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TECHNOLOGY TRANSFER, INFORMATION FLOWS AND COLLABORATION:

AN ANALYSIS OF THE C.I.S

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Technology Transfer, Information Flows and Collaboration: An Analysis of the Community Innovation Survey

(Final report, final draft)

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Table of Contents

List of Tables

Executive Summary

This Report explores the central role of information in innovatory activity. Innovation is defined as the introduction of products or processes that are known to the enterprise. The study examines information flows and technology transfer, both in a competitive and collaborative context.

The results are based upon data from the Community Innovations Survey (CIS). This is a major new source of information from around 40,000 firms in thirteen Member States. Information (and information processing ability) defines the core competencies of the organisation. It is a valuable asset which enable firms to undertake and successfully exploit innovative activity.

By way of background, the Report begins with a brief discussion of the role of information in the innovation process. This provides a definition and outlines the sources of innovation. It considers the various inputs into the innovation process and the associated decisions, including whether to "innovate at all" and whether to "innovate more". This raises the issue of the social optimality of the rate of innovation and, in particular, inadequacies in information as a barrier.

The Report continues by providing data concerning the extent of innovatory activity, which is useful as background to the study of information flows. In doing so, it raises a number of data issues, including the interpretation of international differences using results based upon qualitative (Lickert) scales.

During the course of the Report, the discussion touches on a number of debates which have occurred in the literature. These include issues such as

(i) whether inadequate information acts as a constraint or a barrier to innovation
(ii) are information problems greater for small firms as often perceived in the literature
(iii) R&D can be treated as synonymous with innovation
(iv) innovation is an economy wide or multinational system, rather than a 'stand alone activity'
(v) extent of buyer-supplier chains outside of sectors where these are traditionally recognised as important (as in the case of the motor vehicles industry)
(vi) the ease with which the benefits of R&D and innovation can be appropriated by the firm
(vii) the types (and effectiveness) of protection used by firms for their knowledge
(viii) trade secrets are likely to be (relatively) more important for process than product innovations and for smaller than for larger firms
(ix) the extent to which trade secrets and patents are used as forms of protection
(x) the degree to which patents act to aid or restrict the flow of information about inventions

Information and the Innovation Process

The results suggest that information constraints are important, but, for most countries not as important as other (mainly economic) barriers to innovation. Inadequate information about markets appears somewhat more of a problem than a lack of technological information.

The overall figures, however, hide an important feature (which is consistent with other authors' work), that information problems appear to be greater for innovators than non innovators. However, this result also holds for other types of hinderance to innovation. Either the act of innovation makes firms more aware of such problems or it makes the barriers more acute. However, it suggests that it is not the presence of such hindrances that act as a major deterrent to innovation.

The results, somewhat counter to the arguments expressed in the literature, suggest that information problems are, generally, more acute in larger than smaller firms. Multivariate analysis indicates that this is not a reflection of a lower level of innovative activity amongst smaller firms. It also hints that the policy emphasis of increasing information flows for SMEs (at least relative to larger firms) may be misdirected.

The country and industry results are reasonably consistent across different forms of information problems, although they are not always easy to interpret. There is some evidence that Luxembourg, Greece the Netherlands and Portugal tend to have less problems than Belgium, Spain and Ireland. Coal mining, publishing and printing and public utilities tend to report less problems; there is more variation across sectors reporting problems, depending upon the type of information concerned.

The Report also explores the influences on various forms of innovatory expenditure, particularly those that relate to knowledge generation, such as R&D, patents and licences, product design and market analysis. A first, but important result is that R&D is not synonymous with total innovatory expenditure. Second, R&D as a proportion of total innovatory expenditure increases with firm size, but decreases with the absolute (log) value of R&D expenditure. In other words, firms with larger R&D expenditures spend disproportionately more on other aspects of innovation.

Of the other forms of expenditure, product design is, on balance, one of the most important, although it shows considerable variation across countries. Market analysis and patent/licences are more similar in relative importance, although the former exceeds the latter for most countries.

The results relating to the balance of internal *versus* external expenditure suggest that the latter is important, constituting about 20 per cent of the total of innovatory spending. This suggests that innovation is an economy wide (or a multinational) rather than a 'stand alone' activity. Thus, it may not be enough to direct policy exclusively at individual firms.

Sources of Information for Innovation

Firms use a wide variety of sources of information for their innovation activities. It appears that firms in some countries on balance tend to make more use of all sources than those in other countries. Belgium placed most emphasis on information and France the least.

The survey provided information about thirteen different sources of information. The results showed that there was a considerable degree of consistency in the relative importance of these across countries. In particular, although not surprisingly, the 'within enterprise' source was generally the most important source. However, a number of external sources were also very important, including suppliers of materials and components and of equipment, as well as clients and customers. Thus, the results provide considerable support for the importance of buyer-supplier relationships and chains. A more unexpected source of information was fairs and exhibitions. A number of countries ranked this source in the top two sources and eight countries ranked it in the top five.

In some instances there were clear expectations that particular sources would differ in importance across firm sizes. Internal sources tend to increase in importance with firm size, but this should not be taken to be an indication that external sources become less important. Indeed, the principal result was that, taken overall, more importance was attached to information *per se* by larger than smaller firms.

With regard to the other twelve designated sources, however, *a priori* there was not always a clear expectation that the importance of the source in question would vary one way or the other with firm size. One obvious exception was that patent disclosures would be more important for larger firms, which are known to be much more active in their use of the patent system. This result was confirmed comprehensively by the data. There was some evidence that 'clients and customers' were considered to be more important sources of information by medium sized enterprises (between 100 and 500 employees, depending on the country in question), rather than by the largest firms. In the case of suppliers, the relationship with firm size was less consistent, presumably reflecting international differences in the supply chain relationships. However, the results did provide evidence of positive relationships between firm size and the following sources: consultancy firms, universities and higher education institutes, government laboratories, technical institutions and (as noted above) patent disclosures. The clearest evidence for a negative relationship occurred in the case of competitors which tended to be ranked as a more important source by small than large firms in the majority of countries.

There were important industry differences both in terms of the overall importance of information and in terms of the relative importance of different sources. The results suggest that a number of non-manufacturing sectors find information particularly important. With hindsight, some of these do not appear too surprising, such as manufacture of wearing apparel (ie. elements of the fashion industry), sale and repair of motor vehicles, etc. Some of the rankings of particular sources by industry, however, are not obvious and require some further consideration.

Technology Transfer

The discussion of technology transfer examines both the mechanisms used and the spatial distribution of inflows and outflows. Eight main different mechanisms of transfer were considered in the CIS. The spatial aspects were broken down by various European and non European sources and destinations.

As a general conclusion, firms appear to make use of a wide range of channels for technology transfer. The relative importance of these mechanisms differ between inflow and outflow. However, as we have noted, there is a considerable degree of consistency across countries in the principal routes for both the inflow and outflow mechanisms, although there is less agreement on the emphasis placed on other routes. As might be expected, the most important source of inflow was the 'purchase of equipment'. The most important mechanism of outflow was 'communication with/specialist services provided to other enterprises'. However, other sources were also important, such as 'results for R&D contracted out'. In addition, considerable emphasis was placed on the role of specialist information, including the employment of highly skilled employees, which is consistent with the broader literature in this area.

The spatial distribution of sources and destinations are especially interesting. National sources and destinations are both very important for all of the mechanisms of transfer analysed in detail (although this is still consistent with firms being part of a broader innovatory network - rather than stand-alone units). However, some countries are clearly more integrated in a European context, such as Belgium, Luxembourg and, apparently, Ireland. In addition, there is clear evidence that technology appears to flow from the higher technology towards the lower technology blocs. Examples of this can be found in the fact that both 'non EC European' and 'other' countries tend to be much less important sources of technology than destinations.

The precise results differ between the different transfer mechanisms in question and between countries. In the case of the 'right to use inventions', for example, the USA and Japan figure more highly as sources than in the case of the 'purchase of equipment' or 'communication with/specialist services from other companies'. In addition, the UK and Ireland appear to exhibit stronger links with the USA than most other countries.

Appropriability, Intellectual Property and Information Flows

Appropriability - the extent of a firm's ability to protect the new knowledge contained in any advance - is crucial to the decision to invest in invention or innovation. It is often claimed, for example, that inventive steps are expensive to produce, but cheap to reproduce. Thus, firms that cannot protect their advances are at a cost and therefore a competitive disadvantage *vis á vis* imitators.

The CIS collects information about a wide range of mechanisms that firms can use in order to protect their intellectual property. Perhaps the most widely available form is trade secrets. However, the Report points out that all the alternatives have both costs and benefits, and firms will chose a level and mix that they find most cost effective. In the case of registered forms of IP protection, such as patents, for example, there are not only administrative costs, but also the costs of the disclosure of the novel part the invention. As noted in the earlier part of the Report, patent disclosure is not a high ranking source of information, but it is more important for larger firms in particular industrial sectors.

An important part of the general discussion helped to outline the strengths and weaknesses of the CIS in this area. In particular, it was noted that, while it covered a wide range of different mechanisms, nevertheless, there were no questions on other forms of protection for intellectual property, such as copyright (which might, for example, be important in the area of computer software, publishing, musical recording, etc.).

The importance attached by firms to the problem that innovations are 'too easy to copy' increases with firm size, is more important amongst innovators than non-innovators and varies both across countries and industries. Germany and Spain report more significant problems, while the Netherlands and Luxembourg appear to place less emphasis on such problems. As for industries, ease of copying appears least important in coal mining and quarrying, but more important in manufacture of machinery nec and manufacture of office equipment and computers. Nevertheless, there seems to be no definitive link between, say, level of technology (or technical change) and ease of copying, and there is no clear evidence that such problems act as a major barrier to innovation.

It seems that respondents have interpreted the question in the light of the range of mechanisms already available and, it may well be, that such forms of protection are adequate in areas where otherwise there would be problems. Nevertheless, there is some indication that the problems are more important in higher than lower technology areas.

A key result is that, in absolute terms, large firms report all forms of protection to be more effective than small firms. The difference in reported effectiveness between large and small firms, however, differs between the mechanisms used for protection. Hence the Report spends some time in discussing the routes which smaller firms find to be relatively more important.

One of the hypotheses suggested above was that the literature hinted that trade secrets would be (relatively) more important for process than product and for smaller than for larger firms. This was based on two hypothesis. First, that more information is available about product innovations which makes them easier to copy and 'reengineer'. Second, that trade secrets are a 'low-cost' alternative. Neither of these hypotheses are confirmed by the data. Trade secrets are rated of almost equal effectiveness for both product and process innovation. In addition, trade secrets are rated more important by larger firms both in absolute terms and relatively to other forms of protection.

The effectiveness of a number of the other forms of protection also vary with firm size. Not surprisingly in the light of the earlier discussion, the effectiveness of patents is positively related to size. Indeed, patents are one form of protection that are relatively more important *vis á vis* trade secrets for large than for small firms. The route which small firms find to be relatively more important than large is in terms of lead-time over competitors. This corresponds with our *priors* about the speed and flexibility of smaller firms compared with their larger counterparts.

Again, there is some evidence that suggests that certain industries tend to find all (or at least most) forms of protection more effective across the board. However, there are some important differences in ranking across industries by type of protection for both product and process protection. The industries which tend to figure quite frequently in reporting the various forms of protection as effective include a number of the chemicals and metal products sectors. The results for product and process protection tend to be closer together for the chemicals sector (where more of the equipment is probably sector or product specific and designed within the sector) than for the metal products industries.

Cooperative R&D Agreements

The final section of the Report considers various forms of cooperative agreements, in particular joint R&D projects. This is particularly interesting from an European perspective, given the EC's Framework Programmes that encourage various forms of cooperative and collaborative international networking.

The principal result is that cooperative arrangements are widespread. Taken overall, they appear to be more common in the UK and Denmark than elsewhere, but when the sample is restricted to innovators alone, France stands out as having more cooperative arrangements, although they remain important in Denmark, the UK, Netherlands and Norway.

Exploration of cross-tabulations reveals no simple correlations with various hindrances, including 'lack of opportunities for cooperation' itself. However, there is a very clear monotonic link between the incidence of such agreements and firm size. While under five per cent of firms with less than 50 employees have such agreements, this figure rises to 60 per cent for firms with over 1000 employees. In addition, innovators are significantly more likely to be involved in cooperative agreements than non-innovators - a result that is consistent across all countries in the sample. Thus, it seems likely that cooperation may be a mechanism for achieving or aiding innovation (although innovation may itself stimulate cooperation in some instances).

The spatial distribution of research joint ventures is likely to have been stimulated by EC programmes. Nevertheless, cooperative arrangements are much more common with local (regional) enterprises (48 per cent), compared with almost half that amount in national agreements (just over 24 per cent). Nevertheless, a considerable proportion (9 per cent) are in non-national EC agreements. Agreements with the USA and Japan are more rare (around 3 per cent for both). Indeed, agreements with other countries, including European non-EC and non-European 'other' have more agreements, although, from what we have said earlier, these may be more associated with technology outflows than inflows.

Chapter 1 Information and the Innovation Process

1.1 Introduction

Innovation and technical advance are seen by many as the key to economic prosperity and well being. In addition in a competitive world economy, if firms in other countries are innovating when domestic firms are not, then the resultant loss of competitiveness will mean reduced output, productivity, wage flows and profit flows in the future. Thus, not only is innovation seen positively as the key to prosperity, but, also, the counter factual to investment in innovation is not the *status quo*, but a declining position in the world economy and a loss of economic prosperity. It is precisely for these reasons that there are international concerns that economies should improve their technological performance. Most governments (and most commentators) believe that the rate of innovation is sub-optimal, and that there is considerable scope in most, if not all economies, for it to be beneficially increased.

The Community Innovation Survey enables a much more detailed picture to be painted of the constraints upon innovative activity in Europe than has previously been possible. The aim of this Report is to focus on those aspects of the CIS that relate to technology transfer, information flows and collaborative behaviour in the innovation process. In this particular Chapter we begin with a definition of innovation and an overview of the innovation process (the theory of innovation) addressing the particular role of information related activities in this process. At the end of the chapter we lay out how the remainder of the Report provides further insights through an empirical investigation of the role of information activities, and also how the Report addresses a number of key policy issues.

1.2 Defining Innovation

Innovative activity in its broadest sense concerns "doing something new". It is most useful if this is interpreted as new to the unit of observation under consideration rather than new to the world as a whole ("local" innovation as opposed to "global innovation" as defined by Stoneman, 1992). This distinction between local and global innovation is useful for it enables the diffusion phenomenon to be discussed as a process of local innovation.

Innovation is not just the preserve of the supply side of the economy (ie private firms and public corporations) but is practised by other sectors of society including government departments and households. In fact it may well be that it is the innovatory behaviour of these other sectors on the demand side (ie purchasing new products) that generate the profits which provide the incentive for firms to be innovative and to launch new products. The CIS is however, concerned almost totally with the supply side of the economy, its objective being,

> "to collect firm level data on inputs to and outputs of innovation processes across a wide range of industries and member states and regions" (EC, 1994, p.14).

In this more limited framework, innovation can be defined to encompass firm/enterprise level activities that lead to the introduction of products, production processes, management methods and raw materials (Schumpeter, 1934) that are new to the unit under observation.[1] From this list the survey concentrates on new products and processes as the key defining elements of the innovation process.

The act that defines a firm or enterprise as innovative will thus be the launch of a product different from those previously offered by the firm or the introduction of a new or modified production process. Frequently such product and process innovations go hand in hand, with new products being produced on new processes and new processes producing different products. An episodic view of innovation will however be misleading. Although the launch of a new product or the introduction of a new process may well identify an innovative activity, it is probably more realistic to consider that firms continuously innovate, launching a continuous flow of new products and introducing a continuous flow of new processes.[2] Firms then primarily differ in terms of the rate of flow of innovations generated and introduced.

1.3 Sources of Innovation

The sources of innovation for the firm are many and varied. The classic picture is one in which the firm generates new technologies from its own R&D and then proceeds to introduce them. Improvements in technology over time then result from further R&D spending. Such a conceptualisation is not only too linear but probably also overplays the role of own in house R&D in the innovation process (an issue we return to below). Firms may in fact obtain technology from other (non R&D) activities within the firm as well as from outside the firm. Amongst the list of potential sources are:

Capital goods suppliers. In many cases new technology (especially new process technologies) may be incorporated in new capital equipment (eg robots) and, in general, the principal way to acquire such technology is from capital goods suppliers.

Licensing and technology agreements. Firms may make arrangements with competitors or other firms and organisations (eg technology development companies or consultancies) to acquire technology from them.

Copying. A firm may acquire the technology of competitors, for example, through reverse engineering or other similar activities.

Other internal activities. A firm may well generate improved versions of products and processes, for example, through design activities, learning by doing or learning by using.

Joint ventures. The firm may also extend its technology base through collaboration with competitors, suppliers and non market organisations (eg higher education institutions, HEIs)

The point is that firms do not exist in isolation, they are part of system. Within an economy there are many different organisations developing new technologies, each of which is, at least potentially, a source of technology for the firm. By the same reasoning the firm itself may also be a source of technology for other firms and organisations in the economy.

1.4 Inputs to the Innovative Process

Innovative activity does not occur by chance (despite the apparent assumption to the opposite in much of the mainstream economics literature). Innovation is an activity that requires inputs, often of a specialised and non routine nature. The essence of innovation is that it involves the unit of observation doing something new. Innovation is therefore, by its very nature, a risky activity - often the inputs and costs cannot be known with certainty and the outputs can only predicted with some imprecision. One should expect with a risky activity that there will be failures as well as successes, and in many cases it may not even be possible to precisely state the probability of success.[3] There may be many innovations that do not succeed (for example it is often quoted that 95% of new product launches fail). It is thus worth stressing that the CIS survey is primarily concerned with the extent rather than the success of innovative activity.

The innovative firm requires a variety of inputs. Prime amongst these is information. There are many different types of information that are relevant to innovatory activity:

> Technological. What is scientifically or technologically possible, what is already available in the public domain, what can be provided by capital goods and other suppliers and what is already protected by patent and other mechanisms.
>
> Market. What customers are willing to pay for and accept, what regulations and standards exist in markets, competitors and their activities.
>
> Benchmarking. The alternative costs of different information acquisition routes and, perhaps of key importance, information concerning the firm's own capabilities relative to those of suppliers and competitors. Given that this Report focuses on information, such issues are discussed more fully below.

In addition to information, the prime inputs in to the innovative process are: skilled labour; machines or capital; finance; and managerial time.[4] Clearly the innovative activity of a firm is likely to be be constrained if it is unable to access such inputs.

Skilled labour may be required at a number of stages. There may be internal R&D to be undertaken, or externally acquired knowledge to be interpreted and exploited. The operation of new capital equipment may also require particularly high levels of skills, at least in the initial stages. There is considerable evidence that skill shortages and gaps, constrain the innovative activities of the firm.[5] Firms which do not have adequate skills in house may have to undertake training or acquire them on the open market (if those skills are available).

The "machine" input in to the innovation process can appear at a number of different stages. The R&D process may itself be capital intensive. Alternatively, new technology may be embodied in newly purchased machines (as in the previously quoted example of robots). Acquiring technologies from capital goods suppliers can involve complex customer supplier relationships, the nature of which may spread across a spectrum from "off the shelf" purchasing through to complete product customisation. In the case of complex technologies, the acquisition process may be long and may involve contractual arrangements. Even with off the shelf purchasing, extensive adaptation may be required in order to make the technology match the firm's own particular needs. There may also be a considerable learning process, with the workforce only slowly acquiring the skills required for the machinery to operate at its full potential.

Innovation is an investment activity involving definite expenditures today for an uncertain return in the future. The expenditures may require an outlay upon R&D, the acquisition of new capital goods and/or the purchase of technology (and information) from outside the firm. Such investment activity requires funding, which may come from retained profits, bank borrowing, other debt or equity. Only if such funding is available can innovation proceed. There is a large and extensive literature concerning the problems of funding innovation and the associated issue of "short termism". This literature encompasses issues of information asymmetries between lenders and borrowers, moral hazard the completeness of insurance markets and related topics. Despite the importance of the financing issue, it is not part of our remit and we do not pursue it further in this Report.

The final input that we have identified is management. Although it has often been ignored, it is probably one of the most crucial. The innovation process must be managed. Management activity is directed towards ensuring: the (cost) efficiency of the innovation process itself; the direction of innovation and its relationship with market needs; and the necessary organisational changes that may be required to operate new systems effectively. Management input is not costless, however, and there may be limits to the extent of time and effort that can be devoted and, thus, the level of innovative activity that a firm can reasonably undertake. Such problems are compounded where there is a lack of management knowledge, skills or abilities, which may mean that the existence of such barriers is not even recognised.[6]

1.5 Innovation Decision

The innovative firm does not live in a vacuum. Firms exist in a national and international economic environment where international market and policy developments also create new opportunities and threats. As already stated with regard to sources of information, firms also operate within national, international and even global innovation systems. The firm is surrounded by other organisations that are undertaking innovation and, thus, changing its opportunity set.

In a market economy the incentive for a firm to innovate is provided by the net (of costs) gain in profits that arise from its innovative activity. This gain is equal to the profits that arise after innovation relative to what profits would have arisen if that innovation had not occurred. The crucial point is that such counter factual profits are not be the same as current profits if other firms are innovating.[7] Innovation by competitors reduce the profits of the firm. In a competitive environment, where other firms are innovating, the firm must therefore innovate to in order to stand still. Only achieving a level of innovative activity that puts a firm ahead of its rivals allows it grow and be more successful.

The firm has three interrelated innovation decisions to make: whether, when and how much innovation. For the first, one would expect that the firm would innovate if such innovation would yield a return greater than the risk adjusted cost of capital (the risk being that associated with the innovation project). On the second, the firm would need to take account of the expected innovative behaviour of rivals and the impact of early or late innovation upon the costs of innovation, the risks attached to innovation and the impact of early or late adoption on revenues. On the third decision, the firm would need to consider its ability to undertake innovation, the problems of market acceptance of innovation and again the behaviour of rivals. Such decisions are inherently complex. To state the optimality condition as that, "the firm should innovate at that date when innovation will yield the greatest expected net return (if that rate of return is greater than the risk adjusted cost of capital) and innovate until the rate of return is equal to the risk adjusted cost of capital", is to reduce a complex series of decisions to a what is a simple but probably an inoperable rule.

1.6 Social Optimality in Innovative Behaviour

Nevertheless, a decision rule of this type helps to concentrate the mind upon conditions that may limit the innovative behaviour of firms. One would thus not expect firms to undertake innovation if it is not profitable. Nor would one expect firms to innovate earlier if the effect is to reduce the return to innovation.[8] There is therefore a limit to the rate of innovation that one would expect to observe in a free market economy.

We have already noted that, innovation is an investment activity. The process involves costs today with the (uncertain) prospect of returns in the future (over perhaps a number of years). A typical innovation activity therefore means reduced profit for the firm today and the prospect of increased profits in the future. With such a time profile of returns there will be limits to the level of innovative activity that shareholders or society in general wish to undertake, not only because of the risks involved, but also because any such investment activity must mean reduced consumption (through reduced dividends or wages and/or retentions) today in the prospect of more tomorrow. Given positive rates of interest and time preference there will be limits beyond which society will not wish to take less today in the hope of more tomorrow.

However if investment in innovative activity is too low then firms and or society may actually suffer a fall in consumption in the future, because, in a competitive world economy, if other firms and countries are innovating when domestic firms are not, then the loss of competitiveness will mean reduced demand, output, productivity, wage and profit flows in the future.

Nevertheless, a casual interrogation of the available information and results suggests a number of stylised facts. First, that innovation performance has been central to international competitiveness and the generation of employment opportunities. Second, that innovation performance has been very uneven across European countries. Third, that, on balance, European countries have underperformed compared with a number of key industrial competitors, such as Japan.[9] Fifth, that new sources of competition are emerging, particularly amongst Asian Pacific countries.

It is for such reasons that it is commonly believed that there is considerable scope for the rate of innovation to be beneficially increased in all economies. This belief is rarely attributed to the view that firms do not wish to pursue profitable opportunities. Instead it is more common to argue that there are constraints upon firms that prevent them pursuing profitable innovation opportunities which would be achieved in the absence of such barriers. It is the presence of such constraints that we consider in the next section.

1.7 Information and Other Constraints upon Innovative Activity

It is clear that, if the firm is unable to raise finance, cannot acquire skilled manpower, or has insufficient management capability, then it may not be able to undertake the innovative activity that it would otherwise wish to do. There are however a number f constraints surrounding information that may also act to limit a firm's innovative activity. As these are the prime concern of this Report we spell them out in more detail.

It is necessary to be careful when discussing information in the context of innovation for it has often been the practice in the past to define innovation as the provision of information (eg Arrow, 1962). In this context however, something different is meant. In order to illustrate this point, it is necessary to further discuss the concept of innovation.

As defined above, innovation may involve the development of new technologies (products, processes etc) within the firm or the purchasing of such technologies from outside the firm or some combination of both. The information requirements of such activities are multidimensional. There are requirements with regard to market perceptions of new product specifications, standards and regulation requirements (especially on overseas markets), compatibility issues, price responsiveness, as well as the specifications prices and performance of competing products etc. In R&D there are information requirements relating to basic scientific knowledge upon which advances can be built, the more technological knowledge of engineering new products and processes, and the knowledge relating to the ability to transfer ideas from the laboratory to the production system. If new processes are being brought in then information requirements encompass at least an understanding of the new technologies and their operation and capabilities. Putting new processes into the workplace and/or introducing new product specifications raise numerous information issues relating to how, at what cost and with what impact. There are also questions relating to the organisational changes that may be required to operate new systems effectively. Without such information (or at least some means of obtaining such information) the firm's innovation process may well be constrained.

The information base of the organisation (which is getting very close to the concept of core competences of the organisation - see Cohen, 1995) is clearly a key issue in the innovative process. It underlies the ability of the organisation to undertake innovation and thus the extent of the innovation that it undertakes, as well as the capability of the organisation to obtain returns from innovative activity (which one would expect to feed back upon the extent of innovation). Thus, according to Metcalf,

> "In quite a fundamental sense, innovation and information asymmetries are one and the same phenomena. Indeed, such asymmetries can scarcely be termed market imperfections when they are necessary conditions for any technical change to occur in a market economy". (Metcalf, 1995, pp. 412-413.)

Information (and also information collection and processing capability) is therefore a valuable asset to any organisation for it enables the firm to undertake and successfully exploit innovative activity. In a market economy, however, information is doubly valuable, for the return to a firm from innovatory activity will be reduced if rivals also innovate (except in rather special environments where technologies exhibit network externalities). By implication, if one firm has information enabling it to innovate and a rival does not, then the innovator will be more highly rewarded. This has long been recognised in the literature especially as it relates to intellectual property rights (IPRs) in new products and processes.

Although knowledge of the technical specification of a new product or process may not of itself be sufficient to enable a rival to innovate (see Pavitt, 1995 who argues that other information and abilities are also required), it is a key piece of information. Precisely for this reason, all market economies have a patent system, the purpose of which is to protect such intellectual property rights.[10] The rationale for patents is to protect advances in knowledge (for a limited period) so that the inventor obtains a return for undertaking the activities that lead to such advances. The cost however is that the system denies the free use of such advances in knowledge by others and, thus, during the life of the patent, may slow the rate of innovation elsewhere. On the other hand, one of the prices that the inventor pays for such protection is the disclosure of the information and knowhow contained in the patent.

