively and explicitly upon NTBFs.

The preferred strategy, shown on the right hand side of the table, is to have schemes which focus heavily (but not exclusively) upon NTBFs and where NTBFs are one of a number of foci. As an illustration, Germany has three schemes which focus significantly (but not exclusively) upon NTBFs, whereas Belgium and Denmark have no national schemes focusing upon NTBFs. In the case of Belgium this is primarily because industrial policy tends to be delivered at a regional rather than at the national level, whereas in Denmark it reflects a conscious policy decision to avoid 'selective' assistance.

We begin with a review of those schemes, discussed in the left hand side of Table 3.4, which focus explicitly and exclusively on new technology-based firms. Two such schemes exist in the United Kingdom and one in each of Sweden and Germany. The key point therefore is that comparatively few EU countries have national government financial assistance policies which focus explicitly and exclusively upon new technology-based firms. The more familiar pattern is for governments to provide financial support for a wide range of enterprises, of which NTBFs are possibly an important, but not an exclusive, group. In essence, this implies there is nothing 'special' about NTBFs.

Table 3.4 National Government Direct Financial Support Policy to NTBFs

	Explicit Focus Exclusively on NTBFs					Support Focusing on SMEs but where NTBFs are important			
	Yes / No	Current No. of Schemes	Grant	Interest Relief	Other	Current No. of Schemes	Grant	Interest Relief	Other
Austria	No					2	1		1
Belgium	No					0			
Denmark	No					0			
Finland	No					3	1	1	1
France	No					1		1	
Germany	Yes	1			1	3	1	1	1
Greece	No					2	1		1
Ireland	No					1	1	1	
Italy	No					2	1	1	1
Netherlands	No					2	1		1
Portugal	No					1			1
Spain	No					2	1	1	
Sweden	Yes	1		1		0			
United Kingdom	Yes	2	1	1		0			

Table 3.4 demonstrates there are a variety of different forms of financial assistance provided to NTBFs. It distinguishes between financial assistance provided in the form of grants, interest relief and other forms of assistance such as tax relief and provision of guarantees. An examination of both sides of Table 3.4 shows there is no clear consistent emphasis by Member States on any of these three forms of assistance. For example, on the left hand side of the table it can be seen that grants were favoured in one case, interest relief favoured in two cases and other forms of assistance favoured in another. An examination of the right hand side of the table demonstrates an almost equal diversity. It suggests there is little evidence that experience has found one form of financial assistance is significantly superior to any other in impacting upon the sector.

Turning to Table 3.5, which covers the schemes in Germany, Sweden and the UK, and which focus exclusively and explicitly upon new technology-based firms (i.e. those noted in the left hand side of Table 3.4), these schemes also demonstrate considerable variety. The German BTU scheme can be considered as two separate schemes, one of which provides a guarantee, the other being a co-investor model. Both seek to provide financial incentives for investors to provide equity to support the birth and development of NTBFs. On the other hand, the UK SMART awards are a competition in which the winners are provided with 75% of the costs of first stage financing a new development.

The table also shows that where these schemes have either been running for a number of years, [or, as in the German BTU instance, been in operation in an earlier format] evaluations provide clear evidence that public funding has enhanced additionality quite significantly.

This is a very important finding, given our earlier review of the literature in Part 1, which pointed to the near universal recognition of the presence of market failure in the provision of finance for new technology-based firms. It does appear from these examples that, almost irrespective of whether the instrument used is loans, grants, or even guarantees, and whether the scheme is designed to be of direct assistance to NTBFs or to those providing the NTBF with equity, that substantial additionality is achieved. Although there is no suggestion that 'finance gaps' are eliminated, these schemes clearly serve a valuable function. It is particularly valuable where the schemes are targeted explicitly and exclusively on NTBFs. This confirms our earlier finding that NTBFs experience unique financing problems that are not characteristic of all enterprises or even all SMEs. It implies they merit their own special schemes which can be tailored towards their special needs. Where such schemes have been introduced they appear to have been successful.

The discussion so far has focused on policies for NTBFs, which have an explicit and exclusive focus on NTBFs. However, as Table 3.4 showed, NTBFs in European countries also benefit from schemes which provide direct financial support for a wide variety of types of enterprises.