While imitation has the effect of reducing 'dynamic' incentives, it generally has positive 'static' welfare benefits as the less advanced 'tail' of companies catch up with best practice. This highlights the crucial welfare trade-off between static and dynamic benefits that underlies the optimal design of IPR laws. In essence the problem is one of providing sufficient incentive to invent and innovate without giving rise to restrictive business practices that damage other companies and consumers. A classic example concerns the length (and breadth) of patent protection. If patent life is set too short, there is insufficient protection to ensure investment in innovation. If it is set too long (and too broadly) then a single company benefits in terms of its excessive monopoly power and this causes damage to other companies and to consumers.

The question of protection is not quite as simple as this discussion suggests. Even where IPR protection is sufficiently strong to prohibit imitation, it does not preclude the use of the underlying technical knowhow for other purposes. Indeed, a basic principle of IPR law is that protection is given to some industrial or commercial manifestation of the invention in return for disclosure of the underlying technical knowhow. Thus, the outputs of earlier creative activity contained in scientific papers, patent specifications, etc. form the input into current research,

> "... the routine and systematic use of the existing knowledge base .... has given rise to a new economy in which the central organisational factor in the process of technology creation is the ability of the system to distribute knowledge so it can be recombined." (OECD, 1994, p. 120.)

It is an interesting policy issue whether IPR laws currently fulfil this role effectively (*op cit.*). What seems to be much more important from a welfare viewpoint is not whether a company has a monopoly over an invention, but whether it has a monopoly over the inventive process that precludes other firms being innovative. A monopoly over the invention process (ie. from too broad a patent) has severe consequences from an evolutionary perspective where the generation of diversity from which selection takes place is crucial (Metcalf, 1995).

Information acquisition is costly. Even if the information is, in principle, available free of charge, its effective assimilation and use, as a minimum, generally require the employment of qualified and skilled employees.[11] As we have noted, patent disclosure is one source of technical knowledge, although its industrial coverage is limited and it rarely gives economic or commercial information about the best way to exploit the advance. Such information may come directly from observing buyers, suppliers or competitors. Again, monitoring such flows generally require the employment of skilled and qualified individuals.

We have noted the potentially close links between information acquisition and the production of new knowledge. One mechanism for achieving this is *via* collaborative agreements. These may occur for a whole variety of reasons. The aim is generally to form a more efficient mechanism for the transfer of knowledge. This may have to do with the potential complementarities and synergies that can be achieved in the efficient use of information. While this may involve institutions and firms at different points in the supply chain (as in the case of much of the EC-funded research), it may also involve competitors at the same stage of the production process. For example, competitors may collaborate when the research is highly risky or where it is not clear whether the outputs will be relevant to their areas of activity and competence. In effect, companies are maintaining an option that enables them to continue in that research or to withdraw at a later stage, when more information becomes available.[12]

1.8 Study Objectives and Policy Issues

The prime objective of this Report is to analyse the data contained in the CIS survey as it relates to the role of information in the innovation process at the level of the firm. In Chapter 2 we begin with a number of observations about the data. In subsequent chapters we attempt to do two things

(i) first, a "mapping" exercise, designed to illustrate revealed patterns in each of the areas studied

(ii) second, to explain the revealed patterns and to begin to address questions relating to why? This aspect of the study is limited primarily by the time and resources available. It is clear that much more can be undertaken with the data in the future.

As stated above, most governments believe that the rate of technological change in their own economy is sub optimal and they are concerned with improving innovative performance. The EU, on the other hand, is interested in increasing the rate of innovation in Europe as a whole. The first major policy issue that arises, therefore, concerns what is currently limiting or constraining the level of innovative activity in individual countries and in Europe as a whole. Given the emphasis of this Report, the extent to which informational inadequacies act as a constraint on innovative activity is of particular concern. This issue is explored in Chapter 3, which focuses on the relative importance of information and other constraints on innovation in Europe as a whole and across individual Member States. This is further developed by analysing whether information constraints are more significant in some industries than others and also for small as opposed to large firms. Both EU and national policies have emphasised the problems that face SMEs and it is therefore natural to explore this issue more fully. The discussion concludes with some comments about policy measures that might be taken to overcome information problems.

Further analyses of the data at the EU wide and country level and then by firm size and industry sector are reported in the other chapters of the Report. In Chapter 4 we address questions relating to the sources of information for innovation and technology flows. This analysis gives a rich picture of the nature of information flows in the economy amply illustrating the systems nature of innovative activity referred to above. The policy issue arising from information flows relate largely to questions of the appropriability and disclosure of intellectual property. Chapter 5 is devoted to these policy issues and, for example, addresses whether appropriability problems limit innovative activity, as the literature stresses, how well the patent system protects IPR, whether other forms of protection are more widely used or more effective, etc. Lessons for policy modification can then be drawn.

Chapter 6 is concerned with collaborative R&D agreements. In the pursuit of both improved technological performance and also enhanced European integration, there have been a number of significant policy initiatives at national and European wide levels to encourage collaboration between firms in innovative activity. This chapter explores patterns associated with such agreements and undertakes some preliminary investigations of the factors behind such patterns. Policy conclusions can then be drawn with respect to further initiatives that may encourage greater collaboration in the future.

Endnotes

1. An alternative source of innovative activity is the establishment of new firms rather than the innovative activity of established firms. This latter source is not covered by the CIS.
2. This may well differ between small and large firms with innovation in the former being more "lumpy" (see Bosworth and Wilson, 1988).
3. For a discussion of just how difficult such predictions may be, see Allen and Norris (1970).
4. Note that each of these has an informational component.
5. Bosworth and Dutton (1990) and Bosworth, *et al* (1992).
6. For a discussion in the context of UK experience, see Bosworth and Jacobs (1989) and Bosworth, *et al.* (1994).
7. For a detailed discussion, see Bosworth and Gharneh (1996).
8. For a brief discussion of these issues, see Tirole, (1990, pp. 389-421).
9. For a discussion of points two and three, see, for example, Patel and Pavitt (1995).
10. Patents are just one part of a much broader interlocking system of protection for intellectual property, which includes designs, trademarks, copyright, plant and seed varieties, etc., as well as trade secrets.
11. The comparative international, mainly case study work of the National Institute for Economic and Social Research leaves little doubt about the role of skills and qualifications in determining relative productivity - see for example, Prais (1993). A more dynamic view of the role of graduates can be found in Bosworth, *et al.* (1992).
12. Making public the knowledge contained in such advances in principle prevents wasteful repetition and updates the base upon which others can build.

Chapter 2 Data Issues and the Extent of Innovative Activity

2.1 Introduction

The data being analysed in this study has been subject to considerable "tidying and cleaning" by Eurostat prior to being made available for analysis (details of which are available from the documentation that accompanies the survey results). This process has removed many of the potential inconsistencies that inevitably result in a survey of this size. Other problems remain largely unresolved. These include differences in sample selection, with some countries attempting to obtain representative samples, while others focus disproportionately on innovating companies.[1] There are however two remaining data issues that merit comment and these are addressed in the next section. A key background observation is the extent of innovation taking place in European firms. Similarly a key differentiating factor between firms is whether a firm has or has not undertaken innovation in the sample period. An analysis of the responses to questions 1 - 3 in the survey provides data upon these two issues. These data are analysed in Section 3 of this Chapter.

2.2 Data Issues

A unique aspect of the CIS is the size of the sample, a feature which makes the survey is so informative. In Table 2.1 we detail sample sizes in the CIS survey by country. The most obvious deficiency is the size of the sample for the UK. With only 182 firms in the sample this represents approximately 4% of the relevant population. With such a small sample (and one biased towards innovators) any findings with respect to the UK must be treated with a considerable degree of caution. One alternative is to remove the UK data from the sample. We have resisted the temptation to do this and, throughout the Report, results are derived on the UK as for other countries. The UK results must thus be considered as having a "health warning" attached.

A second data issue is that many of the responses in the questionnaire are based upon a Lickert scale. Thus, for example, respondents are asked to respond to questions according to how a particular factor should be graded on the following scale

1 = insignificant
2 = slightly significant
3 = moderately significant
4 = very significant
5 = critical

It is recognised in the literature that there are particular problems with such scales. For example, "don't knows" tend to end up as registering a 3. In many cases it is better to have a six point scale so that the mid point cannot be chosen so easily. Some researchers have attempted to avoid such difficulties by using extreme scores. There can also be problems with this insofar as extreme cases may be "outliers", and it is not always clear which extreme should be used. Our approach has generally been to use the mean scores, but to check the results using regression analysis and, in some instances, comparing the outcomes with the extreme scores.[2]

In the present context however there is another issue. The survey, although confined to European countries, is multinational. Recorded differences in scores across countries may therefore reflect either the true inherent differences across countries or national characters and cultures in responding to an apparently common scale. If the latter is the case then differences across countries are very difficult to interpret. Differences are further compounded by the different sampling schemes and, hence, proportions of innovative firms (although this can, to some degree, be controlled for by separating the samples into innovating and non-innovating companies). We return to this issue in the next section. This possibility has therefore to be held in mind throughout the analysis below.

2.3 The Extent of Innovation

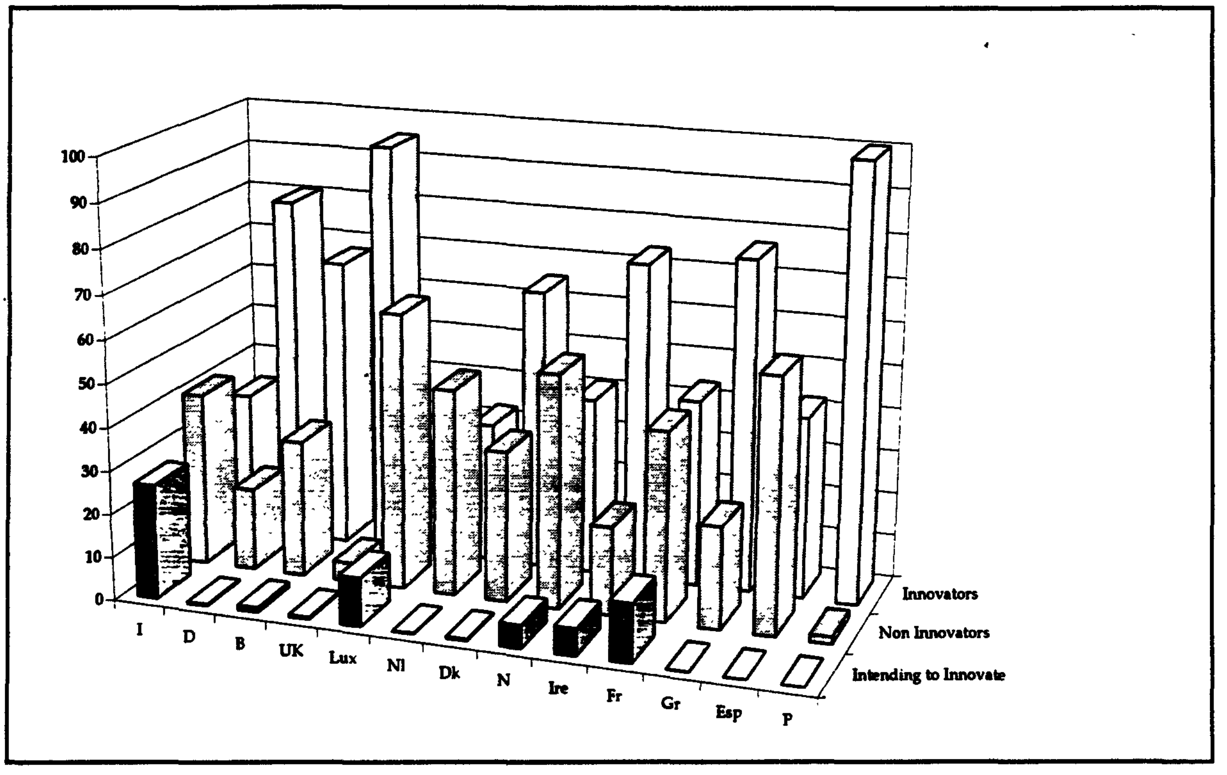
A key background observation to any report in this area is the extent of innovation actually taking place. Similarly a key differentiating factor between firms will be whether they are innovators or non innovators (in the sample period). Analysis of the responses to questions 1-3 in the survey provide data about this issue (see the questionnaire published in EC, 1994, pp 49-59).

Table 2.1 details the extent and nature of innovative activity across countries in terms of the number of firms in the sample undertaking product innovation alone, process innovation alone, both product and process innovation or have not innovated but intend to do so. By deduction one may also calculate the number of firms that have not innovated.

In Figure 2.1 we plot for each country: (i) the proportion of the sample of firms that have undertaken innovations in the period 1990 - 1992 (either product innovations alone, process innovations alone or both product and process innovations); (ii) the proportion of firms that have not innovated but declare an intention to innovate during the period 1993 - 1995; and (iii) the proportion of the sample that has neither innovated nor intends to do so.

It is not within the brief of this particular Report to analyse these data in any depth. The main reason for presenting the information is that it forms a background for the analysis that follows. We do however have some doubts as to whether a direct reading from these data of the proportion of firms undertaking innovation would be a good measure of the level of innovative activity taking place in each country, a point noted by other researchers using the CIS (see the proceedings of the EC *Innovation Measurement and Policies Conference*, Luxembourg, May, 1996). These doubts arise not only because of differences in the industrial and firm size composition of the samples in different countries, but also because of the different target samples (as we have noted, some countries innovating firms were over represented).[3] We may however, immediately observe two relevant points from either Figure 2.1 or Table 2.1,

Figure 2.1 Innovative Activity (as a % of the sample)



(i) innovators primarily undertake both product and process changes and, thus, very few firms undertake product or process innovation alone, and

(ii) except for Italy and France (and perhaps Luxembourg, but here the sample is small), firms that have not previously innovated have few plans to innovate in the future.

The first observation may imply that firms with the capability to innovate in one area (eg product innovation) will also have the capability to innovate in another area (eg process innovation). It may also be the case that the observation is telling us that rarely are product or process innovation separate activities, they do in fact go hand in hand. As far as the analysis below is concerned however, the data suggest that we should not expect to find major differences between firms that undertake product from those that undertake process innovation, because most firm that innovate undertake both.

The second observation, that firms that have not previously innovated generally do not plan to innovate in the future, may be an important one for policy makers. The data suggest that there are in fact two distinct types of firms. Those that have innovated in the past and will continue to innovate in the future and those that have not innovated in the past and have no plans to innovate in the future. If there are two such distinct groups then innovation stimulation policies may have to address them as such. Policies to stimulate innovation may have to exhibit two faces. The first would be a set of policies to get existing innovators to undertake further (more rapid) change. The second would be a set of policies to get non innovators to innovate. The instruments appropriate to the two approaches may be very different. It is interesting to note that Meyer Kramer and Soligny (1989) have explicitly analysed how much more difficult it is for policy makers to get non innovators to do so than to get previous innovators to do more.

Endnotes

1. This makes the issue of weighting to generate population estimates particularly problemmatic.

2. The regressions reported here are based on simple OLS results. In future work on the data we will move to ordered probits.

3. For example, the Spanish survey was terminated after two weeks and innovators may have been over represented amongst the early respondents. In addition, the Portugese survey specifically selected a high proportion of innovators.

Chapter 3 Role of Information and the Innovation Process: An Empirical Analysis

3.1 Introduction

The aim of this chapter is to explore in detail the role of information in the innovation process as illustrated by the returns in the Community Innovation Survey.

Chapter 1 argued that there are at least five main inputs in to innovation: skilled labour, machines, finance, managerial time and information. We also argued that, in the absence of particular constraints on these inputs, firms innovate up to the point where the expected return to innovative activity is equal to the (risk adjusted) cost of that activity. The first task undertaken here is to explore whether information constraints are binding on the innovation process in Europe, or whether, instead: (i) the process is limited by other factors, such as manpower or finance constraints; or (ii) alternatively, there are no such binding constraints and, instead, the rate of innovation approximates the rate that (broadly) equates (the unconstrained) risk adjusted costs and returns.

This is an important policy issue. If policy is to increase the rate of innovation then it will be most effective if directed at constraints that are binding or, if no constraints are binding, at improving the ratio of returns to costs.

The recent Commission Green Paper on Innovation states that, "an initial requirement is the development of 'technology watch' which provides reliable access to the best reports on technological information in the world". This requirement is based upon a view that technological information is a constraint upon innovative activity. The data in the CIS survey allow this view to be more fully tested.

Much policy debate is centred around the special needs and constraints impinging upon small and medium sized enterprises (SMEs). It is thus important to explore whether information constraints are more significant for smaller rather than larger firms. Such a disaggregated approach can be further pursued in order to explore whether such constraints are more important in different sectors and/or countries. Section 2 of this chapter addresses these issues.

Section 3 explores the CIS data concerning total current expenditure on innovation activities, and the proportions spent on R&D and other internal and external (to the firm) innovative activities. The purpose of this is to illustrate a number of points. The first is to lay to rest the assertion that R&D and innovation are synonymous. The data not only enables an analysis of the relative size of R&D in total innovation costs but also more specifically the share of information related costs in total innovation costs. Too often policy debates assume that R&D and innovation are one and the same. This has led to policies aimed solely at R&D rather than the innovation process as a whole (Stoneman, 1986). For many years economists have argued that R&D is only one part of the innovation process (see for example Pavitt, 1995) and that an overemphasis on R&D has been an undesirable aspect of policy. If a more accurate picture of the role of other activities in the innovation process can be illustrated, then the argument for instituting non R&D related policies will be strengthened.

The data also enable a comparison of the in house and external innovation expenditures of the firm. This provides insights about the extent to which innovating firms are part of a networked process rather than isolated actors. The policy importance is that the greater is the network or systems characteristics of the innovation process, the more that policies directed towards the system will be effective. Thus, for example, if there were no system characteristics, policies would best be targeted at individual firms. If on the other hand system characteristics are important, then policies that improve the system would be more relevant, such as policies that encourage co-operation between firms, help overcome constraints on trading information (intellectual property rights) and/or provide information centrally.

In the final section of the Chapter we summarise the findings based on the material analysed and also draw a number of policy conclusions.

3.2 Factors Hampering Innovation

Surveys of the hindrances to innovation are quite common, and an attempt to replicate them would be tedious and of little advantage in the present context. Vickery and Northcott (1995) give a number of good examples of the genre and also illustrate the difficulties of attempting to survey the field. The CIS however is superior to all previous studies in its breadth and coverage and, although not all problems have been resolved, the findings will be of particular importance.

The key data are derived from is the responses to question 12 of the CIS (again, see EC, 1994, pp. 49-59), which asks

> "If any of the list of difficulties hindered the realisation of innovations in your enterprise during 1990-1992 please indicate its relative importance to your innovative activities".

A list of potential difficulties are provided, of which a number are of an information-related kind and respondents score each according to a five-point Lickert scale.

The available responses are broken down into groups reflecting "economic factors", "enterprise factors" and "other reasons". The economic factors include "excessive perceived risk", "innovation costs too high" and "payoff period too long". Jointly these may reflect the firms' decisions about the risk adjusted profitability of innovation. If these factors are important then, in essence, firms consider that innovation is limited by its expected profitability. The enterprise factors encompass issues relating to the capability to innovate and it is within this section that the information constraints are listed. Other reasons reflect issues relating to market competition, appropriability, market responsiveness, regulation etc. Problems with financing innovation are listed under the heading of economic factors.

We may separate out four particular hindrances that would reflect information problems.

(i) lack of information on technologies
(ii) lack of information on markets
(iii) deficiencies in the availability of external technical services
(iv) lack of opportunities for co-operation with other firms and technological institutions.

The last of these can only broadly be considered as within the remit of an information problem but it is also useful to explore in the context of Chapter 6 which discusses cooperation in greater depth. We have also considered looking at problems associated with the "availability of skilled manpower" as an information variable - for example, it is often argued that much information is embodied in human capital. However, inadequately skilled manpower as a hindrance to innovation also reflects more direct influences than information effects and, thus, we do not analyse this further.

(i) Cross Tabulations

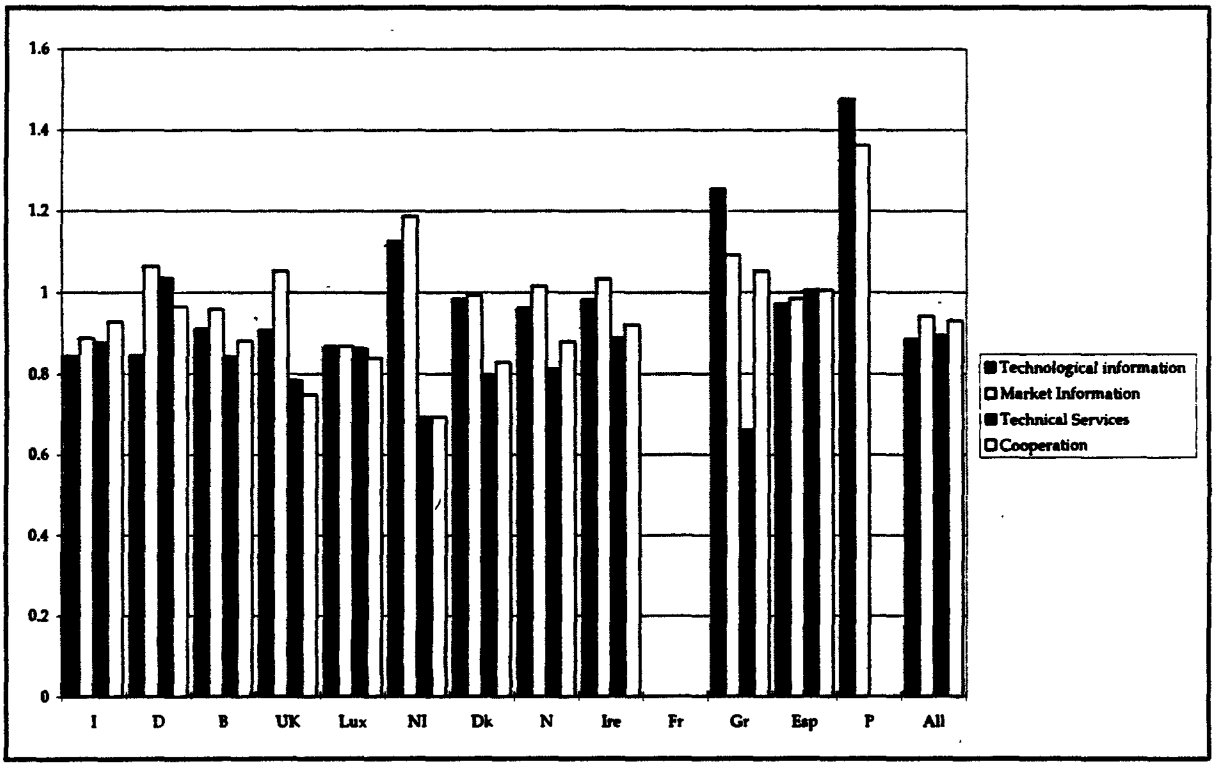
Country Differences. As a first step in analysing the responses to question 12 we report on a number of cross tabulations based upon the mean scores across all respondents. Initially we explore which of the 18 specified factors are the most significant. The top three hindrances to innovation are reported for each country (except France where there is no return). There is considerable commonality across countries in that only five of the factors appear in the top three for any country. The numbers of countries for which each factor appears in the top three are shown in Table 3.1.

All except perhaps the last of these factors are economic in nature. They indicate that expected profitability, problems of financing and risks of innovation are the key limiting factors. There is considerable agreement across different countries that these factors are dominant. It is also worth noting that "innovation costs too high" or "pay off period too long" are the most important factors in most countries. One might reasonably argue this suggests that, the prime constraint upon innovation in firms is that the risk adjusted rate of return is not high enough to encourage further innovation.

However although expected profitability is the dominant constraint other limiting factors also play a role. Our prime concern here is the part played by information problems. Tables 3.2 and 3.3 report the mean score for "lack of information on technologies" and "lack of information on markets" repectively. The three columns in each of these tables show the mean score as: (i) an absolute value; (ii) as a proportion of the mean score over all hindrances listed; and (iii) as a ratio of the score of the factor with the largest mean score.

In our view columns (ii) and (iii) in these Tables are likely to be a more reliable basis for international comparisons than column (i). The latter shows a variance that may just reflect differences in the propensity of national characteristics to give high or low scores (see Chapter 2) whereas the other two columns correct for this. The data in column (ii) is presented graphically in Figure 3.1. Using columns (ii) and (iii) from Table 3.2 we see that, except for the Netherlands, Greece and Portugal, information on technologies is, on average, less of a constraint than the other factors, and, as a proportion of the highest scoring factor, is in the range 0.52 - 0.79 (all countries figure 0.62). Thus, while information on technologies is a hindrance to realisation of success in innovation, but is somewhat less important than a number of other factors (the all country average score of 1.77 on the Lickert scale is only slightly significant statistically). Countries where it appears particularly relatively important based upon (ii) are the Netherlands and Portugal. Of these, however, only the Netherlands maintains its ranking in column (iii).

Figure 3.1 Ratio of Mean Score to Mean Score Across all Hindrances to Innovation



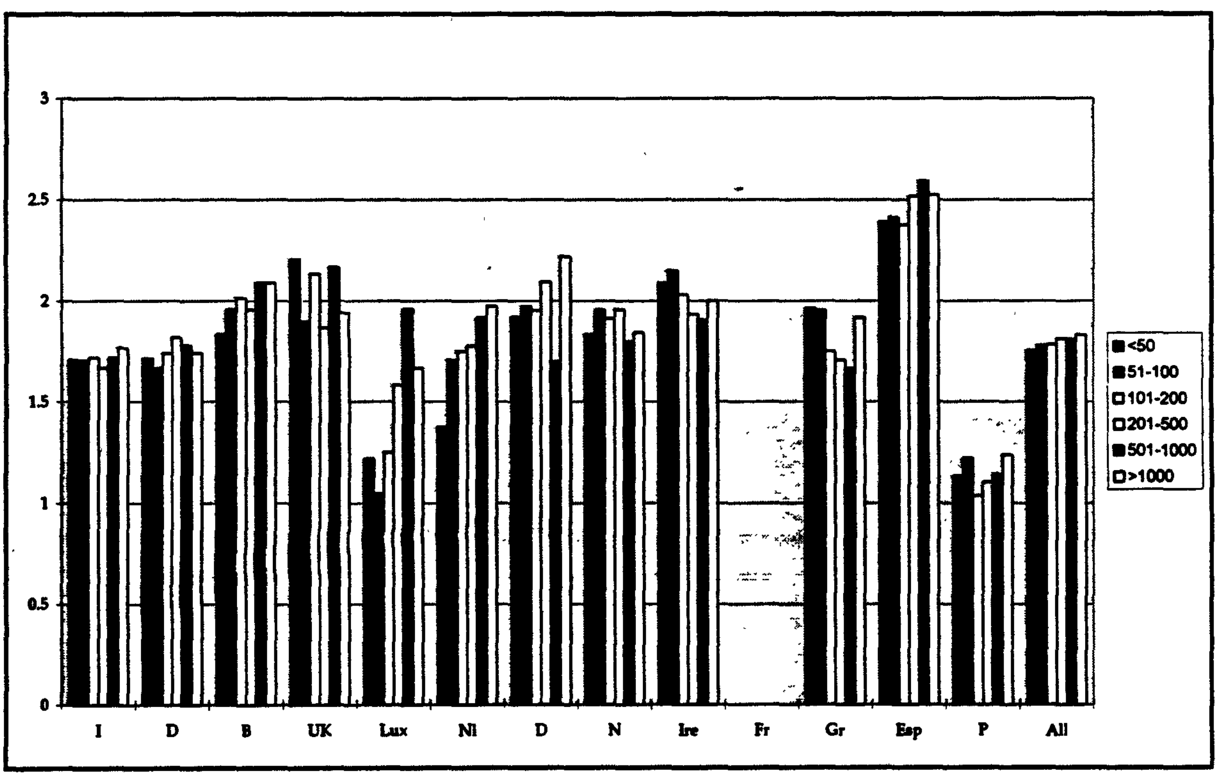
The scores for lack of information on markets (see Table 3.3 and Figure 3.1) are in general higher than for lack of information on technologies - in seven of the countries it scores higher than the average. The countries where it is most important compared with the mean scores across all influences (column ii) are Germany, UK, Portugal, Spain, Netherlands, Norway and Ireland. As a proportion of the highest score it is in the range 0.47 - 0.83 (the all countries figure is 0.66).