Table 3.6 provides some illustrations of the types of policies referred to in the right hand side of Table 3.4. The table is not designed to be comprehensive, and the interested reader can find a more extensive coverage in Fahrenkrog et al. (1993). The table does, however, shows the huge variety of schemes that are currently in operation: some provide grants, others provide interest relief, others guarantees and others tax credits. Whilst some of these schemes have been operating for several years, there appears to be comparatively little evaluation of their overall effectiveness. Where assessments have been undertaken they tends to be in the form of identifying the total number of firms which benefit from the scheme, the sectors in which these firms operate and/or the cash which they receive, rather than assessing the extent to which the scheme is effective in providing additionality to the businesses. Nevertheless the existence of these schemes suggests that they are considered, in most cases, to be an effective mechanism for stimulating economic activity.

Table 3.5 National Government Direct Financing Policies with an Explicit and Exclusive Focus on NTBFs

Country	Scheme Name	Function	Instrument	Comment
1. Germany	BTU [Investment Capital for Small Technology Firms]	To provide an incentive for investors to provide additional support for the birth and development of NTBFs	1. Refinancing model: Kfw guarantees up to 90% of loss to those investing in NTBFs 2. Re-investment model: The DaB will match the investment in an NTBF made by any other investor.	The scheme was piloted as BJTV and modified in 1995. Viewed as successful at generating 'additionality'.
2. Sweden	Seed Financing of Product Development in NTBFs (NUTEK)	Easy access to finance for NTBFs	Subsidised interest rates and access to funding	
3. UK	1. Small Firms Merit Award Scheme (SMART)	To overcome problems in early stage financing of NTBFs	Competition held. Winners receive awards to cover 75% of project costs in Year 1. Further awards possible	Good additionality. Highly regarded scheme.
	2. Support for products under research (SPUR)	To provide support for innovative projects at an early stage	30% flat rate support up to maximum of £250,000	Again good additionality

However the evidence of their effectiveness, as far as NTBFs are concerned, appears less 'clear cut' than with the specialist schemes shown in Table 3.5. This suggests, as above, that the financing of NTBFs may require 'specialist' schemes which to take account of their 'special' problems.

<u>In Conclusion</u>

The majority of EU countries do not have financial support policies which concentrate exclusively and explicitly on new technology-based firms. Most countries prefer instead to have support policies which focus either on SMEs or enterprises more generally, but where NTBFs may be an important sub-group. Our judgement is that this is probably not a wise policy. We believe there is a case for policies which focus exclusively and explicitly upon NTBFs. This is because the problems, particularly of financing, which NTBFs experience are very different from large enterprises in the technology sectors or small firms more generally. In short there is some justification for regarding NTBFs as a 'special case'. This is supported by the Dutch experience which provides quite clear evidence that policies which do focus exclusively and explicitly on NTBFs provide clear additionality.

The section has also pointed to a wide variety of different financing strategies in operation in EU countries in support of NTBFs. For example some countries favour grants, whilst others favour interest relief, guarantees and taxation exemptions. Indeed several countries utilise several policies simultaneously. Unfortunately, due to the absence of careful evaluations in most EU countries, it is difficult to reach a judgement as to which of these policies appears to be the most effective.

Table 3.6 Illustrations of National Government Direct Financing Policies Covering NTBFs

Country	Scheme Name	Function	Instrument	Comment
Austria	Innovations- agentur	Acts as a source of capital for innovation projects	Funding of feasibility study. Funding of second stage using loans, grants and consulting	52 firms received 'seed' support in 1994
Denmark	Development Fund	Support high risk investments	Loans, grants, guarantees	449 projects supported in 1993-95.
Finland	TEKES(Technology Development Centre)	To finance the development of technology and innovation	Provides loans and 'soft' support.	700 Finnish SMEs received support in 1993.
France	ANVAR	To support innovative efforts, technological transfers and partner-ships	Interest free loans to cover up to 40% of payment costs	About 700 young innovative firms per year benefit.
Germany	Loans for small firms for the application of New Technologies	To decrease the financing constraints on small innovating firms	80% of personnel and material costs are subsidised The loan is delivered by a bank and refinanced by KfW	110 firms supported in 1992
Greece	Programme for the Advancement of Industrial Research and Innovation	To assist all types of productive enterprise	Grant programme to cover personnel and operating costs including Market Research	Focus is upon those presenting 'Innovative Business Plans'
Ireland	Enterprise Development Programme	To develop internationally competitive enterprises	Loan guarantees and interest subsidy	Impact on NTBFs over last 17 years has been minimal. It is hampered by lack of firms access to seed and risk capital.
Italy	Law 317/1991	To provide incentives to facilitate access to risk capital by smaller firms	Tax credit and capital account contributions for investment in advanced technologies in small firms	Research on the Lombardia region shows high multiplier effects
Netherlands	1. TOK [Technolog-ical Development Loan] 2. PBTS [Program matic Business Orientated Tech-nology Situation]	To provide support for SMEs seeking to develop risky but promising new products /services To convert the results of scientific research into commer-cially viable products	Up to 40% of loan at 6.15% interest rate. Grants for feasibility studies and demonstration projects. Subsidies up to 37½.	
Spain	CDTI Technology Development Project Schemes	To finance projects seeking to adapt and incorporate new technologies	A variety of instruments for each different scheme including 0% finance, up to 50% of cost covered etc.	There is a risk that, because of the role of EC funding, the technologies stimulated are not ideal for Spain.

There is therefore a strong case for more co-ordinated evaluation of the effectiveness of policy instruments in this area. There is also a case for sharing policy experiences, since it would be surprising that each instrument is equally effective. What is more likely is that different instruments are effective in different circumstances. Unfortunately this review is unable to offer clear directions for policy in this area.

6. THE IMPACT OF TECHNOLOGICAL ADVISORY SERVICES ON NTBFs

Almost all EU countries have a variety of advisory services to assist small and medium enterprises, covering items such as legal, accounting and managerial advice. This section reviews only those advisory services which seek to diffuse technological information to smaller enterprises. However the distinction is not always easy to make since a number of countries have the same organisation providing all advisory services. For example, in Spain IMP provides not only technological services to SMEs, but also more general managerial services. This is also true of Italy where information and training are provided to SMEs by regionally based support organisations such as CESTEC in Lombardia, ASTER in Emilia and DITEL in Liguria. A second definitional issue is that, in a number of countries, the advisory services provided do not always clearly distinguish between small and large firms. For example, CDTI in Spain and the CRTOs in Denmark have large, as well as small, firms amongst their client base.

It is clear there are a wide variety of ways of providing technological advisory services for SMEs. In countries such as Austria the majority of advisory services are provided by private sector organisations such as the banks and also by the Chambers of Commerce. In fact the Austrian and German systems are broadly similar and this is reflected in the work by Pett (1994) who examined new technology-based firms and found the prime institutes or persons consulted for information were Chambers of Commerce and the banks. Significantly less important were, for example, state research and development institutes or technology centres or private R & D institutes.

A central question for policy is, therefore, the extent to which there is a case for the public provision of information and advisory services. If that case is to be justified then the subsidiary question is the extent to which such services ought to be subsidised from the public purse. Our focus here is to address these questions with specific reference to technological information and to reach a judgement about whether the focus should be upon providing technical information to SMEs in general, or to focus upon the particular needs of NTBFs.

The most simple question is whether there is a case for subsidising SMEs to utilise any form of advisory services. Justification is normally based on the observation that SMEs are less likely than large firms to use 'commercial' advisory services. This is partly because the search costs associated with seeking out information are perceived to be higher by SMEs than by larger enterprises. It is also because there is less incentive on the part of the suppliers of these services to ensure SMEs are a major market place. This is partly because the costs of supplying advisory services to SMEs are often higher than supply costs to large firms and because SMEs ability to pay is smaller. Quite simply, therefore, it is argued that if no public subsidy is provided, then SMEs will lack access to information which could be critical to their growth and development. Yet SMEs play a key role in new technological advances and hence economic development, and so constrained access to information will inhibit their development, with losses to the economy as a whole. In addition, subsidising SMEs access to information is also often justified, at least in part, on 'equity' grounds. It is argued that large firms clearly benefit in many respects from public subsidies from which SMEs are excluded. The provision of subsidised information services is therefore an opportunity for SMEs to obtain some benefits in this respect.