A finding of particular interest with respect to the importance of information is whether innovators and non innovators have a similar view of this constraint. Table 3.4 examines the responses about the importance of information on technologies broken down by whether firms have or have not innovated (the results relating to lack of information on markets are very similar). The importance of the information constraint is always less for firms that have not undertaken innovation than for firms that have (except for process innovating firms in Portugal). Further exploration reveals that the mean scores of the responses to the questionnaire is less for non innovators than for innovators for all types of hinderance under consideration. A similar result appears if we break the sample down by intentions to innovate.

This may be interpreted in a number of ways. One possible view is that it is only through the innovation process that firms become aware of the problems involved. Another possibility is that the problems become more severe as firms innovate. Whatever the interpretation, however, it seems reasonable to infer that it is not their view of these hindrances that lead firms to be non innovators for such firms consider these problems less important than innovators.

Firm Size. Next we consider the responses by firm size. *A priori*, small firms might be expected to have have the greatest information problems. The reasoning would rely upon the limited scope of the activities of small firms, their lack of resources for information collection and transmission and their small staffs. Table 3.5 details the scores concerning the lack of information on technologies broken down by numbers of employees. These data are presented graphically in Figure 3.2.

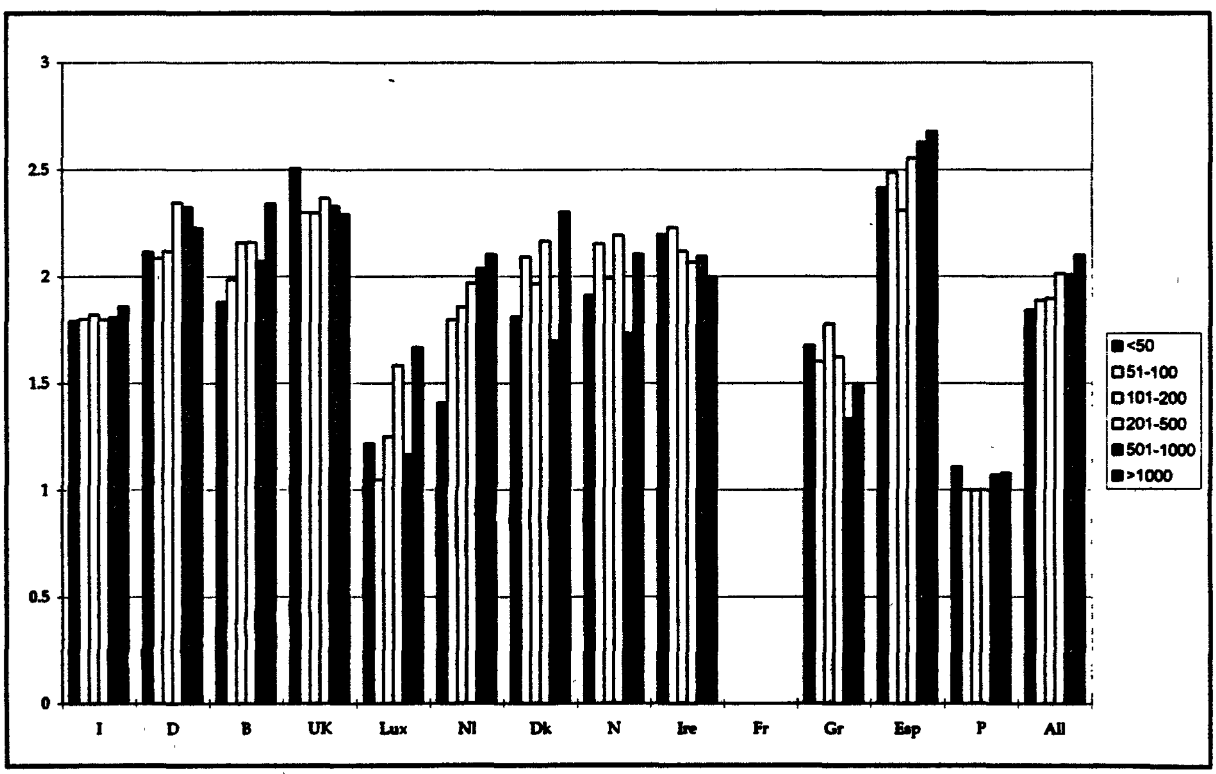
Figure 3.2 Lack of Information on Technologies by Firm Size



In practice, small firms do not appear to have consistently greater information problems. This result emerges in the all country data and for individual countries. Comparing columns 1 and 6, the score in 6 is less than the score in 1 in only three cases. An alternative is to look at the firm size at which each country's score peaks. For two countries it peaks in the smallest firm category, for one in the next largest, for none in the next, two in the next, two in the next and five in the largest. It thus appears that, for technological information, there is no consistent pattern suggesting that smaller firms have greater problems than larger firms (rather the reverse is indicated). One should note however that in no case are these reported means different by more than one standard deviation.

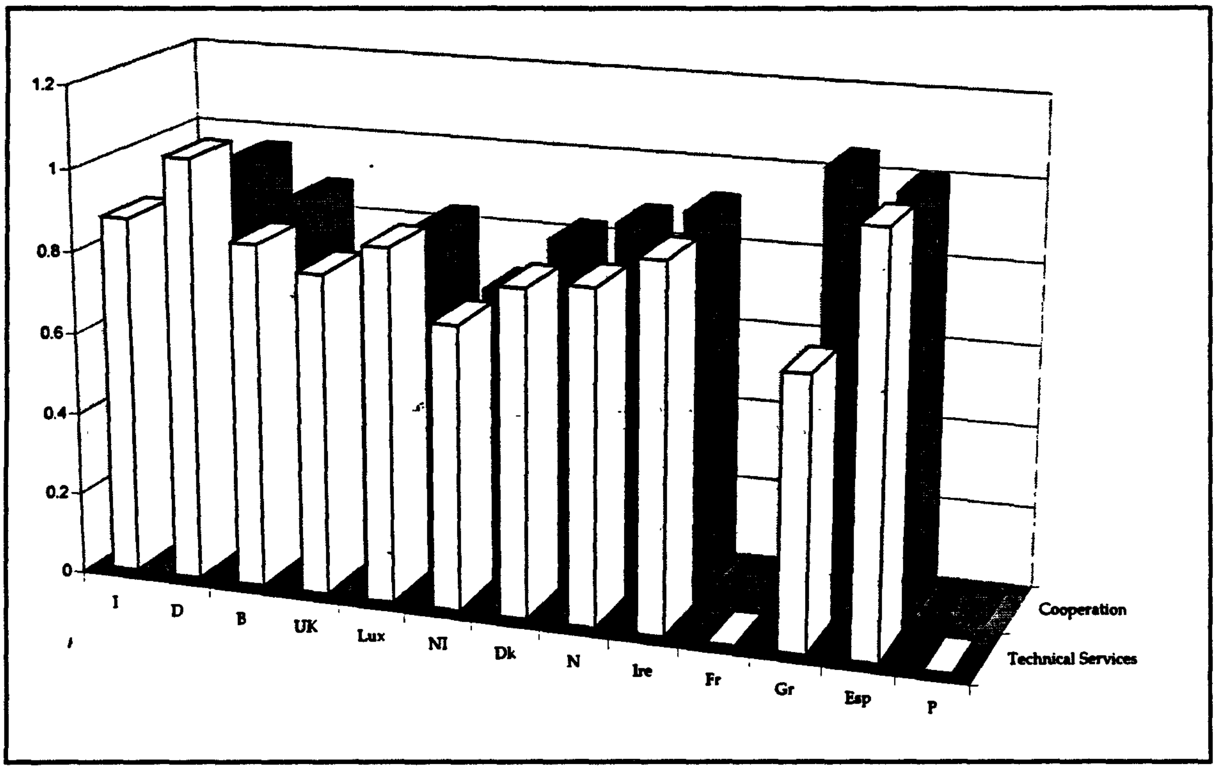
Table 3.6 presents the same firm size break down for market information and the results is shown graphically in Figure 3.3. Comparing columns 1 and 6 suggests that the score is smaller for the larger firm in only four cases. The peak score is in column 1 for one country, in column 2 for one, in column 3 for one, column 4 for three, in column 5 for none and in column 6, the largest firm size, for six. Again, there is no consistent pattern whereby smaller firms indicate that information problems are more of a constraint than in larger firms, if anything, the reverse is indicated (although again the differences in the scores are less than one standard deviation).

Figure 3.3 Lack of Information on Markets by Firm Size



The other two hindrances that can broadly be labelled as information problems are "deficiencies in the availability of external technical services" and "lack of opportunities for cooperation with other firms and technological institutions". Table 3.7 lists the mean score for each of these relative to the mean score across all factors by country, the first hinderance is shown in column (i) and the second in column (ii). The data are presented graphically in Figure 3.4. Except for Spain and Germany, deficiencies in the availability of technical services do not appear especially important (nor do lack of opportunities for cooperation, except in Greece and Spain). These factors are again of lesser importance than economic and other factors hindering success in innovation, and, for some countries, such as the Netherlands, of very little importance.

Figure 3.4 Technical Services and Cooperation (Mean Score/ Average Mean Score)



Industry Differences. Having looked across countries, across firm size and by innovative activity the next step is to examine differences across industries. *A priori* it seems likely that information and related problems are more acute in certain sectors than in others. In technologically fast changing sectors, for example, information problems may be more acute than in stable sectors. However an analysis of the responses by the NACE breakdown shows very little difference across sectors. In Table 3.8 we show the mean responses to the relevant hindrances listed in question 12, where (i) refers to technological information, (ii) to market information, (iii) to external technical services and (iv) to cooperation possibilities.[1]

We note first that no sector deviates from the mean response for the whole sample by more than one standard deviation. If we take the importance of technological information (column i) we see that most responses are either 1.7 or 1.8. The sectors that fall below 1.7 are NACE 22 (publishing and printing), 74 (other business activities) and lowest of all 40 (electricity, gas and water supply). Those above 1.8 are sectors 25 (rubber and plastics), 29 (machinery and equipment nec), 34 (motor vehicles manufacture) and highest of all 32 (radio and television manufacture). This latter group of sectors may well be more technologically sophisticated than the former group but there does not seem to be any overwhelming evidence to support the view that technological information increases in importance as a hindrance as technological sophistication increases.

The scores are generally a bit higher for the importance of market information (column ii). The sectors that fall below 1.8 are NACE 22 (publishing and printing) and 40 (electricity, gas and water supply), with the lowest score. Both of these sectors also scored low on technological information. Those above 2.0 are sectors 30 (manufacture of office machinery and computers), 33 (manufacture of medical instruments, watches and clocks) and, highest of all, 32 (manufacture of radio and TV equipment), which was also highest on technical information. Again, the latter group may face more technologically sophisticated markets, but there does not seem to be any overwhelming evidence to support the view that market information increases in importance as a hindrance to innovation as technological sophistication increases.

In the case of technical services (shown in column iii), NACE 22 (publishing and printing) and 40 (electricity gas and water supply) score lowest, while 45 (construction) and 74 (other business activities) score highest. On cooperation (shown in column iv), NACE 22 (publishing and printing), 23 (coke petroleum refining and nuclear fuels) and 40 (electricity gas and water supply) score lowest, whilst 32 (radio and TV manufacture) is highest. One cannot see any obvious rationale for such scoring.

(ii) Multivariate Analysis

The simple cross tabulations presented above have a distinct advantage in terms of clarity and ease of exposition, but innovative behaviour is complex and is impacted upon by many variables at the same time. Multivariate analysis, by taking into account all variables simultaneously should provide a more robust picture of the different forces at work. The regression results reported below are based upon the full sample of firms. The dependent variable is the score of the ith firm with respect to any particular relevant part of question 12. Using the actual score in this way overcomes any problems that may have been introduced by the use of "mean" scores in the analysis above. For this reason as well, the results from multivariate analysis are to be preferred. Nevertheless, the results should be interpreted as descriptive statistics rather than fully specified causal relationships.

We have related the various dependent variables to a constant, firm size or the log of firm size (the log performs more satisfactorily in terms of statistical significance and explanatory power of the regression), a series of dummy variables representing the country and the industry from which the observation comes and another dummy variable that indicates whether the observed unit has undertaken any product or process innovation in the period from 1990 to 1992. The base observation is an Italian enterprise in sector 15 (manufacture of food products and beverages) that has not innovated between 1990 and 1992. In order to ease the presentation, only coefficient estimates relating to variables that are significantly different from zero at the 5 per cent level are reported. Table 3.9 presents the results of the analysis applied to questions 12.7, 12.8, 12.11 and 12.12 (shown in columns i-iv respectively). In general the estimated R^2 estimates are low, although this is not untypical for a cross section sample of such large size.

Technological Information. The results relating to question 12.7 (column i) confirm a number of findings reported above, but they also have the advantage of indicating where differences are statistically significant. The first two principal results are that the coefficient on the

(i) log of firm size is significant at the 5 per cent level and positive and, thus, as firms become larger (in terms of the number of employees), holding other factors such as industrial sector and country constant, technological information becomes more of a problem

(ii) innovation dummy is also positive and significant and, thus, holding other things constant, firms that have innovated in the recent past consider technological information more of a problem than firms that have not innovated.

If we turn now to the country dummies, bearing in mind that Italy is the base country, it appears that

(iii) Luxemburg, Germany, Netherlands and Portugal score significantly lower than Italy, although for Germany and the Netherlands this is by only a small amount. Portugal and Luxembourg score much lower than in any other country

(iv) Belgium, Norway, Spain, Denmark, the UK and Ireland score more highly than Italy, but Spain is the odd one out, with a score considerably higher than the others.

As noted above, the country results should be interpreted with considerable caution, as a high score may just reflect sampling differences or national scoring characteristics rather than the importance of technological information as a problem in the innovation process.

Turning to the scoring by NACE categories, bearing in mind that sector 15 (manufacture of food products and beverages) is the base, it appears that technical information is less of a problem in categories 10 (coal mining), 11 (extraction of petroleum etc), 22 (publishing and printing), 40 (electricity, gas and water supply), 41 (water distribution), 50 (motor garage services), 55 (hotels and restaurants), 80 (education). Of these, it is least important in 10 (coal mining), 11 (extraction of petroleum etc.) (the lowest score), 55 (hotels and restaurants) and 80 (education). In the other sectors tabulated, technological information is more of a problem, this being especially so in NACE categories 2 and 19 (forestry and leather and leather products). There seem no obvious reasons why such patterns should exist.

Market Information. The results for question 12.8 (shown in column ii), concerning the importance of market information, are very similar to those for question 12.7.

(i) The coefficient on the log of firm size is significant and positive and thus as firm size increases market information becomes more of a problem.

(ii) The coefficient on the innovation dummy is also positive and significant.

(iii) Luxemburg, Greece, Netherlands and Portugal score significantly lower than Italy, although for the Netherlands this is by only a small amount. Portugal and Luxembourg score much lower than any other country. This group of countries therefore appear to find market information less of a problem. Belgium, Germany, Norway, Spain, Denmark, the UK and Ireland all score more highly than Italy, but Spain is the odd one out with a score considerably higher than the others.

(iv) Compared to NACE 15 market information is less of a problem in categories 10 (coal mining) (least important), 22 (publishing and printing) and 41 (water distribution). In the other sectors tabulated, market information is more of a problem, this being especially so in NACE 32 (radio and TV manufacture) and 40 (electricity, gas and water supply).

External Technical Services. The results for question 12.11 (column iii), relating to hindrances arising from deficiencies in the availability of external technical services, are again similar to those for questions 12.7 and 12.8.

(i) The coefficient on the log of firm size is significant and positive and, thus, as firm size increases technical services become more of a problem.

(ii) The coefficient on the innovation dummy is also positive and significant.

(iii) Luxemburg, Greece, Norway, the Netherlands and Portugal score significantly lower than Italy, although for Norway and Portugal this is by only a small amount. Greece and the Netherlands score much lower than in any other country and, thus, for them technical services appear to be less of a problem. Germany, Spain and Ireland score more highly than Italy, but only by small amounts.

(iv) Compared to NACE 15, external technical services are less of a problem in categories 10 (coal mining) (least important), 22 (publishing and printing), 40 (gas, electricity and water supply) and 41 (water distribution). In the other sectors, tabulated market information is more of a problem, especially in NACE 32 (radio and TV manufacture) and 33 (manufacture of medical and optical instruments).

Opportunities For Cooperation. Finally considering the results for question 12.12 (column iv) on the lack of opportunities for cooperation, similar patterns also emerge.

(i) The coefficient on the log of firm size is again positive, although in this case it is not significant. The importance of the lack of opportunities for cooperation does not appear to vary significantly with firm size.

(ii) The coefficient on the innovation dummy is again positive and significant.

(iii) Luxemburg, Greece, the Netherlands and Portugal score significantly lower than Italy, although for Portugal this is by only a small amount. Greece and the Netherlands score much lower than in any other country and, thus, for them, lack of opportunities for cooperation may be less of a problem. Belgium, Germany, Spain and Ireland score more highly than Italy, but only by small amounts.

(iv) Compared to NACE 15, the lack of opportunities for cooperation is less of a problem in categories 10 (coal mining) (least important), 22 (publishing and printing), 40 (electricity, gas and water supply) and 41 (water distribution). In the other sectors tabulated, lack of opportunities for cooperation is more of a problem, this being especially so in NACE 30 (manufacture of office machinery and computers) and 32 (radio and TV manufacture).

Conclusion. From this multivariate analysis we thus see a similar pattern of responses arising with respect to all four parts of question 12: scores increase with firm size and with innovative activity; the scores (relative to Italy) for Luxembourg, Greece, the Netherlands and Portugal tend to be lower, for Belgium, Spain and Ireland higher; NACE categories 10 (coal mining), 22 (publishing and printing), 40 (electricity, gas and water supply) and 41 (water distribution) tend to show low scores (relative to category 15) and, where they are significant (and hence are tabulated), other NACE categories tend to show higher scores.

3.3 Information and Innovation Expenditures

The above analysis indicates that, although not as important as some other factors, information problems play a significant role in innovation. The responses to question 13 further extend the analysis by examining expenditure upon information activities in the innovation process. This question 13 provides data on total current expenditure upon innovation activities, and the proportions spent on R&D, acquisition of patents and licences, product design, trial production training and tooling up, market analysis, and other. Data are also provided upon the proportion of such expenditures that were spent on specialist services outside the enterprise. One would expect that, the greater is the expenditure on information activities, the more significant they are in the process. Unfortunately, partly because of the nature of information as a concept, the responses to Q13 can only give an indication of the role of information costs.

These data can be used to illustrate a number of points, in particular to

(i) lay to rest the assertion that R&D and innovation are synonymous. Too often in policy debates, the assumption that they are the same has led to policies aimed solely at R&D rather than the innovation process as a whole (Stoneman, 1986). For many years economists have argued that R&D is only one part of the innovation process (see, for example, Pavitt, 1995) and that an overemphasis upon R&D has been an undesirable aspect of policy

(ii) obtain estimates of information costs. Clearly for this purpose we are considering that R&D and information are not synonymous (as is the case in much of the literature - see Chapter 1). Although it is only indicative, the estimates of the relative importance of the other cost elements are likely to reflect the importance of information gathering and processing activities

(iii) compare in-house *versus* external expenditures of the firm. This will give some insight in to the extent to which firms undertaking innovation are part of a networked process rather than isolated actors. The greater is the relative share of external expenditures the more one should consider innovation activities as part of a system.

Considering only firms that report positive current expenditures on innovation activity in 1992, Table 3.10 reports R&D as a percentage of total innovation expenditure by country (data are not available for France). Although the measurement and reporting of R&D is subject to definitional problems, it is reasonably safe to conclude that R&D represents no more than 50 per cent of total innovation costs in any one country. Over all countries, the proportion is 32.9 per cent. That R&D and innovation are not synonymous can no longer be disputed.

In the structure-conduct-performance literature, the explanation of R&D expenditures is an important focus, using variables such as firm size and market structure. Our interest is to explore the influences on R&D as a percentage of total innovatory expenditures of different aspects of innovative behaviour. This is undertaken using a multivariate regression of the type described above. The right hand side variables include country dummies, NACE dummies, the log of firm size measured by employment (which performed better, in a statistical sense, than the level) and the log of the R&D spend of the firm. As the R&D spend is in national currency units, the country dummies also account for different currency units and, thus, cannot be taken to indicate any intercountry differences (although they control for these).

In summary, NACE 41 (water distribution) shows a significantly low share for R&D expenditures, while NACE 11 (extraction of petroleum and gas), 24 (chemicals), 40 (electricity, gas and water supply), and 73 (research and development) show particularly high shares. With the exception, perhaps, of NACE 73 the reasons for this are not clear. Of more interest however are the relationships with firm size and R&D spend. The log of firm size carries a coefficient of 0.091 (with a t value of 9.323, which is highly significant) indicating that, as the log of firm size increases, the share of innovation expenditures devoted to R&D also rises. This reflects our expectations that in-house R&D is concentrated in larger firms. The log of R&D spend carries a coefficient of -0.069 (t value of -8.646) indicating that as R&D spend increases, the proportion of total innovation expenditures attributable to R&D declines.

Turn then to the acquisition of patents and licenses, product design and market analysis (Table 3.11). Such activities clearly represent significant proportions of total innovation costs although there are important differences across countries especially with regard to expenditure on product design. This is a major factor in Italy, Germany, the UK, Ireland and Portugal but much less important in Belgium, Denmark and Norway, and of little importance in Luxembourg, and the Netherlands. However, given that countries differ little in the relative importance of product to process innovation these results do not reflect an emphasis upon product innovation.

Column (i) shows that expenditure on acquisition of patents and licenses is always less than 10 per cent of total innovation costs. This result is not surprising. Although such acquisitions may be important as sources of technology in particular industries they are unlikely in general to represent a large proportion of costs. The importance shows variation across countries but the reasons are not immediately clear. Cross correlating with the data in Table 3.2 on the importance of a lack of technological information as a hindrance to innovation does not show that those countries where this hindrance is considered most important also spend a greater proportion of innovation expenditures on patents and licences.

Market analysis takes a more similar share of innovation expenditure in most countries (except Ireland and Greece where it is much higher). Cross correlating with the data in Table 3.3 (indicating the importance of market information as a hindrance to innovation) does not appear to show any correlation indicating that where market information is considered most of a problem then the expenditure on market information is higher.[2] Such activities clearly represent significant proportions of total innovation costs.

Table 3.12 shows the results of the by now standard multivariate analysis of the above data, presenting only significant coefficients. Given that the data refer to shares in total innovation expenditures we first note a rather curious pattern in the data. At the level of the country, to some degree, the coefficient signs are different for different expenditure categories, and market analysis is a substitute for expenditures on patents and licenses and product designs. By individual NACE, however, this is not generally the case. At this stage, it is not clear why this tentative result occurs.

All firm size coefficients are negative suggesting that expenditure on these three information activities (as a share of total innovation expenditures) declines as firm size increases. One may speculate on possible explanations, for example, one explanation may be linked to the fact that it is often argued that smaller firms do not consider their innovative activities to be R&D but rather design activities. This may further reflect the tendency for smaller firms to be involved in more minor modifications and incremental advances. It may also be that small firms are more likely to buy in technology than larger firms. It is not possible at this time to be more definitive. The findings with regard to market analysis may just reflect the lumpiness of such spending.

The multivariate analysis suggests that relative expenditure on patents and licences is highest in Spain and lowest in Belgium. In the case of product design, relative expenditures are highest in Germany and lowest in the Netherlands and Belgium. Finally, in the case of market analysis, Greece ranks highest, with Belgium, at the bottom end. In the case of differences across sectors for patents and licences NACE 22 (printing and publishing) has the highest proportion and NACE 75 (public administration and defence) the lowest. In the case of product design, NACE 18 (clothing) has the highest proportion, with NACE 73 (research and development) the lowest. Market analysis is relatively important in 16 (tobacco), while it is lowest in 37 (recycling).

Finally, in this section, Table 3.13 considers the relative importance of internal *versus* external expenditures. We observe from these data that external expenditures can comprise up to 25 per cent or more of total innovation expenditures (with an average of 20 per cent across all countries). The evidence in favour of innovation as an economy wide (or multinational) system as opposed to a stand alone activity is therefore strong. Our multivariate analysis (not reported in detail) indicates that external as a percentage of total innovation expenditure declines with firm size. Smaller firms may thus be less connected to the total innovation system than large firms.[3]

The raw data indicate that Spain, Denmark and Greece record particularly low values for the share of expenditures going externally: Luxembourg and Germany exhibit particularly high values. The multivariate analysis confirms that Luxembourg and Germany have significantly higher proportions of external expenditure[4]. The reasons for this are not immediately obvious. However, cross correlating with the data on whether the availability of technical services is a hindrance to innovation Table 3.6 indicates that the three countries with the highest proportion of external expenditures (Germany, Luxembourg and Belgium) are three of the four countries that score deficiencies in the availability of external services most highly as a hindrance to innovation. One might think that the greater the hindrance the less that would be spent on external technical services, but clearly this is not the case. It might in fact be (just as innovators in general score hindrances more highly than non innovators) that it is only as firms try to use technical services that the problems in their use and their availability really become apparent.[5]

3.4 Conclusions

In this chapter we have explored the role of information in the innovation process, both as a hindrance to innovation itself and as a proportion of total innovation costs.

Our initial results suggest that it is the expected profitability of innovation, the problems of financing innovation and the risks of innovation that are the key factors that have limited innovation in Europe. The same set of factors tend to be dominant across countries. It is "innovation costs too high" or "pay off period being too long" that are the most important factors in most countries.

One might reasonably argue on the basis of this that, in most countries, the prime constraint upon innovation in firms is that the risk adjusted rate of return is not high enough to encourage further innovation.

If markets and information are perfect then this would indicate that the rate of innovation may approximate its optimal level or, to put it another way, if it is expected profitability that is limiting innovation and if markets are perfect, then there seem few reasons to argue in favour of government intervention to further stimulate the innovation process. However, it is generally accepted that innovation and information markets are far from perfect and as such there may be a good case for government intervention in the innovation process. If it is the case that the major constraints are related to expected profitability then policies aimed at stimulating the returns to innovation, or reducing the risk from innovative activity would appear to be indicated. Such policies may be of a risk sharing nature (eg Launch Aid) or involve subsidies of various kinds to innovative activity.

Although expected profitability is the dominant constraint the other limiting factors also play a role in the innovation process although the role is of lesser importance. We find that technological information has been a hindrance to the realisation of success in innovation, but it has been somewhat less important than a number of other factors. Countries where it appears particularly relatively important are the Netherlands and Portugal. Information on markets has been a more binding constraint than lack of information on technologies. The countries where it is most important are Germany, UK, Portugal, Spain, Netherlands, Norway and Ireland. This is not the ordering expected *a priori*, or the ordering that the EC Green Paper on Innovation recommendations upon support for provision of technological information appears to assume.

The policy recommendations that arise from these findings would centre around instruments that reduce the cost of gathering market information and also ease the means of doing so. Such policies might, for example, subsidise market research activities or involve roadshows and other such information spreading mechanisms. We will see, in later chapters, that these sources of information are regarded as surprisingly important, especially amongst small firms.

We have made one other surprising finding. We note that for firms that have not undertaken innovation the importance of the information constraint is always less than for firms that have (except for process innovating firms in Portugal). Exploring further we have also found that the mean scores of the responses to the questionnaire is less for non innovators than for innovators for all relevant questions. The same result appears if we break the sample down by the intention to innovate. This suggests that it is not the view of the importance of the hindrances that have led firms to be non innovators for such firms consider these problems less important than innovators.

The implication appears to be that the policies required to stimulate innovators to do more are different to those required to get firms to undertake innovation when they have not innovated before. We have raised this issue above and discussed how the literature considers that it may be much more difficult to get non innovators to innovate than to get innovators to do more - but, note that the benefits of doing so may be higher. A problem however is that, if non innovators consider all constraints less important than corresponding innovators, it is difficult to see what is constraining non innovators and thus where policies should be directed. This may be a question of management skills and knowledge, which may require an education or training response.

A further important policy dimension concerns SMEs. The *a priori* expectation was that small firms have the most information problems, but this does not appear to be the case. For both technological information and market information there is no consistent pattern in the data suggesting that smaller firms have more information problems than larger firms (rather the reverse is indicated). From a policy viewpoint this finding is of interest. Much of the literature would argue that, in the presence of information problems, there is some social advantage to be gained from governments undertaking information stimulation strategies. Thus, in the diffusion literature (see for example, Stoneman and David, 1986) there have been discussions of the benefits to be derived from demonstrator projects, subsidies for consultancy activity and such like. However such policies are often directed at SMEs where it has been felt that the problems are the greatest. Larger firms have been considered quite capable of coping with information problems without government assistance. These findings on the importance of information constraints on smaller and larger firms may raise some doubts about the firm size emphasis in such policies.

In terms of the industrial breakdown of the importance of information as a constraint on innovative activity, it was thought, *a priori*, that there may be more problems in high than low tech industries. The findings suggest, however, that NACE categories 10 (coal mining), 22 (publishing and printing), 40 (electricity gas and water supply) and 41 (water distribution) show low scores (relative to category 15) other NACE categories show high scores. These results show little definition across sectors and as such one is reluctant to draw any particular policy implications.

The results relating to hindrances arising from deficiencies in the availability of external technical services are similar to those relating to technical and market information. As firm size increases technical services become more of a problem, innovators rate the problems more highly than non innovators, and there are some differences across sectors and countries.

The results regarding the lack of opportunities for cooperation also show similar patterns. This is of interest primarily for the analysis undertaken in Chapter 6 where cooperation agreements are studied in more detail. For the present we simply note that the problems of cooperation appear to increase with firm size, but not significantly so. There thus seems little difference between SMEs and other firms in this dimension. Innovators rate the problems of cooperation more highly than non innovators, and there are differences across countries and industrial sectors.

The final part of this Chapter has been concerned with innovation costs. It has been shown that R&D represents no more than 50% of total innovation costs in any one country. Over all countries the proportion is about one third. That R&D and innovation are not synonymous can no longer be disputed. This finding suggests that, if R&D represents only one third of innovations costs, then policies aimed at improving the rate of innovation by focusing solely on R&D activity miss a large part of the target. A wider conception of policies is necessary.

The share of R&D in total innovation costs does differ across industries and with firm size. As firm size increases the share of innovation expenditures devoted to R&D increases. This finding needs further exploration. If it is a fair reflection of the situation it implies that R&D orientated policies are more supportive of small firms than large firms. This is not what one would have expected *a priori*.

The acquisition of patents and licenses, and expenditure on product design and market analysis also represent significant proportions of total innovation costs (although there are clear differences across countries especially regarding expenditure on product design). To some degree market analysis appears to be a substitute for expenditures on patents and licenses and product designs. We find that expenditure on these three information activities (as a share of total innovation expenditures) declines as firm size increases, although the rationale for this needs further research, and it would be unsafe to make policy recommendations prior to this.

Finally we analysed the ratio of expenditures on innovation that are internal to the firm relative to external expenditures. In practice, external expenditures comprise up to 25% or more of total innovation expenditures (with an average of about 20% across all countries). This provides strong evidence in favour of the hypothesis that innovation is an economy wide (or multinational) system as opposed to a stand alone activity. Our analysis also indicates that external expenditure as a percentage of total innovation expenditure declines with firm size. Smaller firms may thus be relatively more connected to the total innovation system than large firms.

The relevance of these findings from a policy stand-point is the implication that if, as the figures indicate, innovation is a national/international system then it may not be sufficient to direct policy at individual firms. Instead it may in be necessary to improve the working of the whole innovation system if national innovative performance is to be improved. The findings regarding the effects of firm size may also indicate that smaller firms in particular may need assistance to fully connect to the (inter)national innovation system.

Endnotes

1. In this table, for presentational and statistical purposes, we have limited the NACE sectors to those containing a hundred observations or more.

2. Such cross correlations, reported at a number of points in this Report, can clearly be undertaken in a much more rigorous way, for example, by using firm level data. Such an exercise must be postponed for future research, however, for reasons of resource availability.

3. A problem that we have throughout, given the ordinal nature of the data, is to say whether such factors change disproportionately with size.

4. The multivariate analysis indicates that NACE sectors 18 (manufacture of wearing apparel), 72 (computer and related activities), 73 (R&D) and 90 (sewage and refuse disposal) have a particularly low share of external expenditures.

5. Indeed, one tentative interpretation is that, where informational problems exist, the price that firms have to pay to overcome them increases.

Chapter 4 Sources of Information for Innovation and Technology Flows

4.1 Introduction

4.1.1 Importance of Information

As we pointed out in the introductory chapter, information is central to the operation of firms. Information is a source of knowhow and, thereby, skills and expertise, for companies. It is itself an input into the R&D and innovation processes. In effect it not only defines the core business of the company, but also the speed and efficiency with which the firm can move into new areas of activity. Companies therefore both require a continuous flow of relevant information and the capacity to sift and assimilate this knowledge. While Chapter 3 explored inadequacies in information flows as a barrier to innovation, this chapter turns its attention to the alternative sources of information.

4.1.2 Sources of Information

Information is partly produced in-house from the general operations of the firm (ie. learning by doing) as well as from specific dynamic activities (ie R&D and innovatory investments). However, internal sources are only a part of the story as firms seek (or are pressured) to assimilate information from external sources by other parts of the organisation or by market-forces. There is a wide variety of sources of information which are likely to differ in relative significance across firm size, sector and country. At this stage, however, we know relatively little about the magnitudes and importance of these information flows, particularly in a European context.

Competitors, for example, may be particularly important sources of information in some sectors. The activities, practices and products of competitors may be directly observed. Products, in particular, may be analysed, dismantled and reengineered. The impact of changes in production practices on costs and prices can be observed *via* the effect on market demand (the own and cross price elasticities of demand). The impact of changes in product design *via* quality can be observed in terms of the market's willingness to pay higher prices for a given level of output (the elasticity of demand with respect to quality).

The technological activity of companies, including competitors can be observed indirectly as various forms of protection for intellectual property involve registration and publication. Indeed it is a general principle of IPR systems that monopoly rights over an invention or creative idea are offered in return for disclosure of the associated knowledge - the so-called "reward system" (see Chapter 5 below). In practice the only forms of IP directly covered by the CIS relate to patent disclosures and design registrations (although trade secrets can also be thought of as a form of IP law). Of the various types of IPR, patents are, in principle, very important as they relate mainly to industrial inventions that match fairly closely with the Frascati definition of R&D. However, they are likely to be highly sector-specific. In addition they do not give any clues as to the importance of other forms of IPR (such as designs, copyright, plant and seed varieties, etc.).

While competitors are likely to be important sources, they are likely to try and protect their intellectual property as far as possible (again see Chapter 5). Of course, there can be occasions when it is economic for potential competitors to cooperate (we return to this issue in Chapter 6). Other groups may be more willing to provide information in order to stimulate demand for their products. It is well known that supplier-buyer chains are extremely important mechanisms for the transmission of information in some sectors. These types of relationships are well documented in, for example, the automotive industry and backward linkages are known to run from key retail and distribution firms to their suppliers. However, much less is known about other sectors and it will be interesting to explore their relative importance.

In recent years, there has been an increasing interaction between universities (and other higher educational institutions, HEIs) and commercial firms. In some countries, HEIs have become more entrepreneurial and commercial in their own right. This has sometimes been forced upon them by cutbacks and resulting inadequacies in government funding. In some sectors, the importance of the science base has induced companies to turn to universities for information and knowledge. Finally, government and EC-R&D funding have often encouraged a mix of partners that include private sector companies and HEIs.

4.1.3 Policy Issues

One result of the previous chapter was that informational inadequacies appear to be more of a problem amongst innovating than non-innovating firms. The most obvious interpretation is that information needs increase as the firm innovates or tries to innovate.

One of the justifications for government intervention is to improve information flows where inadequacies affect the efficiency with which markets operate. In order to intervene, however, it is essential to understand the extent and nature of the information flows in the economy, and how these impact on innovation and growth.

It is often thought that small firms have greater information deficiencies and poorer access to technology than larger concerns. If this is correct (and we have already cast some doubt on this hypothesis), it seems to imply that government policies to improve information flows and technology transfer should be aimed at smaller companies. This raises a number of interesting empirical questions which we attempt to throw light on during the course of this chapter. One is whether the overall need for information differs between smaller and larger companies. A second relates to whether the relative importance of different sources of information changes with company size. Of course, the provision of different amounts and types of information may be a necessary, but not a sufficient condition to enable companies to grow.

This chapter also examines the relationship between the importance attached to information and technology flows, as well as differences in the sources across industries. Such differences are clearly important in the light of the major structural changes which have taken place. This will be reflected in changing information and technological knowhow needs as economies have shifted from being rural to industrial and from industry to service based.

Finally, we return to the policy issue concerning the degree to which firms are self-contained and independent in terms of information and access to technology, and the extent to which they are a part of a broader national or international network. This has implications for whether the policy focus should be the individual innovating firm or the whole group of firms and institutions that constitute the network. It also has implications for whether effective policy action can be designed and implemented by the national government in isolation or whether intervention needs to be internationally coordinated.

4.1.4 Organisation of this Chapter

This chapter focuses on the various sources of information used by firms. Section 4.2 explores the different sources, making a key distinction between internal and external. In addition, we examine the role of competitors, buyer-supplier chains and the like, as well as a number of other miscellaneous sources. Section 4.3 focuses more explicitly on technology transfer. As well as the different forms that transfer can take, the discussion considers the spatial distribution of flows. Finally, Section 4.4 draws the main conclusions of this chapter.

4.2 Sources of Information

4.2.1 Definitions and Scope

This section deals with the main sources of information reported by establishments, based upon the results of the responses to question 4 of the survey. This question asks about the relative importance of different sources of information for innovation.[1] A key distinction is made between sources internal to the enterprise or group, and a variety of external locations and routes. The external sources include buyer-supplier chains, competitors educational and research institutions and other more general sources. In what follows, we follow the ordering found in the original questionnaire,

4.1 within the enterprise
4.2 within the group of enterprises
4.3 suppliers of materials and components
4.4 suppliers of equipment
4.5 clients or customers
4.6 competitors in your line of business
4.7 consultancy firms
4.8 university/higher education
4.9 government laboratories
4.10 technical institutes
4.11 patents disclosures
4.12 professional conferences, meetings, professional journals
4.13 fairs/exhibitions

The headings in the tables in this subsection follow this ordering - note that space does not allow the full definition to be included in each case. The results are based upon a scale of 1 to 5, where the weight ranges from insignificant to crucial. The results shown in the figures and tables are generally based upon average scores for the relevant cell, however, following the convention adopted in Chapter 3, the regressions are estimated using the Lickert values reported by each company

The present section begins with a discussion of the results relating to the relative importance of the various sources across countries. The results show some wide variations. Later, we explore whether these can be explained by differences in firm sizes or industry structure across countries. In the first instance, however, it is simply interesting to examine the differences country by country.

4.2.2 Country Differences

While, we have expressed the need to exercise caution regarding the interpretation of the cross-country differences in the raw mean scores, there do appear to be significant differences in the importance attached to these 13 sources of information. The final row of Table 4.1 indicates that Germany, Denmark and Ireland, for example, exhibit overall mean scores of 2.7 or above, while Italy has a value of 2.1 and France 1.9. While we have already pointed out (Chapter 2) that such differences should be treated with extreme caution, they are large and some explanation is needed. In particular, the question arises as to whether there are some important sources for some countries which are not reported in this table.

Table 4.2 attempts to summarise the relative importance of the various sources. It is clear that, while a number of the sources appear in, say, the "top 5" with great regularity in Table 4.2, there are also differences in their ranking across countries. Not surprisingly, perhaps the category internal sources within the enterprise was ranked first by four countries, and second by a further five countries - in the case of Germany, however, it only ranked seventh (and hence does not appear in Table 4.2). It is interesting that, restricting the sample to those firms that are part of a group, other parts of the set of enterprises do not appear to be particularly important, with scores below the average for all countries except Belgium, Luxembourg and France.

Various dimensions of the buyer-supplier chain also appear to be extremely important. Clients and customers (4.5) appeared to be somewhat more important than suppliers (4.3 and 4.4). Clients and customers (4.5) were ranked first in five cases, second in three instances, and once each in third and fourth rank. In other words, this source was never out of the top four ranks. Intermediate input (4.3) and equipment suppliers (4.4) were both rated as very important. Intermediate inputs were never rated higher than third, but appeared four times at that rank and all countries ranked this source in the top five. Equipment suppliers (4.4) were ranked as most important by Luxembourg, and appeared in the top five rating nine out of ten times. While, taken over all, fairs and exhibitions were not so important as the sources discussed above, this source appeared regularly in the lower echelons of the top five rankings, and for Germany, Ireland and France appeared to be a surprisingly important source. Even in the case of the UK and Denmark, it was ranked sixth.

There are some sources that by their very nature, we anticipate would not appear very high up such a ranking. Patents are an interesting case of this type. Under the 'reward system' patent monopolies are awarded in return for the disclosure of information about the novel features of the invention and, it is claimed, patent specifications are an important source of technical information (again, see Chapter 5). However, the coverage of the patent system is fairly limited in terms of the types of inventions for which protection is given. It is not surprising therefore to find that patents rank relatively lowly against these other more general sources of information. Their top rankings appeared in the cases of France (9), Germany (9), and Belgium (9), and lowest in Norway (13).

4.2.3 Firm Size

We might expect that some sources of information become more important with establishment size and other sources less important. It is an empirical question therefore, whether the overall importance of information (ie. from whatever source) increases or decreases with firm size. This can be found by examining the average results across all 13 potential sources, country by country. The results of this exercise are fairly conclusive, as shown in Table 4.3. The emphasis placed on the importance of information increases with establishment size for all countries, with the exception of Greece. The relationship is rarely monotonic, but this is only to be expected, as industry mix and other factors also vary with firm size. In what follows, we focus mainly on a number of the sources which firms have indicated they rank highly. It is interesting to see whether this pattern emerges for each of the specified sources of information, or whether some increase in importance with establishment size and some decline.

Question 4.1 is concerned with the relative importance of internal sources within the enterprise. This was one of the most important of the sources across the vast majority of countries. In the results broken down by establishment size, shown in Table 3.4, there are some differences in the patterns across countries. In the majority of countries there are clear indications of a positive relationship between the importance placed on sources internal to the firm and its size. The main exceptions to this rule are Greece and Ireland, although the pattern for the UK is far from clear. This does not necessarily mean that firms become increasingly "self-reliant" in terms of information. Such a conclusion depends upon what happens with regard to the relationship between other (external) sources of information and size.

Another key source of information for firms was their clients. The corresponding results for this source, based on question 4.5, are shown in Table 4.5. In this instance, there is no *a priori* reason to believe that small establishments would be more or less dependent upon information from their customers than larger establishments. It might be argued, for example, that small establishments are more responsive to their clients, but that larger establishments have more systematic and formally developed links with their customers. In practice, the results are ambivalent on this point, with four of the thirteen countries having a lower mean score for the largest than the smallest size category. However, the data reveal some indication that medium sized enterprises rate this source most importantly. It can be seen that in eight of the countries, firms with between 100 and 500 employees report the highest mean scores.

Suppliers were also seen as important sources of information (questions 4.3 and 4.4). Again, there is no *a priori* reason for believing that there would be a relationship between the importance of these sources and establishment size. It might be that larger establishments glean information from a wider range of suppliers, but the smaller might be more dependent on suppliers for information. Thus, the relationship between size and importance of this source is again an empirical question. Table 4.6 shows that in no instance is there a systematic monotonic relationship between the importance of materials and component suppliers as sources of information and establishment size. Again, while it is true that, in the majority of cases, large firms have a higher mean score than small firms, there is much less pattern than in the cases we discussed earlier. A similar kind of result applies to the importance of equipment suppliers, as shown in Table 4.7. In this instance, the smallest firms report a higher score than the largest in five of the twelve cases for which there are data. In Italy, Germany and the UK, it is companies with less than 100 employees that have the highest scores. Only in four countries is it the largest firm size category that have the highest scores.

Given that we found a positive relationship between the rated importance of the 13 sources taken as a whole and establishment size, there must be some strong positive relationships elsewhere. This is indeed the case. The majority of countries tend to show strong positive relationships with establishment size for the following sources - consultancy firms, universities and higher education, government laboratories technical institutions and patent disclosures. These again seem to be sensible results given that larger establishments tend to be more likely to employ highly qualified individuals and more likely to have in-house R&D facilities.

In the case of patents as a source of information, for example, Table 4.8 demonstrates that, except for Portugal, all countries (for which information is available) show a positive relationship between firm size and the use of patent disclosures. In the majority of countries this was not only a strong relationship, but also a monotonically increasing one. We know from other sources, that the patent system is more suited to larger firms and, thus, even when inventing, smaller firms tend to make less use of it (Bosworth and Wilson, 1988). In addition, medium sized firms are more likely to use independent patent agents and larger firms are more likely to undertake formal R&D and have in-house patent expertise, sometimes in the form of a patent department.

Two other results are worth exploring in a bit more detail. The first is the importance of competitors as a source of information (question 4.6). Without exception, in all countries, larger firms ranked their competitors a more important source of information than small firms. On the other hand, the maximum scores were found in firms with less than 1000 employees in six of the thirteen countries (though normally amongst the larger rather than the smaller firms in this range). The second relates to fairs and exhibitions. We noted above that, for one or two countries, this source of information was ranked surprisingly highly. The firm size data reveal that in eight of the thirteen countries, the smallest firms score this source more highly than the largest firms. Indeed, in ten of the thirteen cases, the highest score is to be found amongst firms with less than 200 employees.

Our general conclusion would be that not only does the relative importance of information vary significantly across firm sizes, but the strength and direction of this relationship depends crucially upon the source of information concerned.

4.2.4 Industry Effects

While, for a number of the sources, we could think of no strong *a priori* reason why the importance of different sources should vary with firm size, there are grounds for believing that they might differ in importance across sectors. In particular, different sectors, by definition, produce different products, often using different technologies; they are reliant to a different extent on the science base; they face different market structures and degrees of competition.

The first thing to note is that some industries give smaller overall weight to these 13 sources of information than other industries. In particular, NACE 18 (manufacture of wearing apparel), 50 (sale and repair of motor vehicles) and 72 (computer and related activities) are amongst the lowest. The case of NACE 72 almost certainly indicates that the tabulated sources are perhaps not so relevant and information is gleaned in some other (unspecified) way (ie. copyright). The highest values are for NACE 70 (real estate activities), 51 (wholesale trade, excluding motor vehicles), 30 (manufacture of office machinery and computers) and 32 (manufacture of radio, television and communication equipment).

A clearer picture emerges if we normalise the data in two alternative ways. First, we look at the relative importance of the various information sources within each industry, by calculating the score for each of the thirteen types as a ratio of the mean across all types of information for that sector. A clear ranking of importance appears, as shown in the first column of figures in Table 4.9 (labelled "number of sectors"). There are essentially three categories; first, one which is important to all sectors (within enterprise); second, these important to the majority of sectors (essentially, suppliers, customers and fairs/exhibitions); finally, these important only to a small number of sectors (competitors and professional conferences, etc.).

The second way of reorganising the industry data is to look at the relative importance of a particular source of information across sectors. To examine this we divide each sector's score for the source of information in question by the average score for that source across all sectors. This reaffirms the view that some sectors find information more important than others *per se*. Nace 70, for example, appears in the top five of sectors in terms of score for 11 of the 13 sources of information. It is worth adding that, while we cannot make much sense of this particular result (as NACE 70 relates to real estate activities), various other service sector activities also populate the table, such as NACE 51 (wholesale trade except motor vehicles). However, we leave the result without any further manipulation of the data for purposes of discussion.

4.3 Technology Transfer

4.3.1 Forms of Technology Transfer

In the remainder of this chapter, we make a distinction between information transfer, which we dealt with above, and technology transfer, although there will be strong links between the two. The extent of transfer and the mechanisms by which access is gained are clearly important issues, and ones which are likely to differ across countries. It has been widely argued, for example, that the purchase of capital equipment from other companies is likely to be an important mechanism for technology transfer for most firms in most countries. However, a variety of other routes have been suggested in the literature. These include buying patent rights and licensing agreements. Other studies have focused on the role of labour mobility (Bosworth, *et al.* 1994).

The CIS obtained information about the channels through which the technology is transferred into or out of each enterprise.[2] The question only relates to technologies which flowed in or out during 1992 (whereas the product and process innovation questions cover the period 1990-92). The forms of technology acquisition included:

- (i) the right to use others inventions (including licences)
- (ii) results of R&D contracted out
- (iii) use of consultancy services
- (iv) acquisition of technology through the purchase of (part of) another enterprise
- (v) purchase of equipment
- (vi) communication with/specialist services from other enterprises
- (vii) hiring skilled employees
- (viii) (and ix) other

Corresponding headings were also used in the categorisation of technology flows out of the enterprise. The headings (i) - (viii) in the subsequent tables in this chapter relate to the above list. The questions were further broken down by the geographical "source" (for inflow) and "destination" (for outflow) of the technology. We return to this in a later section. Note that firms could give multiple responses (ie. more than one geographical area), although most firms only gave one answer for each channel of transfer (German firms gave a relatively high proportion of multiple responses). Nevertheless, it is important to note that the percentages relate to the proportion of responses, rather than the proportion of firms.

4.3.2 Different Channels of Acquisition of Technology

Table 4.10 provides an indication of the relative importance of the different channels, broken down by country. This table has been constructed by dividing the response to each channel by the number of responses to the most frequently used channel. The first row for each country shows inflows (I) and the second row gives the corresponding outflow (0).

The most obvious feature of the table is the consistency of "purchase of equipment" (v) as the primary source of technology acquisition. The exceptions are Germany, the Netherlands and France, although this channel remains important for all three of these countries. In Germany and the Netherlands the most important route was "communication with/specialist services from other enterprises" (vi) and, in France, "results for R&D contracted out" (ii). Likewise, there is a consistent picture of the importance of "communication with specialist services from other enterprises" (vi) as the principal mechanism for the outflow of technology. Italy and Belgium were the exceptions here, with the mobility of skilled employees"[3] (vii) the principal route for Belgium (although category (vi) was not far behind in importance) and (v), sale of equipment, for Italy.

This consistency in principal routes is helpful in comparing other parts of the table. In other places, as might be expected, the differences across countries are much more marked, as are the relative importance of the different channels as routes into and out of firms. The second most important inward route is "hiring skilled employees" (vii) in Italy, Germany and the UK, while "communication with other enterprises" (vi) is second in the list for Luxembourg, Denmark and Ireland. The second most important outward route is "the right to use others inventions (including licences)" in the UK, Netherlands, Norway, Ireland and France, while it is "mobility of skilled employees in Italy, Germany and Luxembourg.

As a general conclusion, firms appear to make use of a wide range of channels for technology transfer. The relative importance of these mechanisms differ between inflow and outflow. While there is considerable consistency across countries in the principal route for both the inflow and outflow mechanism, the emphasis placed on other routes differ widely. However, the key roles of sources of specialist information, including highly skilled employees, shows through clearly in both directions of flows, confirming the previously qualitative evidence in the literature (Bosworth, *et al.* 1994).

4.3.3 Inflows and Outflows

Most firms are involved with a two-way flow of technology. Even the technologically strongest firms buy-in technology from outside. For one thing innovation is a complex and multifaceted activity that requires a variety of technological inputs for its success. Indeed, dynamic firms are likely in absolute terms to buy-in more technology than their static counterparts. Nevertheless, we would anticipate that the technological advances made by dynamic firms will leak back out in a variety of ways, many of which covered by the CIS.

Table 4.11 shows the ratio of inflows to outflows and, for purposes of illustration, Figure 4.1 highlights the results for two channels of transfer (ii) results of R&D contracted out and (v) purchase of equipment.[4] Ratios of less than unity indicate that the number of positive responses regarding inflows is less than the corresponding responses about outflows. The results do not present the overall level of flows; neither do they report on the spatial dimension (which we turn to below). What the underlying data confirm, however, is the interconnectedness of companies in the innovation process. Firms are clearly part of a national (and international) system of innovation. Each firm acts as a conduit, taking in the technological output of other companies and, to a greater or lesser degree, passing on technology to others.