The alternative and contrary argument is that an accurate assessment of the value of information and advisory services can only be obtained within a market place. The true test of the value of advisory services is the extent to which businesses are prepared to pay for them. On these grounds the case for public subsidy is weak since SMEs are unlikely to be a buoyant market for the provision of advisory services. The contrasting argument is that many SMEs fail to realise the benefits which such services can provide before they acquire the information. In other words they are ignorant of the benefits of the services but, once this is provided, they become more aware and are more willing to pay for the service at 'market rates'. On these grounds, public subsidies to encourage the use by SMEs of advisory services are often only justified at the 'initial' or 'introductory' stage.

In Europe, custom and practice in this respect seems to vary considerably. In Denmark, for example, the Certified Technology Organisations seek to cover about two thirds of their income from payments from customers. The newly established Business Links in the United Kingdom are also seeking to cover their costs in the longer run by being able to charge for advisory services. However, Belgium, Ireland, Spain and Sweden seem to have taken a longer-term view of the benefits to SMEs of subsidised information services.

It is therefore important to be clear about the criteria upon which business advisory services for SMEs in general, and NTBFs in particular, are to be judged as valuable. These could include the following:

- the number of customers
- awareness by SMEs of the availability of the service
- take up of the service
- satisfaction with the service

- an assessment of the proactivity with which the service is marketed
- willingness to pay/actual payment of customers
- the impact upon the firms utilising the information/advice

Each of these criteria have merits but also limitations. A simple indication of the number of customers will only be relevant if it is part of a comparison. This might be with numbers of customers in other countries, but that would have to be 'normalised' by a population indicator, and take account of the extent to which public subsidies for the take up of the service were provided. The number of customers could also be compared over time in the same country, so that an indication of changing numbers could be identified. Here it would be assumed that more customers were a sign of better service, other things being held constant.

Associated with this is the second criteria which is that of awareness. Here it is argued that a key criteria for judging the effectiveness of advisory services is that small enterprises should be aware of their availability. By implication, where there is a low level of awareness, the service is performing less well than when awareness is high. Awareness is, however, by itself, not a relevant criteria unless it is reflected in the take up of such services. Hence, it is possible for SMEs to be aware of the provision of services but be reluctant to use them because of perceived difficulties of accessing them, or because they doubt the contribution these services can make to their business.

The fourth criteria is the satisfaction expressed by SMEs utilising the services. Here again there are problems with simple interpretations, in the sense of knowing what is good and what is not. For example, in 1992 an evaluation of Dutch Innovation Centres (ICs) found 60% of the clients of ICs were (very) satisfied and 7% were not satisfied with services provided. Very similar results were also obtained in Denmark. Unfortunately, we have no clear way of knowing whether these results are good or not good.

The fifth criteria could be the extent to which advisory services seek to proactively market their availability. A quantifiable outcome of this could be the number of contacts which were made by the support agencies. However, this criteria is potentially misleading since the definition of a contact could vary from a firm receiving a face to face visit and provided with a business 'health-check' to a firm merely receiving literature through the post.

The sixth criteria has already been referred to, and is the extent to which the SME values the information in terms of its willingness to pay. In principle this should be the clearest criteria for judging success, with the more highly valued services being those for which SMEs are prepared to pay a higher proportion of the total costs. It is, however, easy to confuse a willingness to pay with the ability to pay. In some respects, if SMEs are willing and able to pay the full costs of advisory services, then it destroys the case for public provision of such services. In practice, in most EU countries some payment is required, but there is also some public subsidy, with the balance between the two depending on the nature of the firm and the information supplied. Thus, in the private sector in general, SMEs will be unwilling to pay for information and services which is not going to lead to a clearly identifiable commercial return. SMEs are likely to be even more reluctant than larger firms to contribute, for example, to long term research. On the other hand, they may be prepared to pay fees to obtain access to information on scientific developments which is available within universities and which they feel able to exploit. For these reasons, some measure of willingness to pay does reflect the value of the information provided to an SME.