Figure 4.1 Ratio of Inflows To Outflows by Country and Channel of Transfer

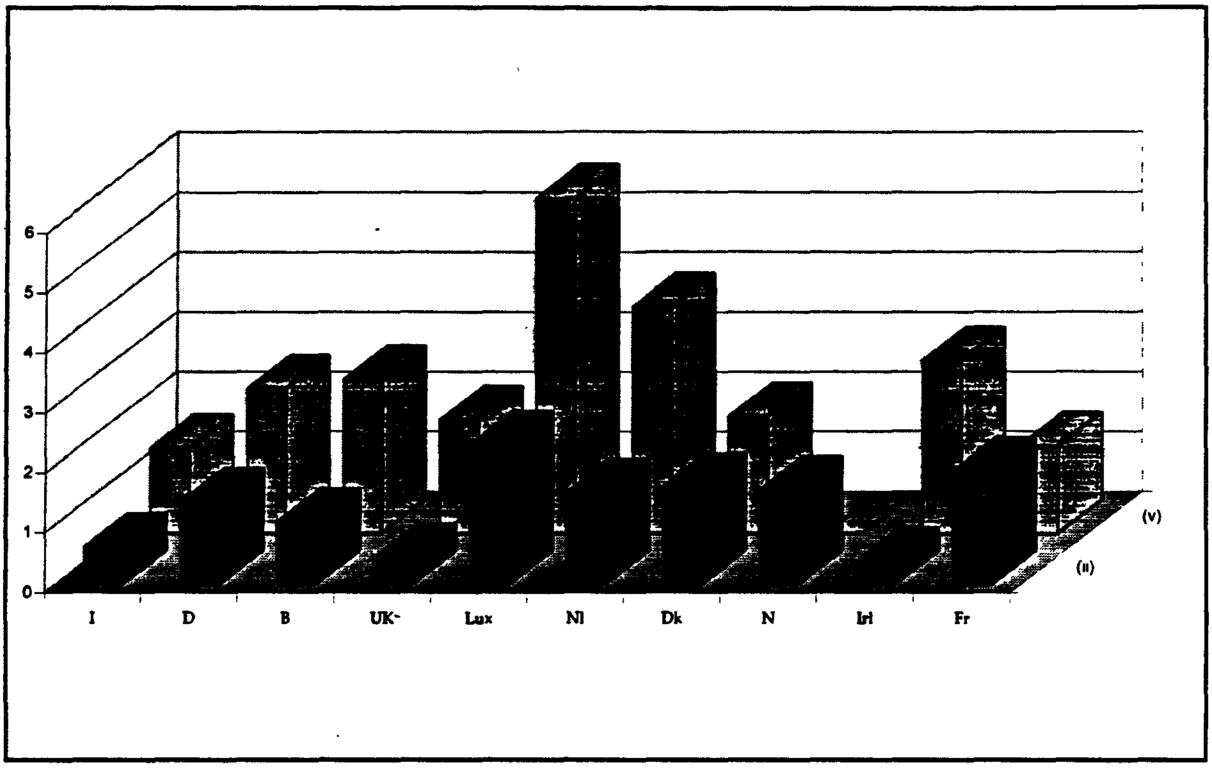


Table 4.11 itself shows that the balance of inflows to outflows differs significantly both according to the channel used in the transfer process and across countries. As we might expect, for example, most companies to some extent rely on other firms for new technologies embodied in capital equipment, but not all are suppliers of capital equipment. Thus, the ratio of inflows to outflows, exceeds unity for every country for column (v) in Figure 4.1. An example where countries differ (insofar as some have ratios of inflows to outflows less than unity and, for others, this ratio is greater than one) is shown by the results of R&D contracted out. Here Italy, Ireland and the UK have ratios under unity.

As might be expected column (iii) of Table 4.11 suggests that, for most countries, more firms buy-in specialist consultancy services than supply them. However, this does not appear to be the case in Belgium, France, the UK or Denmark. In the UK, for example, this may reflect the downsizing and hiving-off of non-core businesses, giving rise to a rapid increase in sub-contracting and purchase of intermediate inputs.[5] In terms of communication with/specialist services from other enterprises (column vi), which is likely to cover aspects of the buyer-suppler chain, companies appeared to believe that they provided more information than was transferred inwards (the exception was the Netherlands). One of the most interesting ratios can be found in column (i), the right to use other inventions, where inflows are less than outflows except in Luxembourg, Italy and Ireland.

This issue relates to the debate about whether the technological balance of payments should be positive or negative. Of course, we cannot obtain a precise fix on the technological balance of payments as Table 4.11 is derived from dichotomous, (0,1), responses to the inflow/outflow questions. However, we can say that the proportion of cells with inflows less than outflows is high, given that firms below best practice are likely to have higher inflows than outflows if they are improving their relative position. The case of best practice firms is somewhat less clear, but those intent on maintaining their relative position will be buying in and building upon the technology of other firms. Thus we were surprised to see that only just over 50 per cent of cells in Table 4.11 had ratios of unity or higher.

4.3.4 Spatial Aspects of Technology Transfer

This section explores the spatial aspects of technology transfer. While there is a huge amount of data in the survey, we provide just one or two key examples of the spatial distribution. Tables 4.12, 4.13 and 4.14 provide three pieces of information broken down by reporting country (Italy, Germany...France) and geographical source/destination (national, EC...other). The first row for each country shows the percentage distribution of technology flows by source (ie. inflow, I). The second row indicates the percentage distribution of outflows by destination. Finally, the third row is the ratio of positive inflow to outflow responses (I/0). Note that the final ratio is not the same as the division of the first by the second rows, as the numbers of companies responding positively to inflows and outflows differ.

We have already noted the tendency for firms to buy-in at least a part of their equipment, which embodies new technologies. The average ratio of inflows to outflows across all geographical areas has already been dealt with in column (v) of Table 4.11. In this section we transfer our attention to the interior of Table 4.12 and Figures 4.2 through to 4.5.

As can be seen from Table 4.12 national sources are always important, but they are not always the most important. In the cases of Belgium, Luxembourg and Ireland, other EC (non-national) sources appear to be particularly important. In the case of outflows a similar pattern emerges, with national sources generally very important, but other EC origins most important for Belgium, the Netherlands and Ireland. Figure 4.2 illustrates the patterns across countries with inflows particularly high for Luxembourg. On balance the ratio of outflows to inflows appears perhaps surprisingly high.

Other European, non-EC in Table 4.12 appears to be an important destination for EC technology (with the exceptions of Norway and Ireland), but a less important source. While there are a number of affluent advanced non-EC European countries (such as Switzerland), this result may reflect the technology gap between the EC and the previously Eastern Bloc countries. As a source, the USA is more important for the UK than for any other country. In addition, 10 percent or more of companies in many countries also report it as a destination for their equipment technologies. As Figure 4.3 illustrates, this is true in the case of the purchase and sale of equipment. We also

Figure 4.2 Purchase and Sale of Equipment in EC

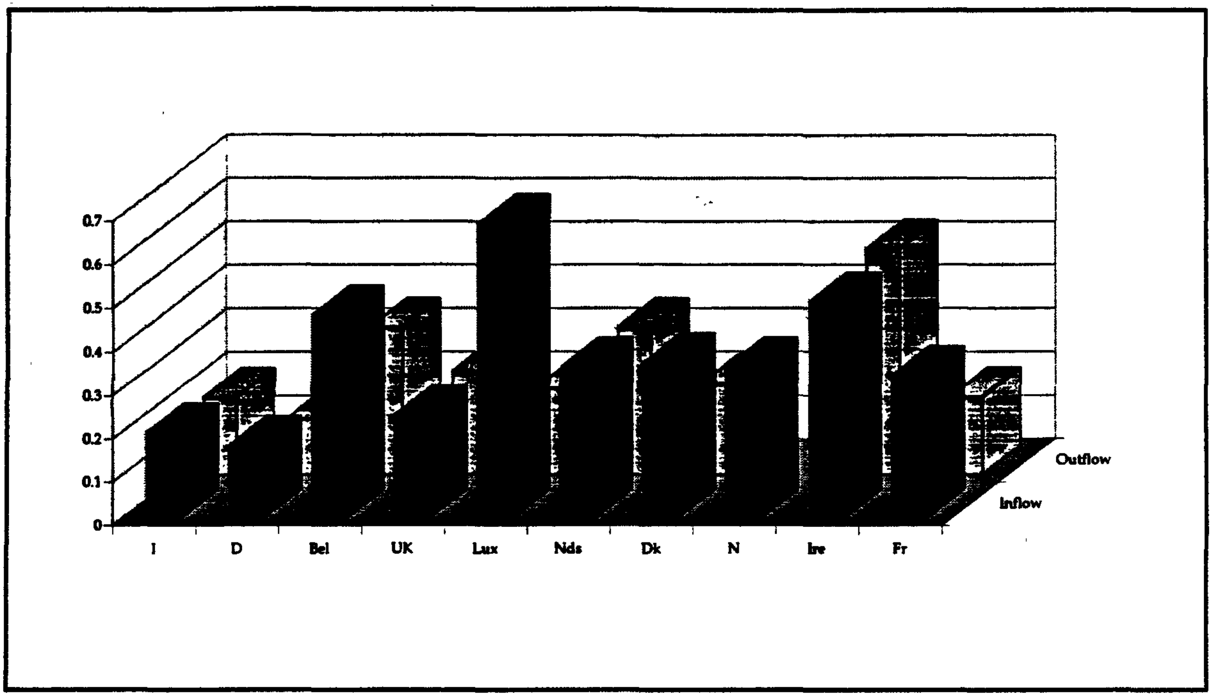
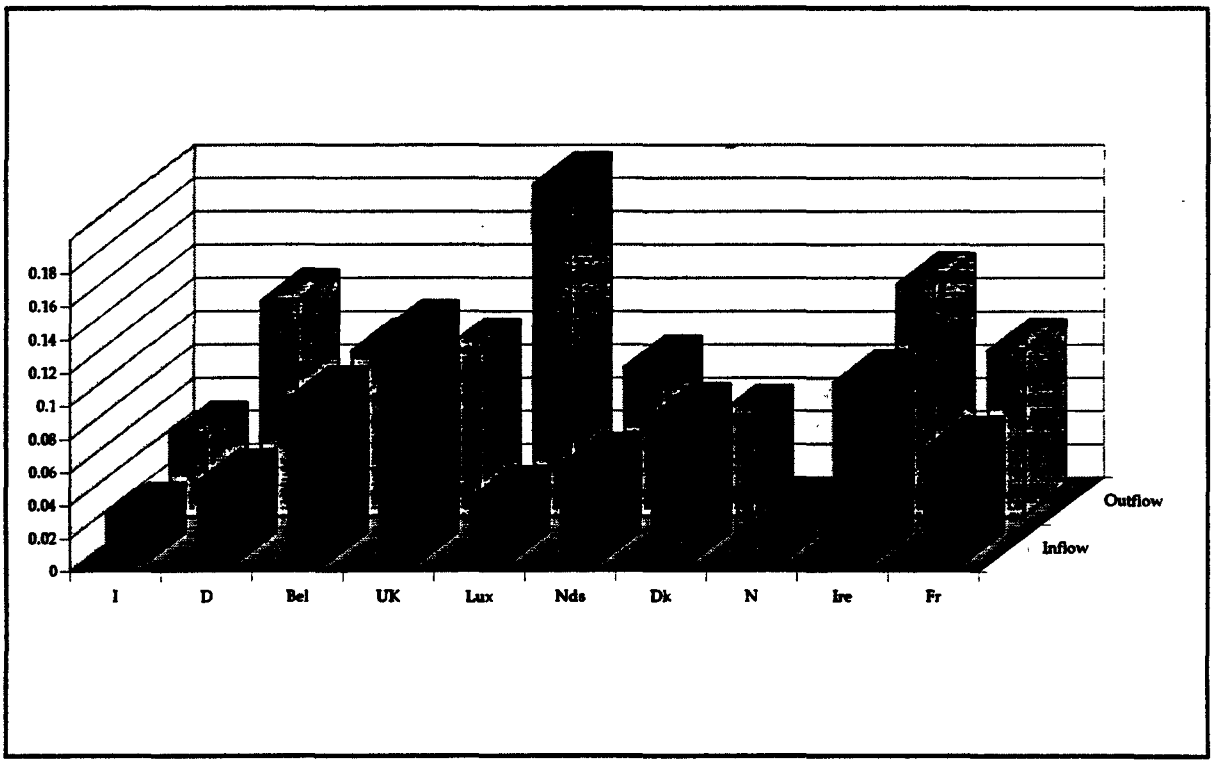


Figure 4.3 Purchase of Sale of Equipment in USA



note, in passing, the apparently high outflow figure for Luxembourg. Part of the explanation for this can perhaps be found in Figure 4.4 which demonstrates the strong inflow of the "right to use inventions" from the USA. In fact there are significant two-way flows for at least Luxembourg, Ireland and the UK for this channel of transfer.

Whilst it is clear that Japan is important, especially for certain channels, we are surprised that it is not more significant, especially for some countries (such as the UK). We illustrate this using Figure 4.5 which reveals, for example, surprisingly high ratios of outflows to inflows and the unexpectedly low figure for inflows in the case of the UK. Our own experience of survey and case study work amongst Japanese companies in the UK is that they have become increasingly reticent, partly because of the extraordinary level of interest in them amongst the research community. Our feeling therefore is that they are probably underrepresented in the sample. Finally, it is clear from the last column of Table 4.12 that, other countries not explicitly covered by the headings, are rarely an important source of equipment technologies, but are often an important destination. Again, the direction of flow here probably reflects the technology gap, for example, between European countries and the Third World. Some support for the direction of flows relating to the technology gap hypotheses can be found in the relatively small ratios of inflows to outflows in columns 3 and, more particularly, 6 of Table 4.12.

Table 4.13 provides more detail about the technology flows relating to "communication with/specialist services from other enterprises". These appear to be more nationally based, as shown by the higher percentage figures in column 1. In this instance, the ratios of inflows to outflows tend to be lower in Table 4.13 than in 4.12. Again, however, they are particularly low for the non EC, European and other countries, almost certainly reflecting their relative levels of technology and knowhow.

Finally, Table 4.14 reports the responses about technology flows relating to the right to use inventions (including licences), again see Figures 4.4 and 4.5. As might be expected given the importance of key non-European countries as sources of inventions, the USA and Japan appear much more important in this table. Again, the direction of flows is generally inward, except in the cases of non-EC European and Other countries.

4.4 Conclusions and Policy Implications

A number of important policy conclusions can be drawn from the results of this chapter. The first is that overall information requirements rise with firm size. The second is that the relative importance of different sources of information also differ across firm sizes. While internal sources become more important, this does not necessarily imply a greater self-reliance, because a number of other, external sources also increase in importance.[6] We provide tentative evidence that, taken overall, the importance of external sources increases more rapidly with firm size than internal.[7] Examples of external sources which are less clearly related to size are various aspects of the buyer-supplier chain. An example which is strongly positively linked, if sectorally limited, is that of patents.

Figure 4.4 Right to Use Inventions (Including Licences) in USA

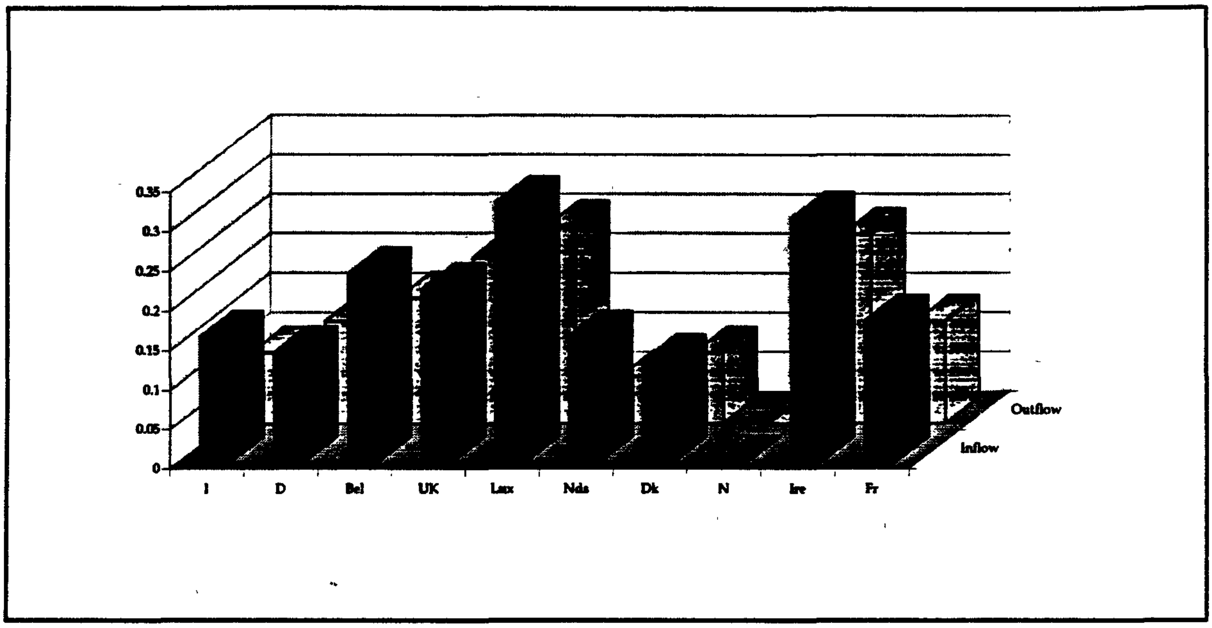
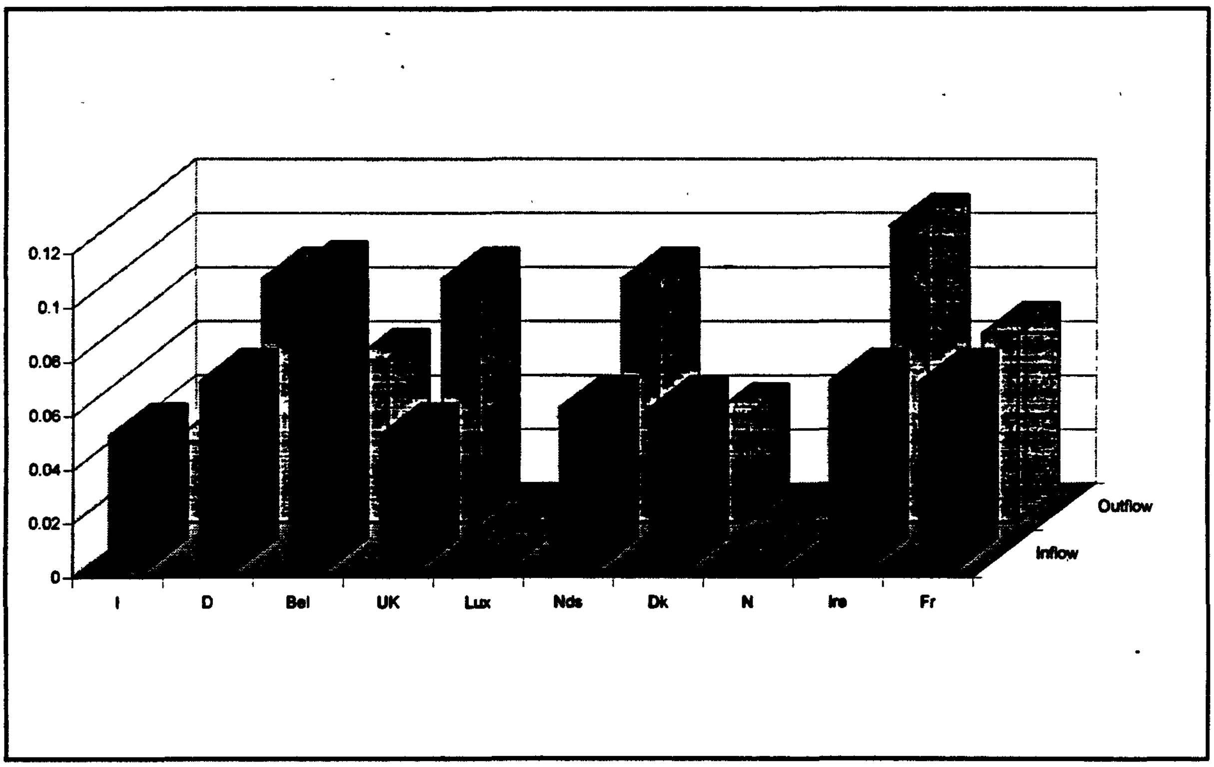


Figure 4.5 Right to Use Invention (Including Licences) in Japan



The evidence of the previous chapter was that the increased information needs of larger companies are not entirely being met and that informational inadequacies tend to be a more significant barrier amongst larger than smaller companies. Rather than to interpret this as an indication that small firms do not face problems,[8] we view it as evidence of the need for improved information flows in order to allow companies to increase in size without adverse consequences. Thus, firm growth may require government intervention to improve information flows.

As we have already noted, we would expect different sectors to have different information requirements. After all, they produce different products using different technologies, varying in the extent to which they rely on the science base. In addition, they face different market structures and degrees of competition. Our results suggest that there are some sectors which are extremely reliant on information flows. Interestingly, these include a number of service sectors, including some of those which distribute and market manufactured goods.

The key policy aspect, however, concerns the implications of changing industrial structure for information flows.[9] Information and technology flows are clearly both a cause and a consequence of changing structure. In both cases they determine the efficiency with which economies adapt to changing social, economic and political circumstances. The shift from rural to industrial and from industrial to service-based activities remains an important feature in different parts of Europe, each with its own implications for the amount and type of information and technology.

The final policy area concerns the "network" aspects of information and technology flows. We have already noted that sources of information internal to the firm are extremely important. However, external sources are also significant and may have become increasingly so with the passage of time, encouraged, in part, by the EC Framework Programmes. One set of results relating to this issue shows the ratio of inflows to outflows. As with the technological balance of payments a high inflow to outflow may not reflect a weak technological position insofar as companies buy in and build upon the technological knowhow of others. While inflows marginally exceed outflows, we were somewhat surprised by the relatively large number of cells in which outflows exceed inflow.

This picture of information flows between companies is reinforced by the spatial analysis. Here we demonstrate that information flows within a given country are often the single most important source. Nevertheless, there are significant flows between countries. Thus, it is important to see access to information and technology in an international context. The results indicate a balance of flow from more towards less advanced economies.

Endnotes

1. "Various types of information are required in the development and introduction of new products and processes. We are interested to know more about where this information is found... Please indicate the importance of the following internal sources (these include management, production, R&D, sales and marketing functions), and/or external sources of information for your enterprises innovation activities during 1990-92". (EC, 1994, p. 52).

2. "We would like to ask about the channels through which your enterprise gains access to new technology". Q6, "please indicate whether your enterprise has acquired any new technologies during 1992 in one or other of the following ways....". Q7, "Please indicate whether your enterprise transferred any new technologies out of the enterprise in one or other of the following ways during 1992...". (EC 1994, p.54).

3. Mobility of skilled employees presumably, in the majority of cases, relates to members of staff who leave to join another enterprise, which will generally have a negative impact on the reporting firm but a positive effect from a social viewpoint, linked to the broader dissemination of knowledge (Bosworth, *et al.* 1994). In probably a minority of cases, it may relate to the movement of individuals whilst still in the employment of the firm. This might be the case with the transfer of employees to different parts of a group or the movement of individuals between firms undertaking a research joint venture.

4. Note that these ratios cannot be derived directly from Table 4.10, which normalises the inflow and outflow results as a proportion of the highest flow value.

5. Of course, it may also be the consequence of the small sample insofar as this gives rise to some form of sample selection bias.

6. Evidence also exists that external sources may have become relatively more important over time for firms of a given size (Rothwell and Beesley, 1989, p. 89).

7. This result is not entirely consistent with that of Chapter 3, which suggested that R&D spend increased as a proportion of total innovatory expenditure as firm size increased.

8. Rothwell and Beesley (1989, p. 98) argue that, "We have been unable to obtain any evidence to suggest that lack of access to external technology and knowhow is a significant barrier to SMFs that have growth potential".

9. While sectoral analyses are enormously valuable in highlighting medium to long term trends in product demand and employment (Wilson and Lindley, 1991; Heijke, 1994), they often require further more qualitative elaboration

(Wilson and Bosworth, 1987; Lindley, 1987). The implications for information often depend upon the way in which products and services are delivered. Examples would be the growth in ICT - delivered services, which are changing the organisation of industry and the degree to which output is traded internationally.

Chapter 5 Appropriability, Intellectual Property and Information Flows

5.1 Introduction

5.1.1 Aims and Scope

While we have briefly touched upon a number of issues relating to intellectual property at various points during the Report, we deferred a more detailed discussion until the present chapter. The CIS Report contains a wealth of new information about the role of IP in the stimulation and diffusion of inventive activity, broadly defined. In particular, question 12.15 is concerned with the issue of appropriability insofar as it addresses the importance of the problem that "innovation is too easy to copy". Question 9 deals with various forms of IP protection as a method of maintaining and increasing the competitiveness of product and process innovations. In addition, as we noted in Chapter 4, question 4 of the CIS examines the extent to which patent disclosures are a source of information amongst firms. Before discussing these results, however, this chapter outlines the reasons why IP is potentially so important in considering the topic of information flows. In doing so, it sets out some of the strengths and weaknesses of the CIS for analysing the role of IP in the innovation process. It then presents the results of our preliminary exploration of the data, before drawing of the main conclusions of this chapter.

5.1.2 Role of IP in Information Flows

A key feature of new knowledge is that it is relatively expensive to produce and cheap to reproduce. At its simplest, the creation of a revolutionary new technology may cost millions of ECUs, but it might be reengineered at a fraction of the cost. This is clearly more important for some sectors than for others, depending on the ratio of the costs of 'creation' to 'copying'. The normally quoted example is chemicals or pharmaceuticals. Here, the medical properties of, for example, a newly produced drug may require extensive research and development, as well as medical trails, prior to marketing. On the other hand, with modern technologies for analysing the composition of compounds, the precise chemical content can be reanalysed quickly and accurately at low cost. Thus, some form of protection is required in order to ensure that the inventor (or owner) appropriates the benefits.[1]

There are a number of different forms of protection for a company's intellectual property. From what we have already said, the difficulty of copying or 'reengineering' a product is likely to be important in some areas. Highly complex designs or products that cannot be dismantled or analysed without affecting key attributes or features, fall into this category. In addition, again dependent on the complexity of the product, copying or introducing a suitable alternative product takes time. In some instances, this may be long enough to establish a market advantage or even dominance, for example, through advertising and other barriers to entry. In other cases, having a sufficient lead time advantage over other firms can provide the 'space' to further upgrade the product and maintain a competitive advantage. Thomas Watson, Chairman of the Board of IBM is quoted as saying, "I believe that when we make a new machine announcement, we should set up a future date at which we can reasonably assume that a competitor's article of greater capability will be announced. We should then target our own development programme to produce a better machine on or before that date". (Quoted in Ordover and Willig, 1985, p. 311).

It is often believed that Japanese companies behave in this manner. From the point of view of the present Report, we should make a distinction between these two forms of protection. Where complexity is the issue, other things being equal, information is inherently difficult to extract. Where lead time is the issue, *ceteris paribus*, information may be freely available, but the commercial efficiency of the firm ensures appropriation of the benefits. However, in general, we would expect these two forms of protection to be related, with complexity offering the firm an opportunity to exploit lead-time.

The other main way of protecting creative outputs is through the system of intellectual property laws. Often, writers make a distinction between secrecy and protection, under intellectual property rights (IPRs). The reason is that, in general, most forms of IPR protection under the law involve some form of disclosure of the newly created information, while secrecy does not. This is a relevant distinction, but it is important to note that 'trade secrecy' is an integral and important component of IPR laws.

Trade secrets are often viewed as an inexpensive method of ensuring appropriation. This may be misleading because secrecy may involve the introduction of security devices and staff. It may also require the payment of higher salaries to employees who have access to key codified and (particularly) uncodified information. Although there is protection under the trade secrets law (and there have been some notable cases, such as the move of a Senior Director of General Motors to Volkswagen),[2] legal cases can be expensive and messy. Nevertheless, secrecy is likely to be an important part of the armour in technically and commercially sensitive areas and, in some of the comparisons which follow, we often treat trade secrets as a "base-line" form of protection which, in principle, is available to all firms. Trade secrets have been argued to be potentially more important for process than product innovation. The former can be more effectively kept within the confines of the firm, while the latter is more often sold-on to the firm's customers. This is an interesting empirical question which can be answered with the aid of the CIS results.