Finally, the value of the provision of information and advice to SMEs clearly depends upon the impact which the information and advice has upon the business. In this respect it is often much more difficult to assess the impact which the public provision of information and advice has upon SMEs than it is to determine the impact of the direct provision of finance. Because additionality is always hard to measure, and because information/advice is less tangible, its impact is likely to be particularly difficult to identify. A second problem is that information and advisory services are likely to be delivered to a larger number of clients than the provision of finance. This means the 'impact' upon firms is likely to be smaller and hence more difficult to identify. As Delapierre et al. (1995b) point out, it is difficult to distinguish, in terms of the impact upon firms, the extent to which a given public intervention influences the trajectory of the firm compared with the internal activities of the business or the macro economic situation in which the firm operates. These authors also note that, even if it is possible to identify impacts at the level of the firm, such policies are focused on the development of enterprise as a whole, rather than on individual firms. In other words, the purpose is to improve the industrial fabric, rather than to lead to some modest private gain for individual businesses.

Other important policy issues which emerge are the extent to which special scientific advisory services should be channelled through existing support mechanisms towards SMEs in general, or the extent to which there should be separate organisations providing these services. A secondary policy question is whether the support organisations should provide only scientific services or whether these should be combined with managerial services.

Illustrations of all these models are found in Europe with Table 3.7 providing details of several schemes. For example, in Ireland the Programmes in Advanced Technologies (PATs) are primarily designed to harness and develop research strengths in Irish universities and then to channel these into developments in industry. They are exclusively science-based programmes devoted to SMEs. The activities of IMPI in Spain, however, combine for the provision of managerial services with a whole wide range of other support services for SMEs including a technological diagnosis programme. IMPI therefore focus exclusively upon SMEs, but incorporate the technological dimension within the

Table 3.7 Technological Advisory Services for SMEs (NTBFs) in European Union

Country	Provider	Function	Comment
Austria	Bureau for International Research & Technology Co-operation (BIT)	BIT is the central institution providing information on EU programmes. It deals with all sizes of enterprise and research institutes	Austria generally favours information/advice provided by semi-private sector organisations
Belgium	Brussels - Technopol	Established in 1991 it seeks to link universities, large enterprises and SMEs in four areas: health, agriculture and food, communication and precision instruments	Separate centres exist in Flanders, Wallonia and Brussels. Generally the technical services are well received
Denmark	Technological Information Centres (TICs)	Provide advice and 'signposting' services, 15 located throughout Denmark. They combine technical and managerial advice	Users are generally positive, but the price charged for the services is a cause of complaint
Finland	TEKES	Experts advise SMEs on technology and product development. Technology Centres are to be the main actors in SME policy	TEKES covers only scientific and technical advice. Managerial advice is delivered by other agencies e.g. KTM and KERA
France	Centres Technique Industries (CTI)	Undertake technology monitoring, provide individual commercial services (technical trials, product certification, training etc.)	Focus is upon all sizes and types of firms
Germany	VDI Technology Centre in Berlin	Providing consultancy services, devising business plans, selecting projects for state support and assisting NTBFs	
Greece	EOMMEX	To provide advice to SMEs on technology issues and promote technology transfer	Two Innovation Centres have closed and the other two did not meet their primary goals. They are now functioning as training centres.
Ireland	Programmes in Advanced Technology (PATs)	To develop technological strengths in Irish universities and channel them towards industry. PATS include Biotechnology Advanced Manufacturing Technology, Opto-electronics and Materials	Potentially very important for generating new NTBFs but hampered by the need to generate revenue at an early stage
Italy	CESTEC, ASTER, DITEL	Regional-based information and training initiatives	
Netherlands	Innovation Centres (ICs)	ICs were established in 1988 and became independent in 1994. They seek to assist technology transfer to SMEs from universities and Research Institutes	An evaluation in 1992 found them well known by their target group. 60% of SMEs were satisfied with the service received
Spain	Centre for the Development of Industrial Technology (CDTI)	To improve the competitive position of Spanish business by raising their technological level. It combines finance and advisory services	CDTI also provide assessment in international technology transfer operations through a network of correspondents in most developed economies
Sweden	Technology Centres (TCs)	Started in 1984 to facilitate the diffusing of new technology to SMEs by linking their other local actions. Supported by national and local government	Alliances have been formed but pricing of services has caused problems. SMEs have found the TCs to be an effective network
UK	Business Link (BL)	Innovation and Technology Counsellors within BL seek to identify sources of technical information and help including grants, access to networks, problem solving and consultancy	Only recently established (ITCs). No proper assessment

organisation. In the UK, Business Links can be considered to be support organisations primarily geared to SMEs, but within these organisations scientific advisory services are provided by the Innovation and Technology Counsellors (ITCs).