The other part of the legal system, however, includes a variety of registration systems,[3] the most widely researched of which concerns patents. Patent law is broadly comparable across the EU and is covered by similar domestic laws, the European Patent Convention and "equal access" to world-wide patents under the Patent Cooperation Treaty. (We return to other forms of protection and the interpretation of the term 'registration' below). Patents give the inventor (or owner) monopoly rights over their invention for a fixed period (normally 20 years), subject to meeting a number of legal and administrative commitments (such as the payment of renewal fees). The protection, however, is given in return for disclosure of information about the invention. Note, that disclosure relates to the "technical" details of the novel part of the invention and does not require the inventor to declare the economically most viable route to its exploitation. Thus, in practice, expenditures to purchase or licence may also require other payments for "knowhow".

5.1.3 Policy Issues

Appropriability and IPRs form an area of enormous policy interest and debate. While we touch upon a number of issues in the present section, not all aspects of the debate can be informed, let alone resolved by the CIS (this was never the aim of the survey).

The IPR system should be seen as an interlocking network of different forms of protection, where each type is intended to stimulate a particular aspect or area of creativity. The system is designed with a number of sometimes conflicting aims in mind:

(i) to provide an incentive which ensures a sufficient flow of inventions/innovations (first commercial use)

(ii) to ensure adequate disclosure of the underlying inventive output in order to increase the stock of knowledge on which future creativity draws

(iii) to minimise adverse static (short-run) welfare effects on consumers caused by the incentive offered to the inventor/innovator.

The CIS touches upon all of these issues in a positive sense, mapping the extent to which different forms of IP protection are viewed as effective and exploring the use of various forms of IP as sources of information. However, coverage of the different dimensions of IPR in the CIS is fairly limited. In summary, the list of methods for maintaining and increasing the competiveness of both product and process innovation covered by the CIS are:

(i) patents
(ii) registration of design
(iii) secrecy
(iv) complexity of design
(v) lead-time over competitors

In the tables which follow, we use the notation (i)-(v) above, where space does not permit the inclusion of the full title. Thus, it is clear that, while the CIS covers a number of interesting forms of appopriation, it does not deal with copyright or trade and service marks, amongst other things. This makes it difficult to use the survey to address issues of gaps and overlaps in IPR in any detail. However, it should be possible to consider the question if whether firms use a single form (if any) or a combination of different types of protection for their innovation.

In this context, it is important to note that, despite the amount of attention they have received, patents only form a small (although important) part of the legal system of IPRs. Patents relate particularly to industrial inventions (and correspond fairly closely with some part of the outputs of R&D as defined by the Frascati manual). There have been some extensions of the interpretation of patent coverage to include genetically engineered material and, to a lesser extent, computer software - though there is intense current debate about the use of patents in these areas.[4] At the moment, for example, software appears more likely to be protected under copyright law. Again, this is not covered by the CIS. While we cannot hope to resolve the policy debate about the optimal extent of patent coverage, it is interesting to explore differences across sectors in the effectiveness of patent protection.

The CIS includes a small amount of information about the use of design protection. Designs relate to the shape, pattern or configuration of an object. Not all designs need to be registered, although this is the case with patent designs, textile designs, etc. Designs may prove to be more important than they appear at first sight. It has been noted by some commentators, for example, that they appear to be more widely used by Japanese than by UK companies. In addition, casual inspection of the trends in IP in Japan reveal that they play an important part in stimulating and protecting the initial phases of the indigenisation of R&D activities. In addition, designs may be an important source of information that can be drawn on in current creative activity. The CIS enables some light to be thrown on the use of designs by firm size, sector and country.

On the other hand, the CIS does not deal with a number of other forms of IPRs. In particular, there are the areas of trademarks and service marks, which may be linked to new product (service) launches.[5] In addition, there is copyright, which is generally not registered (although in the case of publications governments sometimes seek to have a copy lodged with the national library). There is also protection for plant and seed varieties. Each form of IPR is more applicable to a particular area of economic and social activity. Without going into detail, the point is that they form types of protection not covered by the CIS, but may be essential to the creativity of particular individuals, companies and institutions. We will be interested to see whether we can find any evidence of this omission in our results which might suggest a revision to the design of any future CIS.

Finally, we turn to the issue of trade secrets. While this is often treated in the literature as a residual form of protection, it is nevertheless an integral and extremely important part of IPR laws. Nevertheless, every firm to some degree has accress to trade secrets, unlike patents which are only relevant to certain sectors. It might be hypothesized, for example, that small firms are more reliant upon trade secrets than large firms. It is well known, for example, that small firms have a lower propensity to patent than their larger counterparts. Although we have couched the discussion of firm size in terms of trade secrets and patents, it will be interesting from a policy perspective to see if small firms have different access to effective protection than large firms.

5.1.4 Contents of this Chapter

This chapter continues with a discussion of the problems of appropriability as a hinderance to innovation. Section 5.3 then considers the effectiveness of different forms of protection. It outlines the different forms of protection reported to be used and questions whether firms are able to find more effective protection for product or process innovations. It also considers whether the effectiveness of protection differs across countries, firm sizes and industrial sectors. Section 5.4 specifically looks at the role of patent disclosure as a source of information. Finally, Section 5.5 provides a discussion of the main conclusions and policy implications.

5.2 Appropriability

As discussed in Chapter 1, the firm's own knowhow is likely to be more valuable (to the firm itself) if it is able to protect that information. Where protection is not available or secure, the firm may be unable to appropriate the benefits of its innovative activity and thereby the incentives to innovate may be reduced. As a consequence, we have investigated the answers to question 12.15 which attempt to quantify the importance of "innovation too easy to copy" as a hindrance to innovation. Following the pattern established above, Table 5.1 tabulates the responses by country and then we present the results of a multivariate regression.

These data suggest that, across all countries, the score on the Lickert scale indicates this hinderance to be "slightly significant" with a value roughly equal to the mean score across all factors. This is somewhat surprising. So much of the literature emphasises the appropriability issue that one might have expected the scores to have been higher (although one could of course argue that, as policies have been put in to place in all countries to overcome appropriability problems (ie. intellectual property laws), appropriability is no longer a significant hindrance to innovation.

The results of a multivariate analysis of the data are presented in Table 5.2 (only variables with parameters significant at the 5 per cent level are presented in order to economise on space). Again the base observation is an Italian Firm in NACE 15. The data indicate (as with all other questions) that innovators consider the problem more significant than non-innovators. Thus, firms that innovate are more likely to report that ease of copying constitutes a barrier to success. While ease of copying has not stopped them innovating, it may have prevented them from innovating more. Across countries we see that firms in Germany and Spain score the problem more significant than in other countries, whereas firms in the Netherlands and Luxembourg score it least relevant. The significance of the problem appears to increase with firm size and is, thus, of more importance to large than small firms. This suggests that either large firms innovate in ways which are easier to copy (ie. simpler technologies) or, more likely, that their chief source of competition comes from other large firms that have the resources and capacity to imitate more easily.

Across industrial sectors the problem is of least importance in NACE 10 (coal mining), 14 (other mining and quarrying), 40 and 41 (jointly, electricity gas and water supply) and most significant in NACE 29 (manufacture of machinery nec) and 30 (manufacture of office machinery and computers). While the latter certainly appear to be higher technology industries, nevertheless the rationale for this is not obvious. The literature often suggests that these problems are of greater significance in chemicals and pharmaceuticals (NACE 24). For this sector however the coefficient estimate although positive is not significant. Again, this supports our view that the respondents have answered this question in the light of the degree and effectiveness of protection that is currently available in their sector. It is widely believed, for example, that patents are an effective form of protection in various parts of the chemicals sector. We return to this issue below.

5.3 Effectiveness of Different Forms of Protection

5.3.1 Background

From what we have already said, it can be seen that the various forms of protection have different implications for information flows. The prime examples, are the case of trade secrets, which is a direct attempt to restrict the flow of information, and patents, that require disclosure of at least the technical information, but seek to restrict the direct use of the invention by other firms for a limited period. Information on the relative importance of those different sources has not been available in Europe (although they were revealed in a USA survey - see Patel and Pavitt, 1995).

The responses to question 9 are restricted to the eight countries that appear in the tables in subsequent sections of this chapter. Note that the question relates to,

> "...the effectiveness of the following methods for maintaining and increasing competitiveness of product [process] innovations introduced during 1990-92."

In what follows, we will use the terms "importance" and "effectiveness" interchangably, although there may be some difference in interpretation. The following sections explore the relative effectiveness of the five tabulated sources: (i) for product and process innovation; (ii) across countries; (iii) over different firm sizes; and (iv) across industries.

5.3.2 Cross Tabular Results

(i) Product *Versus* Process Protection

Table 5.3 and Figure 5.1 set out the results for all countries separately for product and process innovation. The overall effectiveness across the five different forms of protection are very similar (mean scores of 2.7 and 2.5). However, these overall averages conceal some interesting results. First, that trade secrets score almost identically for both product and process. There is no real evidence that trade secrets are more effective for process than product innovation (although very tentative support might be given by the slightly higher ratio of trade secret score to the overall average in the case of process innovation). Second, patent protection, as annecdotal

Figure 5.1 Effectiveness of Different Forms of Protection for Product and Process Innovation

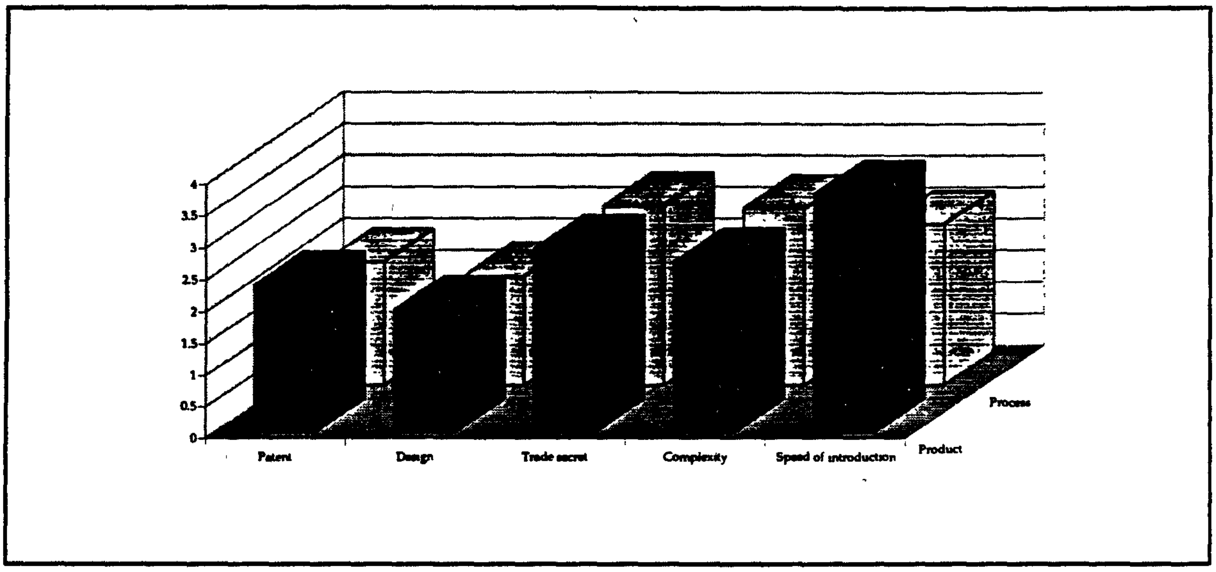
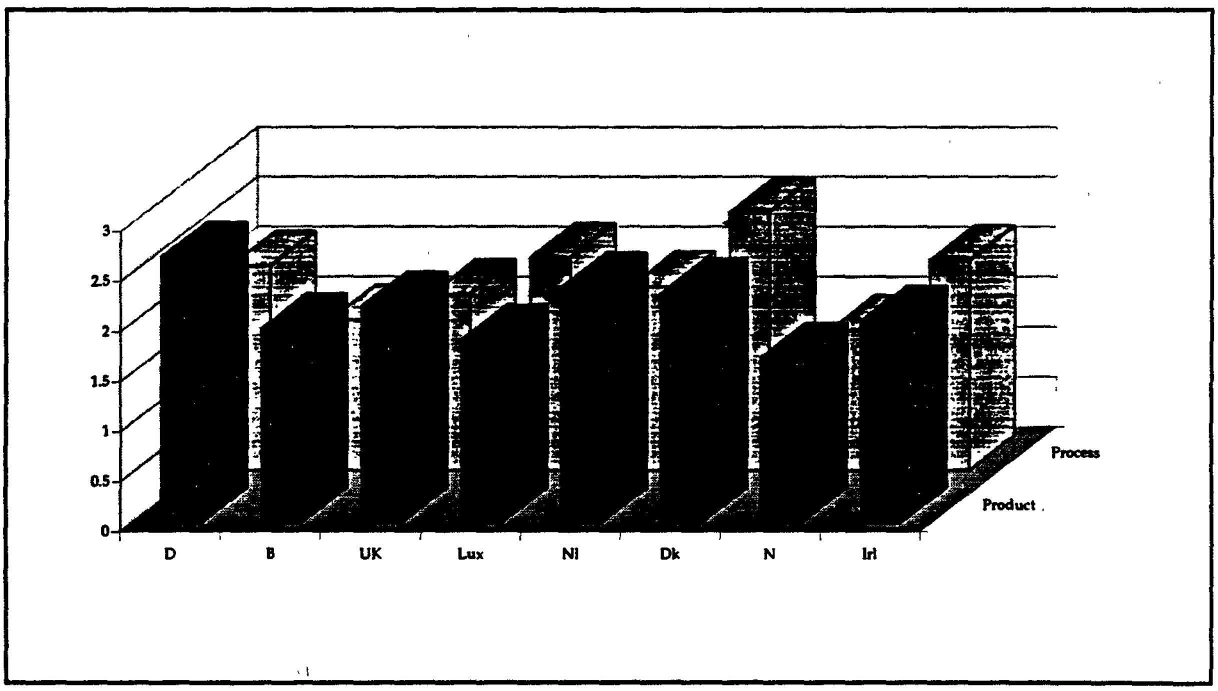


Figure 5.2 Effectiveness of Patent Protection by Country



evidence suggests, is more important for products than processes. Third, as we might expect, speed of introduction is more important for products (ie. speed to market) than processes.

(ii) Country Comparisons

The first feature of Table 5.4 is the difference in the responses for product and process innovations. A simple expectation that all forms of protection will be more important for product than for process innovation is clouded, not only by the likely linkage between product and process change (ie. doing one often requires some change to the other), but also by the difference in the extent of these types of innovative activities across countries. In the case of Germany, which is probably seen as the most product innovative of all the countries listed (at least in terms of the types of product arising from traditional R&D activities), the outcome is absolutely clear cut, with all forms of protection ranked more highly for product than for process change. While there is somewhat more evidence here that secrecy is on balance more important for process than for product change, this is only true in five of the eight cases. A similar result applies to the complexity of design. The table suggests that patents and the registration of designs tend to be more important for product than process innovation (although there are some exceptions). The clearest evidence, however, is in the case of 'lead-time advantage', which is more important for product than process innovation in seven of the eight cases (Denmark is the exception).

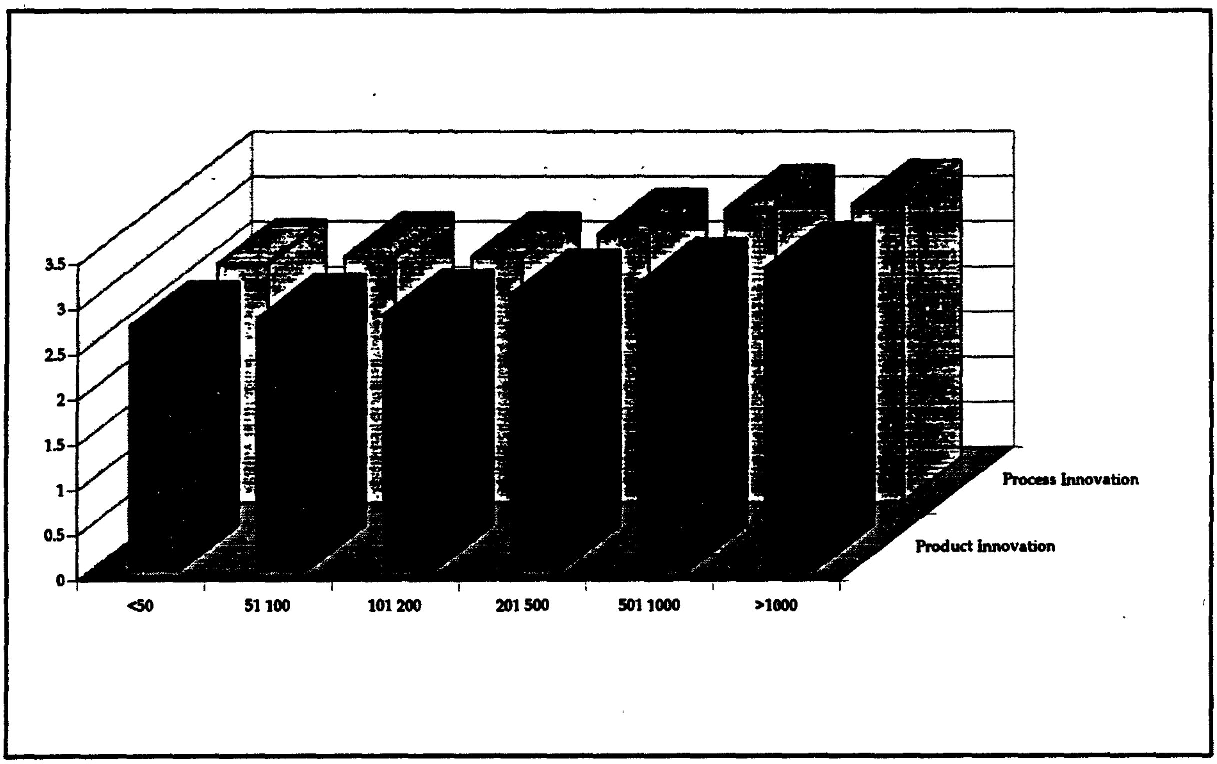
If we look at the importance of the various forms of protection across countries, we find that, in the case of product innovation, Germany appears to give a higher score to all the forms of protection than any other country. In the case of process innovation, while Germany still has some of the highest scores, Denmark records the highest scores for three of the five types of protection. What is clear, however, is that there are very major differences in average scores across the countries for each of the types of protection. In the case of patents for product protection, for example, Germany has a figure of nearly 2.7, compared with Norway's 1.7 (see Figure 5.2). In the case of complexity of design in the product area, Germany has a figure of 3.3 compared with 1.4 for Denmark. Similar magnitudes of difference can be seen across countries in the case of process protection, for example, compare Denmark's value of nearly 3 for design registration with the 1.3 for Norway.

(iii) Firm Size Comparisons

One of the most important driving forces behind the choice of the form of protection seems likely to be firm size. We noted in the earlier sections of this chapter, the likely link between firm size and the use of patents discussed in the literature. The results of the CIS relating to the importance of patents are set out in Table 5.5 and in Figure 5.3. In general, we would anticipate a monotonically increasing relationship, but this will be confounded for some countries by differences in the industrial composition of firms in different size categories. In the case of Germany, for example, there is a monotonic relationship for firms with more than 50 employees for both the product and process areas. The slightly higher figure for the less than

50 group may reflect the relative use of purely national patents amongst the smallest firms, compared with the use of the EPC route amongst the larger companies. While there are some 'blips' in the relationships, the largest firms consistently rate patent protection more effective than smaller firms. The all country average for the effectiveness of patent protection, shown in Figure 5.3, largely evens out these other effects and is approximately monotonic. Broadly similar conclusions apply in the case of registered designs (not shown), although there are one or two exceptions.

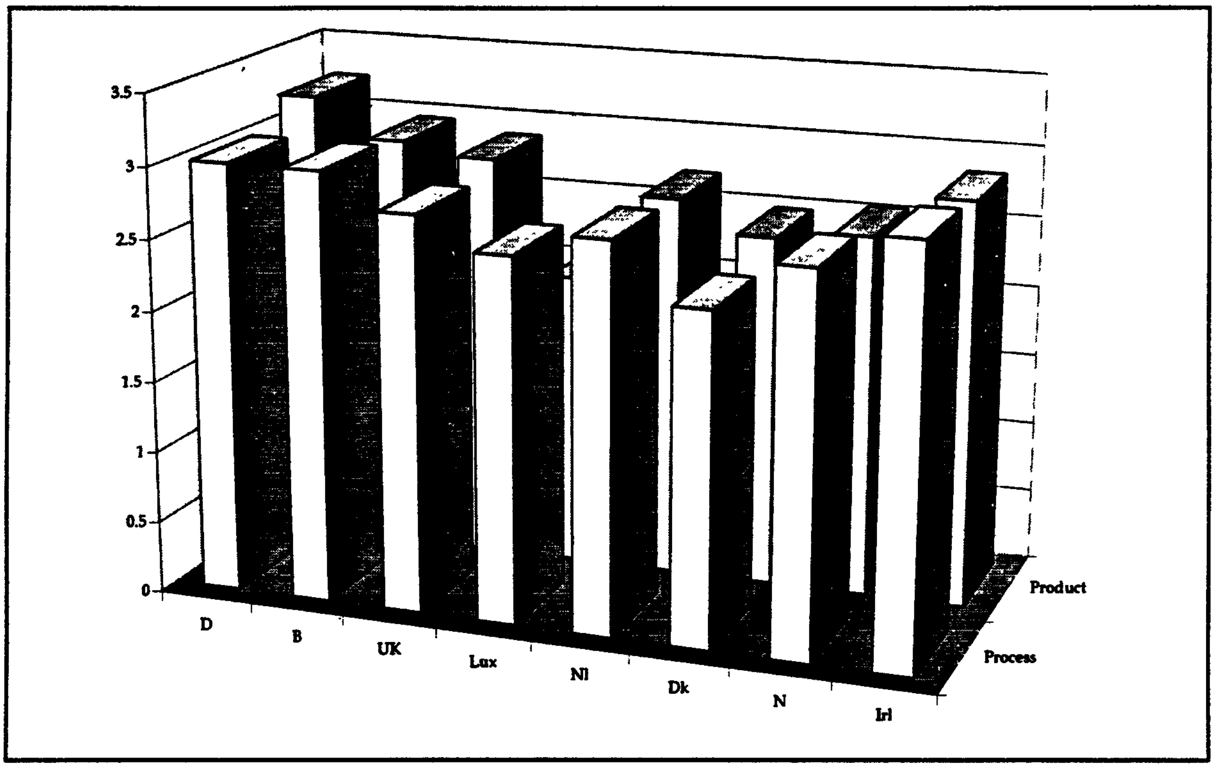
Figure 5.3 Effectiveness of Patent as a Form of Protection (mean score)



Our interest, however, turns to secrecy. As noted in the previous section, there may be some grounds for believing that this might be a relatively more important source for small than for large firms. For example, although we have argued otherwise, secrecy is often talked of as if it is a 'least cost' option. Figure 5.4 and Table 5.6 show that the effectiveness of secrecy tends to rise with firm size - it is always more important for the largest firms than for the smallest, although, again, the relationships are not monotonic (possibly because of differences in industry mix across size categories). Note, however, that the importance of all forms of protection tends to rise with firm size and we need to examine whether secrecy is relatively more important than other forms of protection for small than for large.

In order to undertake this comparison, Table 5.7 looks at the ratio of the importance of secrecy to each of the other four forms of protection in the area of product innovation for both large and small firms. In effect the results in this table control for the fact that large firms find all forms of protection more effective. The first column shows the outcome of the relative importance of secrecy *vis á vis* patents. The result is entirely conclusive - large firms find patents a much more effective form of protection than small firms (the only exception is Norway where the ratios for the two size categories are almost identical). The case with design registration is less clear cut, but in a majority of countries, large firms report secrecy to be more effective *vis á vis* design registration than small firms. A similar conclusion applies to 'complexity of design' and this result is even more clear cut in the case of 'lead time', with the balance in favour of small firms finding this effective even more conclusive.

Figure 5.4 Relative Effectiveness of Trade Secrets



These results are important. They suggest that larger firms find all forms of protection for product innovations to be more important than small firms. Having taken into account the overall difference in the level of effectiveness, small firms clearly find patent protection to be less useful than secrecy compared with larger companies. However, small companies appear to find complexity of design and, most especially 'lead time' to market to be relatively more effective than secrecy compared with large companies. The picture which emerges is that larger companies are better able to appropriate the information surrounding product innovation than small companies. It seems likely that this devolves from their greater resource and, probably, from their greater market power. The smaller companies are probably in a more competitive situation, where keeping secrets is, anyway, relatively more difficult. However, where they can differentiate their design, competitors appear less able to copy. In addition, their primary advantage, relatively speaking, lies in their speed to market. This is the form of protection where the absolute difference between small and large firms are least clear cut.

We now turn to a more detailed analysis of the relative importance of different forms of protection for process innovation. We have already noted that the same result applies as for product innovation, namely, that, almost without exception, the reported effectiveness of protection increases with company size for every type of protection in all countries (there are three exceptions out of a total possible of 40 instances). In considering differences in the relative effectiveness of different forms of protection between small and large companies (not shown), the differences are not as marked in the case of process than product innovation. Nevertheless, broadly the same patterns emerge. In particular, patent protection is significantly less important *vis á vis* secrecy for small than for large firms. On the other hand, in the majority of countries secrecy is more important than all other forms of protection for large firms than for small firms. Again, we find evidence that small firms, relatively speaking, find process complexity and 'quickness to market' in some sense more important than larger firms. Again, just to reiterate, this arises from a comparison of the relative importance across forms of protection - in an absolute sense, large firms find all forms of protection more effective than small firms.

(iv) Industry Results

The extent to which different forms of protection of information are utilised and the importance attached to them appears, at least *a priori*, to be a clear case where there should be significant industry differences. In earlier sections, for example, we noted the general 'industrial' orientation of patent protection. The first question to ask is whether, given the range of different forms of protection on offer, in some industries their overall effectiveness is higher than in others. In the main, the answer to this seems to be that there is relatively little variation in the average score across industries, except for various parts of the service sector, such as NACEs 50 and 51 (which deal with aspects of vehicle sale and repair), 72 (various aspects of computer services) and 74 (other business). Again, this appears to reflect the somewhat 'industrial' orientation of the types of protection listed. Of the more traditional manufacturing sectors, printing and publishing reports one of the lowest scores, which is probably linked to the absence of copyright (amongst other things) from the list. The effectiveness of the listed forms of protection seems highest amongst the chemicals, electrical and parts of the engineering sector.

Table 5.8 sets out the results in a fairly straightforward way, listing the NACEs which report the highest scores across the five different forms of protection covered by the CIS. The outcome is quite clear, with NACE 34 (motor vehicles) reporting the highest score for product innovation and appearing third in the list for process innovation. Based on the number of times NACE 34 had the highest score, it appeared first (equal) on the list for both product and process innovation (along with NACE 33 - precision instruments - which was ranked second in both cases according to its average score). There is more difference between the overall product and process innovation positions, although there is still a fairly strong correlation between the two (more so for the number of rankings of scores than the average overall scores themselves). The main conclusion of this exercise is that, in general, the more effective protection seems to be secured by particular industries, which may relate to the types of technologies involved and the ease of appropriability, but also to industry structure. Ignoring the service sectors, where there is a greater questionmark about the coverage of different types of measures, the ratio of average overall (ie across the five measures) product to process scores ranges from 0.97 in NACE 19 (leather and leather products - the only industry with a ratio less than unity) to 1.10 in NACE 34 (motor vehicles). While, at first sight, this does not seem an enormous variation, it is clearly well over 10 per cent.

As expected, there is considerable variation in the reported effectiveness of patent protection across sectors. However, in general, those industries which indicate that patents are relatively important for the protection of product innovation also report the same for process, bearing in mind that, overall, patents are more important for the former than the latter. Only in one industry, again, NACE 15 (leather and leather products) is the score higher for process than product innovation. The industries where patents are relatively important are NACE 24 (chemicals and chemical products), 29 (machinery and equipment), 31 (electrical machinery - product only), 32 (radio and telecommunications equipment), 33 (precision instruments), 34 and 35 (motor vehicles and other transport - both product only). The precise ranking is set out in columns (1) and (7) of Table 5.8. Comparison of the two columns futher suggests that there are some interesting differences in the relative effectiveness of patent protection for product and process innovations across sectors. As in the case of the overall average figures, the two scores are closer together in the various chemicals related industries, than in the engineering-based industries. This is almost certainly a reflection of the extent to which such industries design their own capital stock, rather than buy it in from other firms.

Again, the results suggest that secrecy is not especially linked to product rather than process innovation, but its importance does vary across sectors - although it is again correlated with other forms of protection, such as patents. The highest scores for secrecy in both product and process innovations can be found in NACE 24 (chemicals and chemical products). The next highest score for product innovation can be found in NACE 29 (machinery and equipment), while the next highest score in process innovation is associated with NACE 34 (motor vehicles). In this instance, there are some interesting differences. NACE 29 (machinery and equipment), for example, ranks second in terms of the emphasis placed upon secrecy in product innovation, but does not appear in the top five for the corresponding process innovation. NACE 19 (leather and leather products), however, appears in the top five in the process innovation column - perhaps because of the 'craft' nature of the skills involved in this industry, while NACE 15 (food, drink and tobacco) appears in the equivalent product column.

Many of the sectors that we have already reported in the earlier columns reappear in columns (4 - 'complexity') and (5 - 'lead time'). However, NACE 25 (rubber and plastics) makes its first appearance in both columns (4) and (5) for product innovation and in column (5) for process.

5.3.3 Multivariate Results

This section reports on a small number of multivariate results which examine firm size, industry and country effects on the reported effectiveness of the various types of protection. The regressions broadly follow the "standard form " developed above, although there is one important difference which makes comparison with other multivariate results difficult. In particular, in this instance, there are no results for Italy. Hence NACE 15 from Germany is taken as the base group. In this section we adopt a somewhat different way of presenting the results, based upon the earlier discussion.

(i) Firm Size Effects

The firm size parameters from the regressions are all significant positive. They indicate the effects of a 1 per cent rise in firm size (measured by employment) on the effectiveness of each form of protection. The ranking of the first two, patents and secrecy, are consistent for product and process innovation (rankings are indicated in parentheses). The others are more alike, but are consistent with the earlier conclusion that small firms are relatively more reliant on complexity and speed to market than larger firms.

(ii) Country Effects

The country effects shown in Table 5.10 have at least one obvious and dominant pattern. Almost all coefficients are negative, indicating that every source of information is reported as less effective by other countries than by Germany. The only possible exception to this is Denmark, which places more importance on designs for both product and process innovation, but also places more emphasis on patents and on complexity for process innovation than Germany. The second feature of the table, is that the differences between countries appear to be lower for process than product innovation. Third, the largest differences which appear in the table relate to the complexity of the product the rankings here appear to make some sense in terms of the technological complexity of the products.

(iii) Industry Effects

It is probably better to talk about the industry effects rather than to try and compress them into a single table, as they differ significantly across forms of protection.

(iv) Patents. Within the manufacturing sector, NACE 29 (machinery and equipment), 33 (medical and precision instruments) and 32 (radio and telecommunications equipment) have the highest (significant coefficients) for product innovation. In the case of the effectiveness of patents in the protection of process innovations, there are relatively few industries which exhibit significantly larger coefficients than NACE 15 (food and drink - the base group). Indeed, only NACE 24 (chemicals) and 29 (machinery and equipment) stand out in this respect. On the other hand, there are several sectors that report significantly lower levels of effectiveness, including NACEs 21 and 22 (pulp, paper and paper products, and publishing, printing, etc.).

(v) Registered Designs. Again, focusing on production sectors, product design protection appears most important in NACE 31 (office machinery and computers) and 34 (motor vehicles), followed by 29 (machinery and equipment). In the case of process innovation protection, significant positive coefficients are formed in NACE 18 (manufacturing of wearing apparel), 22 (machinery and equipment) and 25 (radio and telecommunications).

(vi) Trade Secrets. There were relatively few sectors that found trade secrets more effective than NACE 15 (food and drink) for the protection of product innovations - NACE 24 (chemicals), however, was one that was significantly higher at the 10 per cent level. Many more sectors appeared significantly lower, including NACE 50 (sales, maintenance and repair of motor vehicles) and 51 (wholesale trade in motor vehicles). Within manufacturing NACE 15 (publishing and printing) was amongst the lowest. There is clearly a distinction here between sectors that rely on the dissemination of information and the others. There were other examples of this type, such as NACE 85 (human health activities). In the corresponding case of protection for process innovation, NACE 17 (chemicals) again stood out as the isolated significant positive case. In a similar way to product innovation, there were many more significant negative coefficients (ie. where trade secrets were less effective than in food and drink). Most of those noted above reappeared, along with NACE 40 (electricity, gas and water).

(vii) Complexity. In the case of product complexity, only NACE 24 (chemicals) and NACE 33 (medical and precision instruments) exhibited significant positive coefficients. Amongst manufacturing sectors, NACE 22 (printing and publishing) and 18 (manufacture of wearing apparel) had significant negative coefficients, although there were a number of service sectors (including a number of those noted above) that also had significant negative signs. In the case of process protection, the majority of manufacturing sectors reported complexity to be more effective than NACE 15, while the majority of service sectors reported it to be less so. In manufacturing, the highest positive coefficients can be found in NACE 17 (manufacture of textiles) and 24 (chemicals), although a large block of metal goods product sectors also shared positive coefficients.

(viii) Lead Time. Again the majority of manufacturing sectors reported lead time to be at least as or more important than NACE 15. Of these, NACE 20 (manufacture of wood and wood products), 24 (chemicals) and 33 (medical and precision instruments) have the largest significant coefficients. Similarly NACE 35 (construction), and 34 and 35 (various aspects of selling motor vehicles) had amongst the lowest coefficients. Very similar conclusions apply in the case of process innovation, with NACE 24 (chemicals) and, in this instance, NACE 21 (pulp and paper) above the base sector, with broadly the same block of industries below.

5.4. Patents and Information Flows

The CIS also collects information on the importance of patent disclosure as a source of information (although, as we have noted, not about information revealed by other forms of IPR protection). This is collected in question 4 which, effectively asks the respondent to indicate the importance (using a five-point Lickert scale) of patent disclosures for their enterprise's innovation activities during 1990-92. However, we have already discussed these results in some detail in Chapter 3 and, therefore, only give them fairly cursory treatment here.

(i) Cross Tabular Material

In the case of patents as a source of information, for example, Table 4.8 demonstrated that except for Portugal, all countries (for which information is available) show a positive relationship between firm size and the use of patent disclosures. In the majority of countries this was not only a strong relationship, but also a monotonically increasing one. This is further illustrated in Figure 5.4 which shows the firm size relationship for the use of patent disclosures for the highest (France) and lowest (Norway) usage countries. We know from other sources, that the patent system is more suited to larger firms and, thus, even when inventing, smaller firms tend to make less use of it. In addition, medium sized firms are more likely to use independent patent agents and larger firms are more likely to undertake formal R&D and have in-house patent expertise sometimes in the form of a patent department (Bosworth and Wilson, 1988). In terms of industries, as might be expected, there were important differences between the use of patent disclosures. Of the manufacturing sectors, NACE 24 (chemicals and chemical products, which includes pharmaceuticals) ranks patent disclosure most highly, followed by 33 (medical and precision instruments), 29 (manufacture of machinery and equipment) and 32 (manufacture of radio, television and communications equipment). The only other higher ranking, however, is not so obvious. This was NACE 51 (wholesale trade and commission trade excluding motor vehicles), although this does include the wholesale of pharmaceutical goods.

(ii) Regression Analysis

The results of estimating an OLS regression equation for the relative importance of patent disclosures at the firm level, adopts the 'standard 'model' used in previous sections. The results show clearly the importance of firm size, with a 1 per cent increase in size producing a 0.09 increase in the reported importance. This variable is highly significant. It confirms the fact that larger firms are more likely to search patent databases and is consistent with the general use of the patent system across firm sizes, as noted above.[6] In the light of our earlier observations about the "industrial" orientation of patents coverage, however, this result should be interpreted with some care. Patent disclosures are not relevant to all sectors. The sectors with the highest coefficients are NACE 24 (chemical products), 29 (manufacture of machinery and equipment), 33 (precision instruments watches and clocks), and 51 (food, drink and tobacco). The lowest usage was reported amongst 40 and 41 (electricity, gas and water) and 90 (sewerage and refuse). These rankings correspond fairly closely with our *a priori* expectations. Even holding firm size and sector constant, there remains considerable country variation, with Germany reporting the highest level of importance. Interestingly, the next ranked country is Spain which may reflect the growth and development of Spanish industry in the 1980s, but also sample selection problems for Spain.[7] Observing a mix of countries at various levels of development using information from patent disclosures is not too surprising as the adoption and modification of technologies produced elsewhere may be a particularly important strategy for growth.

5.5. Conclusions and Policy Implications

While, as we pointed out from the outset, it is not possible to throw light on all of the wide ranging policy debate concerning appropriability and information flows, the CIS has provided considerable insights about the role of IP across firms in the European Union.

The first result is that the lack of appropriability does not, at first sight, appear to be a principal hinderance to innovation. The fact that innovations are too easy to copy is only rated about average across the various barriers to innovation. On the other hand, it is rated significantly more highly amongst innovators. This may mean that non-innovators may simply underestimate the problem. On the other hand, while it may not prevent firms from innovating it may stop them from "innovating more". In addition, the problem increases with firm size and is significantly greater in a number of "higher technology" sectors (such as office machinery and computers),

The second feature of the data is that there is tentative evidence that protection is more effective for product than process innovation. Patents and "speed of introduction" appear relatively more product than process oriented.

An important feature of the results, however, is that there is evidence that the different forms of protection covered by the CIS are not so much substitutes for one another, but complementary. German companies, for example, not only tend to rate patents as being more important than firms in other countries but rate every form of protection more highly. Similarly, larger firms tended to rate protection as a whole as being more effective than smaller firms. It seems that IP protection should be thought of as a package in which, if it is worth doing, firms attempt to defend all aspects of their property. Nevertheless, we would want to add the caveat that the sectoral results suggested that the CIS may have defined IP too narrowly. Some indication of this can be gleaned from the fact that none of the designated forms of protection seemed to be important in, for example, communications and the media. On the other hand, we felt that copyright would have been important here, as it would have been in the computer software industry. The role played by trademarks was also not covered in the CIS.

The results concerning patent protection confirm that it tends to be sectorally specific. In addition, there is clear evidence that larger firms view patents to be significantly more effective than smaller firms. Broadly similar results apply to patent disclosures as a source of information. In combination the findings reinforce the widely held view that the patent system, at least as it operates at the present time, is more suited to and more heavily utilised by larger than smaller firms.

We have been at pains throughout to stress that trade secrets are an important part of the IPR system, with particular implications for information flows. This is confirmed in the results. Trade secrets rated as an important form of protection, with a much broader constituency of users than, for example, patents or designs. Interestingly, however, trade secrets do not appear to be quite the "residual" form of protection that we sometimes believe. Trade secrets have to be worked at and are not a cost free option. Indeed, larger firms report trade secrets as being more effective than smaller firms.

Endnotes

1. The inventor is not always the legal owner. Individual inventors can sell or licence their rights. Inventions made by an employee of a company as part of their normal daily tasks (ie. a research chemist), normally belong to the company. Note that companies can also sell or licence the information to other companies.

2. See also Brooks (1971), "One Free Bite", Chapter 10.

3. Note that "registration" is not always necessary to secure protection, as in the cases of copyright and trademarks. Nevertheless, where it is available, it has a number of advantages which often outweigh the costs.

4. In the case of biotechnology, see for example, "Public Hearing on the Patenting of Biotechnological Inventions ...".

5. For a discussion of this interpretation of trademark data, see Bosworth, *et al.* (1996). For an attempt to supplement CIS data with IP flow data from the World Intellectual Property Organisation, see Bosworth and Stoneman (1996).

6. Bosworth and Wilson (1988).

7. The Spanish survey was terminated after only two weeks and may have captured only the more innovative manufacturing firms.

Chapter 6 Co-operative R&D Agreements

6.1 Introduction

Firms and other economic "actors" may interact in many ways.[1] The prime method is through markets, but non market collaboration is also common. A possible distinguishing characteristic of non market interaction in the innovation process is the existence of collaborative agreements. These can take many forms. They may be formal or informal (ie. contractual or not), they may involve two or many more partners, involve one way or two way relationships, have different geographical dimensions and involve different types of actors. The existence of such agreements would be yet another indication that innovation is a "systems" as opposed to a "stand alone" activity.

The existence of such non market collaboration could in a general sense be attributed to the difficulties that exist in trading information and technology on markets (Arrow, 1962).[2] It is useful however to further explore why such arrangements exist. The reasons will of course relate to the nature of the collaborative arrangement itself, for example, an industry/university collaborative arrangement is likely to have a different rationale than an horizontal agreement between two competing firms.

The economics of collaborative research has received increasing attention in recent years (see for example, Ordover and Katz, 1990, Mowery and Rosenberg, 1989, Geroski, 1995). Although the potential advantages of collaborative arrangements have been subjected to only limited empirical evaluation, this literature suggests that for collaboration in research between firms in the same industry the advantages encompass the ability to

- (i) share and lower costs of innovation and to share risks
- (ii) reduce problems arising from appropriability and informational spillovers
- (iii) reduce duplication in R&D
- (iv) exploit scale economies in the R&D process.
- (v) explore non core areas of research, maintaining an option for the future

However cooperative agreements are not limited to horizontal relationships. Vertical agreements also exist. Although, like horizontal arrangements, these may have some potential market power, one would expect that the major advantages to the participants would be in terms of product tailoring for the buyer and reduced demand uncertainty for the supplier.

Collaborative arrangements may also exist because one of the participants is not in fact a market actor. Thus, as largely non market players - universities, government laboratories, research institutes and industry operated R&D labs may only be able to collaborate through such agreements. Collaboration between other parts of the same group of companies is also likely to be external to the market and involve such agreements.

There are, therefore, many reasons for collaborative agreements and why they may encompass different aims and objectives. University/industry collaboration may involve the purchase of expertise from a higher educational institute that cannot be acquired or is too expensive to maintain in-house. For the University it may be a means of financing curiosity driven basic research. On the other hand, a supplier-buyer agreement may be at the applied end of the R&D spectrum, as are agreements with consultancies, although these may relate more to "how" rather than what".

The CIS survey does not enable the reasons for the existence of collaborative agreements to be explored in any great depth, but provides considerable insights into their prevalence and nature in Europe.

The study of collaborative agreements is policy relevant for two reasons. First, such arrangements at the European level can be seen as a way of promoting European integration. Second such agreements can be seen as a means to stimulate innovative activity *per se*. The EC Green Paper on Innovation stresses this policy relevance by its expressed view that issues worthy of debate are

(i) fostering cooperation among enterprises (large and small) and strengthening groupings based on technology or sector in order to realise the potential of local know how
(ii) reinforcing university - industry cooperation
(iii) supporting innovation projects based on cooperation between enterprises at the European level
(iv) developing support for regional innovation strategies and inter regional technology transfer

The material in this Chapter will enable us to at least map out the extent to which such things are already happening. We are less optimistic as to whether it enables one to consider why they are (or are not) happening.

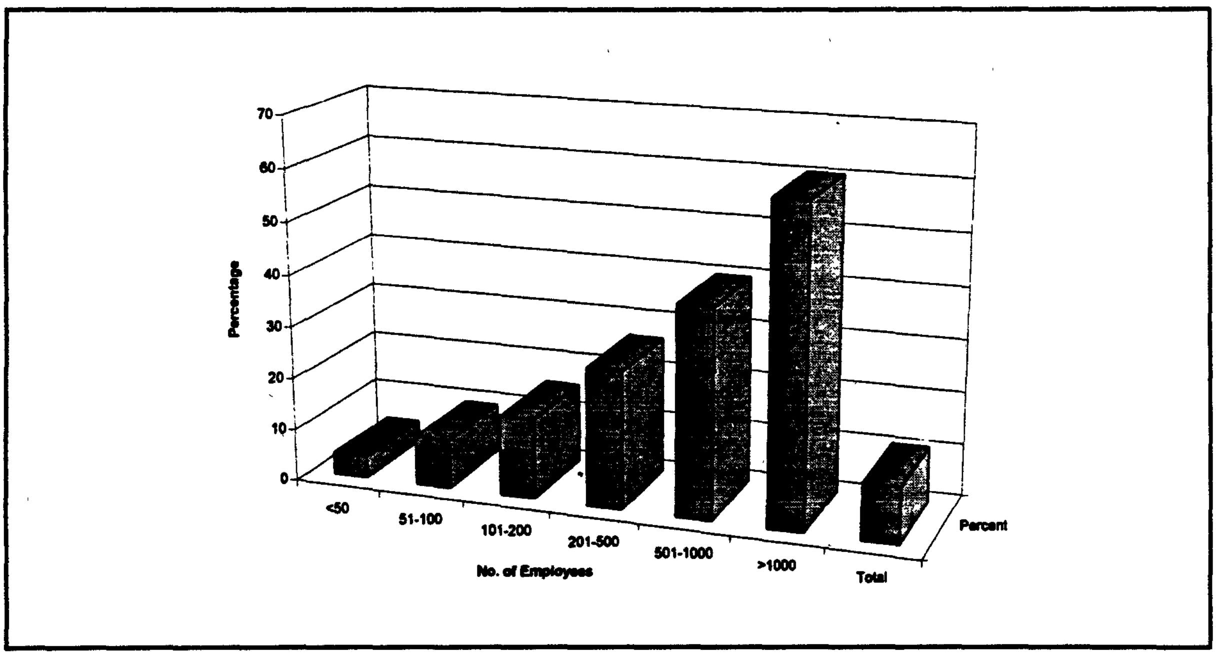
6.2 Pattern of Collaborative Arrangements

Question 11 in the survey defines a cooperative arrangement as one involving active participation in joint R&D projects. The initial enquiry asks whether the respondent had any such agreements[3] and then requests further details about the nature of the partners involved. For the first enquiry the number of firms responding positively, broken down by country, are detailed in Table 6.1 with percentages as a proportion of the number of innovators (firms that do either product, process or product and process innovation) and as a proportion of the whole sample. There are no figures for Portugal.

We observe that cooperation agreements are widespread, although, as a percentage of the total sample, they are more common in the UK and Denmark than elsewhere and much less common in Luxembourg and Italy. When we look only at innovators, however, France, Denmark, the UK, Netherlands, Norway (and to some degree Belgium) stand out as more likely to have collaborative arrangements, although France stands out from the other countries in this respect. We have attempted to cross correlate the data with information from question 12 on whether "lack of opportunities for cooperation" was a hindrance to innovation (see Table 3.7). No clear patterns emerge. Cross correlating with data in Table 6.1 as to whether cooperative agreements are more common when appropriability is a major hindrance to innovation (a causality suggested by the literature) again yields no clear patterns.

Looking across all countries, the breakdown of the existence of a collaborative agreement by firm size is shown in Table 6.2. These data are presented graphically in Figure 6.1. The results clearly show that the probability of a firm having a collaborative agreement increases monotonically with firm size. Whereas the smallest firms have only a 4 per cent chance of being in a collaborative arrangement, the largest firms have a 60 per cent chance. One might note however that (see Table 3.9), as a hindrance to innovation, the difficulty of making cooperative arrangements did not vary significantly with firm size. It would thus seem that whatever is driving the increase with firm size it is not the difficulty of establishing such arrangements.

Figure 6.1 Existence of Collaborative Agreements by Firm Size: All Countries



However, the fact that "innovation too easy to copy" increases in significance with firm size noted above (see Table 5.2), suggests a link with appropriability problems. In the absence of a clear indication as to why small firms are less likely to have collaborative agreements and/or why they might find appropriability problems less severe than large firms, it is difficult to draw any policy implications. If however such agreements are considered "a good thing" *per se*, then these findings suggest that any policies put in place to encourage collaboration should be directed at smaller rather than larger firms.

Looking by NACE (and restricting the reported results to categories with more than 100 observations), the probability of a firm having a collaborative agreement is greatest in sector 72 (33.1 per cent) (computer and related), 32 (29 per cent) (radio and

TV manufacture), 24 (28.3 per cent) (chemicals), 30 (25.8 per cent) (manufacture of office machines and computers) and 33 (25.8 per cent) (manufacture of medical and optical instruments), and lowest in 18 (1.25 per cent) (manufacture of wearing apparel), 19 (2.0 per cent) (leather manufacture), 36 (3.9 per cent) (furniture and other manufacture nec) and 17 (4.0 per cent) (textiles). These findings tend to suggest that collaborative agreements are more common in high and less common in low technology sectors. The reasons for this however are not entirely clear, although there may be a tendency for firms to look to collaboration in new, riskier areas (which, where more radical technological changes are involved, will generally be non-core areas). We have cross correlated these sectoral results with the NACE breakdown of responses on the importance of collaboration difficulties as a hindrance to innovation (Table 3.8). No clear patterns emerge. Similarly we have cross correlated with the NACE breakdown on appropriability (see, for example Table 5.2) and, again, no clear patterns emerge.

6.3 Spatial Aspects of Cooperative Arrangements

Firms responding positively to the first part of the question were asked to answer more detailed questions concerning the nature of their partners and the geographical basis of their collaborative links. Not all those responding positively to the first part of the question provided further information. The breakdown by country is shown in Table 6.3. There are no detailed responses for Italy and Portugal. Nevertheless, the pattern of results in Table 6.3 conforms fairly closely with that reported in Table 6.1

From those responding to the detailed question, Table 6.4 reports on the spatial pattern of positive responses across the whole sample. The data specify the number of firms that report an agreement of each type. Note, however, as firms may have more than one agreement of any type, figures which are based upon the total number of such reports, do not measure percentages with respect to either the number of firms or the number of agreements. In fact the percentages may be best considered as relative to the number of firms that report at least one collaborative agreement of any type. The data in the row and column totals are presented graphically in Figures 6.2 and 6.3

The results indicate that the most common cooperation partners are suppliers (22.8 per cent), clients/customers (21.6 per cent), universities and HEIs (higher educational institutes) (13.0 per cent) and "mother/daughter/sister" enterprises (10.7 per cent). We also see that regional cooperation agreements dominate (47.5 per cent) followed by national agreements (24.4 per cent). Non national agreements are in the minority. Across all different types of arrangements, only 2.8 per cent are with the USA, 6.8 per cent with Japan, 9.0 per cent cross national boundaries with firms in other EC countries and 6.2 per cent with firms in non EC European countries. The most common arrangement is with suppliers in the same region, followed by a client in the same region, followed by a university or HEI in the same region.

Figure 6.2 Percentage of Cooperation Agreements of Different Types

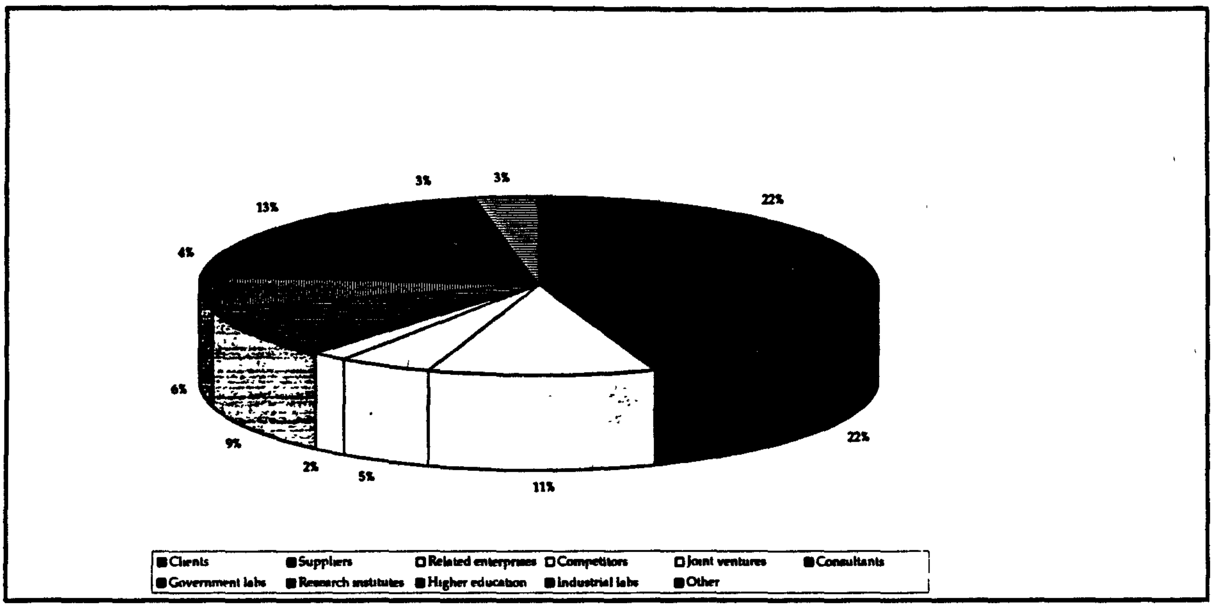


Figure 6.3 Spatial Distribution of Cooperation Agreements (%)

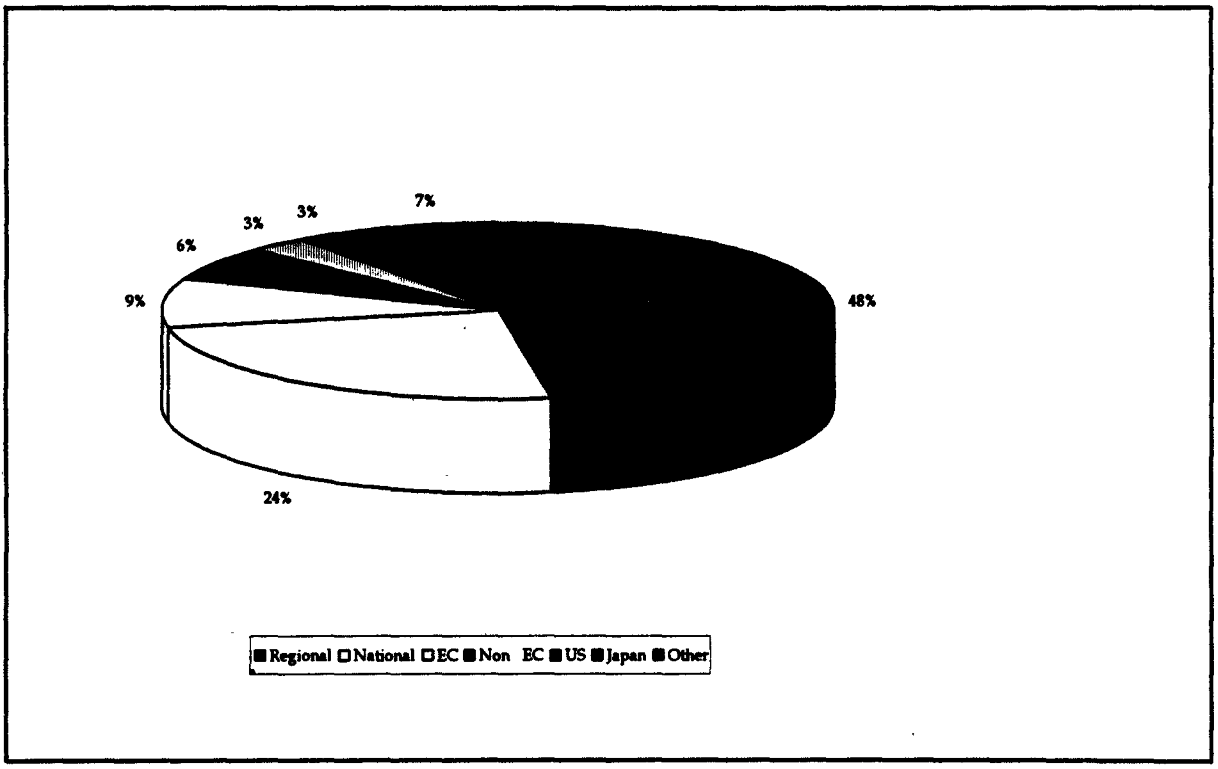


Table 6.5 explores the types of agreements reported country by country, where the percentages are with respect to the total number of the different types of agreements reported in the country. The data indicate that there are significant differences in the patterns across countries. Particular highlights are the importance of agreements with clients in the UK and France, with suppliers in France and with universities laboratories and research institutes in Greece.