A third model is where the scientific advisory services are provided by an organisation which does not exclusively focus on SMEs, but rather on all sizes of private sector firms. An example of this is the Relay Centre Network which has been established in Italy.

It is difficult, given the lack of clear criteria for identification of success, together with the lack of assessment studies which have been undertaken, to reach a clear judgement as to which of these organisational forms are the most appropriate. On balance, our judgement would probably be that, from the viewpoint of SMEs, they would feel happier approaching an information source which was exclusively directed towards their needs, rather than one better known for providing information to larger enterprise. There would therefore appear to be a case for specialised technological advisory services in specialist organisations. It also seems appropriate for these organisations to provide information that is not exclusively scientific or technological, but also to be prepared to either provide managerial and other forms of assistance within the organisation or be able to guide the SMEs (NTBFs) to suitable providers. The fundamental problem which SMEs have is their inability to digest information which is provided for them. Assistance therefore has to be provided with this digestion process in mind to enable it to be fully effective. It would seem that this is more effectively undertaken in an organisation which specialises in SMEs, rather than one which specialises in scientific information.

The current trend in Europe is for advisory services to be housed in a 'one stop shop', as illustrated by the creation of 'Enterprise Houses' in the Netherlands and Business Links in the UK. The powerful role of Chambers in Germany and Austria also illustrate this point. The central problem is that NTBFs are different; their problems differ, their typical founder differs from those in new firms generally, their financing differs and their information requirements differ. It is therefore appropriate to question whether the trend not to differentiate NTBFs from other SMEs is wise.

<u>In Conclusion</u>

It is difficult to reach a judgement on the effectiveness of delivering information and advice to NTBFs. In part this is because of the absence of clear criteria by which such services are judged to be valuable; it is also hampered by the absence of thoughtful and well-conducted evaluation studies.

Despite these problems, there is a clear recognition that owners of NTBFs do appreciate the information and advisory services provided. The central policy questions are the extent to which these services should be provided by the public purse, and the extent to which the firms themselves should pay. A second policy question is the extent to which these should be provided by SME-related organisations, as opposed to organisations assisting all sizes of enterprises. Thirdly some countries prefer to combine advisory services within the same organisations which provide financial assistance whereas others treat NTBFs as a separate group - often combined with larger technology-based firms. Finally, some combine technological and managerial advice within the same organisation; whereas others keep them separate.

The considerable diversity of forms or organisation of provision of advisory services implies the absence of clear benefits of one particular format. It illustrates the need for more careful, policy-relevant research in this area.

Part IV

SUMMARY AND POLICY RECOMMENDATIONS

1. SYNTHESIS AND POLICY IMPLICATIONS

It is almost 20 years since the Arthur D Little Consulting Group produced its path-breaking report on new technology based firms (NTBFs) in the United Kingdom and West Germany. Its broad conclusion was that, in comparison with the United States, there were significantly fewer NTBFs per head of population in both the UK and West Germany. Furthermore, the European firms which did exist were generally smaller and less likely to exhibit substantial growth than those in the US.

Twenty years later our review suggests, in these respects, little has changed. In the US over that period firms such as Apple Computer, Intel and Microsoft have grown from nothing into household names. Europe has no comparable 'success story' in this area.

This report documents carefully the development of new technology-based new firms in 16 European countries and points to some factors which constrain the development of these types of firms. It devises a new methodology for assessing the contribution of NTBFs and concludes by emphasising that, if matters are to change in the next twenty years, policy needs to recognise the 'special' characteristics of NTBFs.

Key Findings from the Analysis of Europe's High Technology Sectors

The definition of new technology based firms is problematic. Some authors argue that the term should only be applied to a rare breed of new and young firms which are at the forefront of advanced technological developments. This report uses a much broader definition, counting all new firms established in the high technology sectors as new technology based firms.

However, because data on company age is not generally available, it is not possible to isolate, for most European countries, the contribution of new firms (as opposed to established firms) to employment creation and other economic phenomena. For this reason, Part II of the report did not assess the economic impact of new technology based firms, but instead analysed the evolution of the high technology sectors in Europe and commented on the changing contribution of small, medium sized and micro firms to employment within these sectors. Most of this changing contribution was due to the entry and growth of new firms.

Despite these definitional problems, the analysis revealed some important findings:

- During the 1980s high technology manufacturing employment in Europe as a whole actually fell. This was largely due to the contraction of the electronics sector, but was not the case for all countries. In Austria, Denmark, Finland, West Germany, Luxembourg, Ireland and Norway high technology manufacturing employment increased, but it declined in Belgium, France, Italy, Portugal, Spain, Sweden and the UK.. Given that the high technology sectors are expected to be an important source of future employment, this is a remarkable result.

- Despite the decline, in many countries, in employment within the high technology manufacturing sectors, the total number of enterprises in these technology-based sectors increased in almost all countries. In some countries the increase was 50% or more over the decade.

- *A priori*, over a decade new industries were expected to grow, both in terms of the number of active firms and in terms of the industries' total employment. We called these Type I industries and expected most of the high technology sectors in Europe to be Type I industries.

- Despite these expectations, the evidence showed that whilst in some countries technology based industries were generally Type I, there were many other countries in which they are not. In particular, there were many countries in which several or most of the high technology industries were Type IV; that is, industries in which there was an increase in the number of enterprises, but a decrease in the total employment.

- Over the 1980s, West Germany distinguished itself by the fact that all of its high technology sectors were Type I. Other countries with a large number of Type I sectors included Austria, Denmark, Finland, Ireland, the Netherlands and Norway.

- By contrast, especially in Belgium, France and the UK, there were a large number of Type IV sectors - i.e. sectors in which there was an increase in the number of firms but a decrease in total employment. Following from this, it is probable that the high rate of new firm formation in the high technology manufacturing sectors in countries such as the UK has at least as much to do with 'negative' factors, such as the down-sizing of large companies, as it has to do with 'positive' factors, such as the entrepreneurialism of the founders of the new businesses.

- In contrast to the high technology manufacturing sectors, the high technology services sectors were much more likely to be Type I. Within manufacturing, whilst the office equipment and computer manufacturing sector and the pharmaceuticals sector tended to Type I, the electronics and instruments sectors were Type I and Type IV in different countries.

2. POLICY ISSUES

Three key policy issues are discussed in the report.

- the Supply of Entrepreneurs
- Financing of NTBFs
- Public Policy Frameworks

i) Supply of Entrepreneurs

Although in most EU countries there has been an increase in the number of enterprises established, European countries need clearly to do significantly more to increase both the quantity of individuals prepared to become entrepreneurs and to enhance the quality of the businesses which these individuals establish. This review points to several issues on the supply side which require attention.

The first is the key issue of increasing the throughput of PhDs. It is increasingly likely that in the future the creation of technology-based firms at the leading edge of knowledge will require individuals educated to the highest scientific standards. Only these firms will have the ability to transform societies and market places.

Secondly, it has to be recognised that a PhD is not exclusively a passport to academic life. Individuals with doctorates should be entering the private sector as well as research institutes and universities. Furthermore, they should be encouraged to recognise that within a conventional 'career path' they can to seek to commercialise their research ideas. Universities and research institutions should remove the barriers which prevent the commercialisation of research ideas by their employees. Indeed, the universities should even highlight as 'role models' individuals who may maintain a position within the university, but who are also seeking to commercialise research ideas.

Thirdly, efforts have to be made to combine the empirical skills of scientists and engineers the managerial skills of others who have experience in the private sector. Here science parks and technology support organisations can play a key 'marriage bureau' role.

Many of these developments are, of course, currently taking place. However, none occur with sufficient frequency. They also seem to vary quite markedly between EU countries. For example, Italy, amongst the larger EU countries, currently appears to have the weakest links between industry and the academic community. But all countries need to accelerate these developments considerably.

ii) The Financing of Technology-Based Enterprises

There is a fundamental difference between Europe and the United States in the extent to which the venture capital industry is willing to invest in early stage technology-based ventures. In the United States about three quarters of early stage funding focuses upon the technology-based sectors, whereas in Europe it is about one quarter.

Two contrasting reasons are offered to explain the comparatively low European figures. Those supplying the finance point to an absence of suitable projects, and particularly an absence of individuals with suitable managerial skills to make the project successful, as the key reason for the reluctance to invest. In contrast, those entrepreneurs seeking finance point to the technological naiveté of the financial community and the availability in Europe of comparatively high rewards for making investments in conventional sectors with which bankers are more familiar.

Our judgement is that there is some validity in both arguments. During the 1970s and 1980s, in both France and Sweden, there was clearly a willingness on the part of financiers to invest in technology-based smaller enterprises. Unfortunately, the results were so poor that financiers subsequently became very cautious about investing in technology-based firms. This emphasises that the selection of technology-based projects for investment is difficult. On the other hand, the evidence in this report from several European countries suggests that small technology-based firms have higher growth rates, and survival rates which are at least as high as those of small businesses in non-technology-based sectors. On these grounds, investment in technology-based new and small enterprises should be equally, if not more attractive, than investments elsewhere.

Our judgement is that, whilst few of the European ventures have the growth potential of some in the United States, the European financial sector at large currently lacks the expertise to distinguish the 'good' technology-based proposal from the 'bad'. There are, of course, some specialist firms with this ability. In general and in essence, investments in technology-based firms may be deemed more uncertain, even if they are not more risky. Bankers and financiers in Europe, therefore, because they generally lack the expertise, and that expertise is expensive to acquire, have tended to favour investments outside the technology-based sector. This serves to reinforce the difficulties experienced by technology-based new and small firms in raising capital.

Public policies to address these problems have, therefore, to focus upon reducing the uncertainty faced by financial institutions. This could be through the provision of public subsidies to cover the cost of assessments of technology-based proposals, or the further development of seed-corn funding for technology-based firms. Finally, of course, an increase in the supply of quality projects, as discussed in the previous section, would also serve persuade financial institutions to invest in this sector.

iii) The Public Policy Framework

This review documents the extensive range of financial and information support available to technology based firms in EU countries. Our strong impression, however, is that in many respects the 'special' requirements of new technology-based firms are not adequately reflected in the framework of support services available. In most countries, whilst support is available to new and small technology-based firms, the same support is available to other types of enterprises.

Yet, new and small technology-based firms are 'special' in two respects: they differ from other types of small firms; but they also differ from the larger enterprises in their sectors of activity. These differences are grounded in the fact that NTBFs are often seeking to cover the cost of undertaking research and development, the returns from which are likely to be long term and uncertain. This is because of the greater difficulty of making an accurate assessment of a new product/service than one already sold within the market place. Technology-based firms may also characterised by short 'windows of opportunity', so that, if investments are not made at the appropriate times, all may be lost. The characteristics of technology-based entrepreneurs are also fundamentally different from those in conventional sectors - they are much more likely to be highly educated, yet they often lack the managerial skills accumulated by entrepreneurs from other occupations.

Finally, and most importantly, these new technology-based firms have the potential to fundamentally transform the ways in which societies and markets operate. They are, quite simply, crucial to the long term development of an economy and in this sense deserve special treatment.

Our judgement is that policy makers have, in most European countries, failed to recognise the special qualities and requirements of new and small technology-based firms. Where policies have been focused exclusively upon these firms - as in Germany and the United Kingdom - the policies themselves appear to have been extremely successful. On the other hand, where they have been a comparatively small component of general industry or state support programmes, a positive impact upon these technology-based firms is more difficult to determine.

We therefore believe there is a case for governments to take new technology-based firms more seriously, in terms of formulating specific policies to nurture and enhance their development. Without such support, another report in twenty years time may well point to Europe having been overtaken not only by North America, but also by South East Asia and possibly other parts of the world as well.

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