Table 6.6 provides information about the geographical pattern of agreements by country. The main result concerns the preponderance of regional agreements, which is common to most countries except Denmark where national and European agreements are relatively more important. Perhaps not surprisingly the UK shows the highest proportion of US and Japanese agreements and a greater than average number of European non EC agreements. This result is more in line with our *a priori* expectations than those relating to the geographical sources of technology discussed in Chapter 4.

6.4 Conclusions

The data from the CIS survey indicate that cooperation agreements are widespread in Europe although with certain noticeable differences across countries. We find that collaborative agreements are more common in high and less common in low techology sectors. The data also clearly show that the probability of a firm having a collaborative agreement increases monotonically with firm size. Whereas the smallest firms have only a 4 per cent chance of being in a collaborative arrangement, the largest firms have a 60 per cent chance. The result is related to the greater range of souces and extent of networking of larger firms, as well as their higher research intensity.

Given that the Green paper on Innovation suggests that "fostering cooperation among enterprises (large and small)" may well be an important issue for EC policy makers these findings suggest that any such policy would be best directed at the encouragement of collaboration involving SMEs (probably in low tech sectors). The problem with this however, is that we have been unable to clarify the rationale for the existing patterns of collaborative arrangements. Thus for example we have explored whether:

(i) lack of opportunities for cooperation was a hindrance to collaboration - no clear patterns emerged.

(ii) whether appropriability problems stimulated cooperation agreements and, again, no clear patterns emerged.

The Green Paper also indicates that the reinforcing of university/industry co-operation is an important issue. We find that the third most common type of co-operation agreement is between firms and universities (the most common cooperation partners are suppliers and clients/customers). There is thus already considerable cooperation, especially in Germany and Greece. It may well be desirable to enhance such collaboration further but the data do not enable us to specify what the constraints are upon this.

A further suggested policy objective in the Green paper is to encourage cooperation between enterprises at the European level. The pattern of agreements shows that non national agreements are in the minority. Relative to the number of firms that report at least one collaborative agreement of any type, only 9 per cent are with firms in other EC countries and only 6 per cent with firms in non EC European countries. By comparison only 3 per cent are with the USA and 7per cent with Japan. One suspects that the number of intra European agreements has been increasing, but, if the policy objectives of greater integration and the creation of a European wide innovation system are to be met, further encouragement and incentives for European collaboration are required.

Nearly half of all cooperation agreements are regional and about a quarter are national. The Green Paper recommends discussion of policies that will develop support for regional innovation strategies and inter regional technology transfer. These data indicate that there is already considerable regional collaboration. In fact it might indicate that the innovation system is more regional than national. If this is so, then there might already exist quite strong regional bases upon which innovation strategies can be built.

Endnotes

1. The firm itself is a collection of individuals and groups which interact in the production of a good or service. We have shown how important internal (intra-firm) sources of information are within the total in Chapter 3.

2. Problems of at least the asymmetry and appropriability of information.

3. "Did your enterprise have any co-operation arrangements on R&D activities with other enterprises or institutions in 1992".

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Table 2.1 Extent of Innovative Activity

Country	Product Alone	Process Alone	Product and Process	Intention only	Total Innov	Total Sample
Italy	90	108	7356	6066	13620	22788
Germany	28	15	2306	11	2360	2918
Belgium	6	6	490	9	511	748
UK	2	0	171	1	174	182
Luxembourg	0	3	90	42	135	372
Netherlands	24	10	1288	6	2149	4094
Denmark	9	0	428	3	440	674
Norway	2	3	396	53	454	982
Ireland	9	12	711	63	795	999
France	84	21	1566	525	2196	3879
Greece	81	6	218	-	305	399
Spain	33	4	954	-	991	2372
Portugal	11	12	387	-	403	410

Table 3.1 Major Hindrances to Innovation

Factor	Number of countries for which the factor appears in the top three
Innovation costs too high	11
Pay off period for innovation too long	9
Lack of appropriate sources of finance	7.5
Excessive perceived risk	5.5
Enterprise innovation potential too small	1

Table 3.2 Lack of Information on Technologies (mean scores)

Country	Absolute value (i)	As ratio of mean score across all hindrances (ii)	As ratio of score most important hindrance (iii)
Italy	1.708	0.845	0.586
Germany	1.739	0.847	0.622
Belgium	1.930	0.911	0.682
UK	2.060	0.908	0.652
Luxembourg	1.226	0.868	0.669
Netherlands	1.624	1.126	0.782
Denmark	1.975	0.984	0.759
Norway	1.868	0.962	0.733
Ireland	2.075	0.983	0.793
France	n/a	n/a	n/a
Greece	1.902	1.255	0.524
Spain	2.410	0.972	0.648
Portugal	1.132	1.477	0.520
All countries	1.772	0.886	0.621

Table 3.3 Lack of Information on Markets

Country	Absolute value (i)	As ratio of mean score across all hindrances (ii)	As ratio of score most important hindrance (iii)
Italy	1.797	0.889	0.617
Germany	2.182	1.063	0.780
Belgium	2.031	0.959	0.718
UK	2.385	1.052	0.755
Luxembourg	1.226	0.868	0.669
Netherlands	1.712	1.187	0.825
Denmark	1.993	0.993	0.766
Norway	1.971	1.015	0.773
Ireland	2.180	1.033	0.833
France	n/a	n/a	n/a
Greece	1.654	1.092	0.470
Spain	2.442	0.985	0.656
Portugal	1.044	1.363	0.479
All countries	1.882	0.941	0.659

Table 3.4 Lack of Information on Technologies by Innovative Activity (mean scores)

Country	Product Innovation		Process Innovation	
	Yes	No	Yes	No
Italy	1.739	1.693	1.734	1.695
Germany	1.815	1.433	1.815	1.444
Belgium	2.093	1.611	2.087	1.623
UK	2.087	1.556	2.064	2.000
Luxembourg	1.289	1.206	1.280	1.208
Netherlands	1.954	1.006	1.955	1.021
Denmark	2.048	1.840	2.065	1.817
Norway	2.000	1.777	1.992	1.782
Ireland	2.157	1.864	2.154	1.870
France	n/a	n/a	n/a	n/a
Greece	1.816	2.160	1.795	2.040
Spain	2.696	2.206	2.692	2.219
Portugal	1.128	1.250	1.135	1.000
All countries	1.866	1.697	1.862	1.702

Table 3.5 Lack of Information on Technologies by Firm Size (mean scores)

Country	Employees					
	<50	51-100	101-200	201-500	501-1000	>1000
Italy	1.709	1.706	1.719	1.667	1.718	1.766
Germany	1.716	1.669	1.739	1.819	1.779	1.741
Belgium	1.835	1.958	2.014	1.955	2.088	2.090
UK	2.206	1.900	2.133	1.867	2.167	1.941
Luxembourg	1.219	1.048	1.250	1.583	1.961	1.667
Netherlands	1.375	1.708	1.749	1.777	1.918	1.974
Denmark	1.922	1.974	1.952	2.094	1.697	2.217
Norway	1.834	1.955	1.912	1.958	1.800	1.842
Ireland	2.088	2.149	2.032	1.933	1.905	2.000
France	n/a	n/a	n/a	n/a	n/a	n/a
Greece	1.963	1.956	1.750	1.708	1.667	1.917
Spain	2.389	2.413	2.374	2.517	2.593	2.523
Portugal	1.135	1.222	1.038	1.103	1.143	1.237
All Countries	1.756	1.779	1.783	1.813	1.811	1.831

Table 3.6 Lack of Information on Markets by Firm Size (mean scores)

Country	Employees					
	<50	51-100	101-200	201-500	501-1000	>1000
Italy	1.793	1.800	1.821	1.798	1.808	1.859
Germany	2.115	2.084	2.118	2.348	2.327	2.230
Belgium	1.881	1.986	2.159	2.160	2.070	2.343
UK	2.508	2.300	2.300	2.367	2.333	2.294
Luxembourg	1.219	1.048	1.250	1.583	1.167	1.667
Netherlands	1.408	1.798	1.856	1.968	2.035	2.103
Denmark	1.811	2.092	1.966	2.167	1.697	2.304
Norway	1.911	2.152	1.991	2.194	1.733	2.105
Ireland	2.199	2.230	2.119	2.067	2.095	2.000
France	n/a	n/a	n/a	n/a	n/a	n/a
Greece	1.675	1.600	1.778	1.625	1.333	1.500
Spain	2.417	2.488	2.311	2.556	2.630	2.682
Portugal	1.108	1.000	1.000	1.000	1.071	1.079
All countries	1.843	1.889	1.898	2.014	2.008	2.100

Table 3.7 Technical Services and Cooperation (mean score/ average mean score)

Country	Technical Services (i)	Cooperation (i)
Italy	0.878	0.928
Germany	1.035	0.965
Belgium	0.843	0.882
UK	0.785	0.749
Luxembourg	0.863	0.839
Netherlands	0.693	0.693
Denmark	0.796	0.829
Norway	0.812	0.880
Ireland	0.889	0.921
France	n/a	n/a
Greece	0.660	1.052
Spain	1.006	1.006
Portugal	n/a	n/a
All countries	0.895	0.930

Table 3.8 Response by NACE (mean score)

NACE	Sample Size	(i)	(ii)	(iii)	(iv)
15	2689	1.7	1.8	1.6	1.8
17	2476	1.7	1.8	1.7	1.8
18	2333	1.7	1.8	1.8	1.9
19	1658	1.8	1.8	1.9	2.0
20	921	1.7	1.8	1.7	1.8
21	830	1.7	1.8	1.7	1.8
22	1441	1.6	1.7	1.5	1.6
23	139	1.7	1.8	1.6	1.6
24	1698	1.8	2.0	1.7	1.8
25	1373	1.9	2.0	1.9	2.0
26	2082	1.8	1.8	1.8	1.9
27	947	1.7	1.8	1.7	1.7
28	4110	1.8	1.9	1.8	1.9
29	4267	1.9	2.0	1.9	1.9
30	168	1.8	2.1	1.9	2.0
31	1419	1.8	2.0	1.8	1.9
32	493	2.0	2.2	1.9	2.1
33	859	1.8	2.1	1.9	2.0
34	770	1.9	2.0	1.9	2.0
35	587	1.8	1.9	1.7	1.8
36	2256	1.8	1.9	1.8	1.9
40	212	1.4	1.4	1.4	1.5
45	168	1.8	2.0	2.0	1.9
72	144	1.8	1.9	1.7	1.9
74	126	1.6	1.9	2.0	2.0
Total	34587	1.8	1.9	1.8	1.9

Note: Values only reported where sample size >100

Table 3.9 Multivariate Analysis: Hindrances to Innovation

Variable	Question (i)	Question (ii)	Question (iii)	Question (iv)
Intercept	0.304	0.315	0.346	0.408
Log employees	0.007	0.011	0.008	0.004*
Belgium	0.116	0.105		0.043
Luxembourg	-0.240	-0.278	-0.280	-0.348
Germany	-0.027	0.115	0.172	0.059
Greece		-0.149	-0.468	-0.152
Norway	0.110	0.113	-0.058	
Netherlands	-0.054	-0.082	-0.448	-0.473
Spain	0.282	0.243	0.285	0.256
Portugal	-0.422	-0.532	-0.078	-0.079
Denmark	0.118	0.064		
UK	0.154	0.235		
Ireland	0.155	0.151	0.053	0.054
NACE2	1.035			
NACE10	-0.322	-0.460	-0.396	-0.403
NACE11	-0.561			
NACE18	0.045	0.059	0.040	
NACE19	0.762	0.072	0.089	0.083
NACE20			0.048	
NACE22	-0.056	-0.048	-0.033	-0.054
NACE24		0.066	0.032	0.035
NACE25	0.068	0.084	0.079	0.055
NACE26	0.037	0.042	0.038	
NACE28	0.067	0.065	0.062	0.063
NACE29	0.095	0.106	0.099	0.093
NACE30	0.081	0.135	0.115	0.143
NACE31	0.084	0.109	0.076	0.069
NACE32	0.098	0.159	0.115	0.131
NACE33	0.066	0.122	0.108	0.107
NACE34	0.069	0.056	0.076	0.063
NACE35	0.045	0.073	0.058	0.074
NACE36	0.055	0.066	0.062	0.057
NACE40	-0.174	0.255	-0.251	-0.210
NACE41	-0.117	-0.203	-0.180	-0.175
NACE45	0.100			
NACE50	-0.206			
NACE55	-0.300			
NACE72	0.093	0.111	0.103	
NACE80	-0.362			-0.468
Innovation Dummy	0.100	0.131	0.036	0.013
R^2	0.058	0.073	0.099	0.075
F	32.669	41.183	60.458	43.880

Notes: Only coefficient estimates significant at the 5 per cent level are reported (except for *, which is included for completeness). Sample size: 34587.

Table 3.10 R&D as a Proportion of Total Innovation Expenditure

Country	Per cent	Sample Size
Italy	32.9	7523
Germany	27.1	1636
Belgium	44.7	493
UK	32.6	164
Luxembourg	29.3	93
Netherlands	45.6	175
Denmark	40.1	434
Norway	32.8	365
Ireland	22.2	174
Greece	50.6	262
Spain	36.4	977
Portugal	22.9	210
All countries	33.5	12499

Note: The sample sizes refer to the number of firms that answered 13(a) and also went on to answer Q13(b). This explains the small sample for the Netherlands.

Table 3.11 Information Acquisition as a Proportion of Total Innovation Expenditure

Country	Patent and Licences (i)	Product Design (ii)	Market Analysis (iii)
Italy	5.0	31.9	5.3
Germany	3.4	27.8	6.1
Belgium	1.5	11.3	6.6
UK	2.7	28.4	8.9
Luxembourg	8.9	8.4	4.3
Netherlands	6.1	7.6	19.8
Denmark	5.3	15.8	8.2
Norway	4.2	14.2	5.5
Ireland	4.3	22.1	38.5
Greece	6.4	**	13.2
Spain	8.0	**	8.8
Portugal	4.1	24.5	5.4
All countries	4.6	24.0	6.6

Table 3.12 Acquisition of Information as Proportion of Total Innovation Expenditure: Multivariate Analysis

Variable	Patents & Licences (i)	Product Design (ii)	Market Analysis (iii)
Intercept	-0.651	-0.403	-1.353
Log Employees	-0.181	-0.134	-0.153
Belgium	-1.048	-0.672	
Luxembourg		-0.494	0.568
Germany	-0.256	0.111	
Greece			0.658
Norway	-0.835	-0.577	0.267
Spain	0.219		0.325
Denmark	-0.662	-0.635	
UK	-0.628		0.220
NACE 16			0.948
NACE 18		0.273	-0.251
NACE 19	-0.636	-0.187	
NACE 20		-0.246	
NACE 22	0.759		0.210
NACE 24	-0.514	-0.675	-0.321
NACE 25	-0.484	-0.219	-0.289
NACE 26	-0.457	-0.186	-0.194
NACE 27		-0.304	-0.382
NACE 28	-0.263	-0.098	-0.326
NACE 29	-0.848	-0.142	-0.505
NACE 30	-0.862	-0.600	-0.924
NACE 31	-0.632	-0.136	-0.447
NACE 32	-0.853	-0.320	-0.623
NACE 33	-0.786	-0.334	-0.667
NACE 34	-0.661		-0.354
NACE 35	-0.548		-0.462
NACE 36	-0.539		
NACE 37			-1.899
NACE 45		-0.573	
NACE 50			1.851
NACE 72		-0.583	
NACE 73		-0.726	-0.593
NACE 74		-0.520	-0.370
NACE 75	-2.459		-2.25
NACE 80		-0.939	-0.916
NACE 90	-1.159		-0.777
R^2	0.268	0.135	0.153
F	17.421	24.812	18.066

Table 3.13 External Spending as Proportion of Total Innovation Expenditure

Country	Per cent
Italy	***
Germany	29.2
Belgium	21.2
UK	15.9
Luxembourg	26.4
Netherlands	20.2
Denmark	9.0
Norway	17.6
Ireland	20.4
Greece	11.7
Spain	6.3
Portugal	16.8
All countries	22.4

Table 4.1 Importance of Various Sources of Information, by Country (mean scores)

Q4	Country													
	I	D	B	UK	Lux	Nl	Dk	N	Irl	Fr	P	Esp	Gr	All Countries
4.10	3.59	3.06	3.81	4.27	3.36	3.43	3.86	3.47	3.83	3.10	3.52	3.26	4.23	3.48
4.20	1.70	1.92	3.04	2.17	2.78	2.47	2.47	2.16	2.51	2.04	1.40	-	-	1.46
4.30	2.84	3.50	3.24	3.37	3.32	3.31	3.33	3.03	3.24	2.23	-	2.23	1.21	2.89
4.40	2.93	3.26	3.30	3.11	3.39	3.19	3.23	3.16	3.16	2.29	2.80	3.58	-	3.01
4.50	3.05	4.31	3.72	4.01	3.29	3.80	3.91	3.53	4.00	2.34	2.32	5.68	3.31	3.35
4.60	2.47	3.50	2.99	3.36	2.48	2.91	3.15	2.69	3.30	1.85	2.05	4.30	2.43	2.77
4.70	1.98	2.04	1.73	1.65	1.84	1.94	1.87	1.83	1.96	1.33	2.16	2.41	-	1.93
4.80	1.33	2.48	2.12	2.10	1.68	2.00	2.11	2.01	2.07	1.40	1.89	1.92	1.68	1.70
4.90	1.27	1.92	1.79	1.50	1.26	2.11	2.12	2.08	1.78	1.46	1.65	1.84	-	1.57
4.10	1.26	1.89	2.04	1.82	1.55	1.73	2.41	2.31	2.25	1.72	1.35	2.30	-	1.63
4.11	1.55	2.45	2.14	1.89	1.71	1.81	1.90	1.58	1.94	1.75	1.28	2.16	0	1.80
4.12	2.15	3.70	2.99	2.54	2.90	2.80	2.84	2.96	2.80	2.10	3.01	2.59	2.38	2.56
4.13	2.80	3.73	3.20	2.65	3.03	2.99	3.01	3.02	3.30	2.36	2.89	3.50	2.10	2.98
Total	2.13	2.74	2.69	2.58	2.36	2.58	2.73	2.54	2.70	1.94	2.02	2.58	1.33	2.35

Table 4.2 Ranking of Sources: Top Five

Q4	Source	Rank					No in top 5
		1	2	3	4	5	
4.1	Within enterprise	4	5	0	0	0	9
4.3	Supplier of materials and components	0	0	4	5	1	10
4.4	Suppliers of equipment	1	0	4	3	1	9
4.5	Clients or customers	5	3	1	1	0	10
4.12	Professional conferences, meetings, journals	0	0	1	0	0	1
4.13	Fairs, exhibitions	0	2	0	0	6	8

Table 4.3 Overall Importance of Information, by Firm Size (mean score)

Firm Size	Country													
	I	D	B	UK	Lux	Nl	Dk	N	Irl	Fr	P	Esp	Gr	Al l Country Av
<50	2.06	2.60	2.40	2.46	2.24	2.37	2.58	2.39	2.64	1.73	1.89	2.51	1.30	2.22
51-100	2.10	2.61	2.64	2.52	2.44	2.55	2.71	2.65	2.74	1.83	1.79	2.59	1.41	2.13
101-200	2.21	2.74	2.81	2.63	2.79	2.66	2.74	2.63	2.78	1.92	1.98	2.62	1.42	2.42
201-500	2.30	2.80	2.77	2.61	2.39	2.70	2.82	2.61	2.90	1.98	2.04	2.70	1.35	2.51
501-1000	2.30	2.87	2.91	2.72	2.42	2.83	2.72	2.67	2.60	2.14	2.09	2.97	1.40	2.57
>1000	2.60	2.97	2.99	2.82	2.72	2.84	2.96	2.76	2.89	2.52	2.28	2.85	1.27	2.76
Total	2.13	2.74	2.69	2.58	2.36	2.58	2.73	2.54	2.70	1.94	1.98	2.60	1.33	2.35

Table 4.4 Overall Importance of Internal Sources by Firm Size (mean score)

Q4.1	Country													
	I	D	B	UK	Lux	Nl	Dk	N	Ire	Fr	P	Esp	Gr	All Country Av
<50	3.43	2.99	3.67	4.29	3.20	3.23	3.87	3.30	3.82	2.83	3.46	3.18	4.34	3.38
51-100	3.64	2.87	3.83	4.18	3.63	3.44	3.95	3.53	3.87	3.02	3.28	3.23	4.29	3.50
101-200	3.80	3.07	3.89	4.37	3.73	3.47	3.77	3.65	3.86	3.07	3.58	3.26	4.32	3.57
201-500	3.90	3.08	3.83	4.20	3.80	3.53	3.81	3.47	3.82	3.16	3.59	3.37	3.84	3.56
501-1000	3.84	3.22	3.94	4.42	3.33	3.51	4.08	3.56	3.45	3.47	3.57	3.53	3.67	3.57
>1000	4.21	3.20	3.94	4.24	3.67	3.84	3.81	3.83	3.50	3.74	3.68	3.50	3.91	3.68
Total	3.59	3.06	3.81	4.27	3.36	3.43	3.86	3.47	3.83	3.10	3.52	3.26	4.23	3.48

Table 4.5 Clients and Customers as a Source of Information, by Firm Size (mean score)

Q4.5	Country													
	I	D	B	UK	Lux	Nl	Dk	N	Irl	Fr	P	Esp	Gr	All Country Av
<50	3.04	4.29	3.52	3.95	3.07	3.65	3.81	3.54	4.03	2.22	2.19	3.64	3.39	3.25
51-100	3.04	4.21	3.80	3.79	3.75	3.80	3.82	3.54	4.02	2.31	1.94	3.70	3.26	3.31
101-200	3.10	4.35	3.77	4.03	3.91	3.92	3.96	3.54	4.13	2.36	2.19	3.57	3.68	3.41
201-500	3.04	4.31	3.69	4.27	3.00	3.83	4.05	3.66	3.84	2.26	2.55	3.82	3.03	3.47
501-1000	2.94	4.38	3.94	4.17	3.83	3.83	3.80	3.22	3.30	2.41	2.29	3.86	3.25	3.45
>1000	3.26	4.33	3.97	4.00	3.67	3.92	3.95	3.39	3.88	2.76	2.97	3.53	2.46	3.62
Total	3.05	4.31	3.72	4.01	3.29	3.80	3.91	3.53	4.00	2.34	2.32	3.68	3.31	3.34

Table 4.6 Importance of Information from Materials and Component Suppliers, by Firm Size (mean score)

Q4.3	Country												
	I	D	B	UK	Lux	Nl	Dk	N	Irl	Fr	Esp	Gr	All Country
<50	2.82	3.53	3.19	3.38	3.32	3.16	3.23	2.94	3.22	2.05	2.10	1.10	2.79
51-100	2.81	3.58	3.25	3.29	3.00	3.33	3.30	3.06	3.29	2.13	2.17	1.40	2.88
101-200	2.85	3.39	3.34	3.40	3.73	3.39	3.35	3.14	3.22	2.24	2.35	1.36	2.95
201-500	2.95	3.50	3.24	3.47	4.00	3.40	3.31	3.09	3.37	2.22	2.39	1.32	3.00
501-1000	2.92	3.40	3.32	3.08	2.67	3.31	3.20	3.07	2.85	2.36	2.74	1.42	2.99
>1000	2.97	3.53	3.20	3.47	3.00	3.24	3.43	2.94	3.38	2.79	2.39	1.46	3.12
All	2.84	3.50	3.24	3.37	3.32	3.31	3.30	3.03	3.24	2.23	2.23	1.21	2.88

Table 4.7 **Importance of Information from Equipment Suppliers, by Firm Size (mean score)**

Q4.4	Country												
	I	D	B	UK	Lux	Nl	Dk	N	Irl	Fr	P	Esp	All Country
<50	2.96	3.36	3.32	3.02	3.45	3.05	3.26	3.10	3.15	2.20	2.60	3.55	3.00
51-100	2.90	3.25	3.33	3.29	2.88	3.20	3.13	3.15	3.11	2.07	2.83	3.60	2.98
101-200	2.89	3.21	3.34	3.13	3.91	3.23	3.19	3.21	3.09	2.26	2.85	3.50	3.00
201-500	2.89	3.21	3.26	3.10	3.40	3.32	3.25	3.15	3.43	2.37	2.90	3.58	3.06
501-1000	2.82	3.10	3.36	3.08	3.00	3.22	3.36	3.33	3.00	2.42	2.93	3.78	3.00
>1000	2.93	3.30	3.22	3.12	2.33	3.16	3.52	3.39	3.13	2.70	2.90	3.97	3.10
Total	2.93	3.26	3.30	3.11	3.39	3.19	3.23	3.16	3.16	2.29	2.80	3.58	3.00

Table 4.8 **Importance of Information from Patent Disclosures, by Firm Size (mean scores)**

Q4.11	Country												
	I	D	B	UK	Lux	Nl	Dk	N	Irl	Fr	P	Esp	All Country
<50	1.45	1.99	1.62	1.73	1.48	1.58	1.70	1.41	1.85	1.45	1.30	2.08	1.58
51-100	1.50	2.09	1.85	1.79	2.25	1.79	1.86	1.72	1.94	1.61	1.17	2.04	1.67
101-200	1.65	2.36	2.38	1.77	2.00	1.88	1.81	1.62	2.00	1.68	1.27	2.18	1.84
201-500	1.87	2.72	2.20	1.97	1.60	1.86	2.08	1.56	2.37	1.76	1.35	2.23	2.08
501-1000	1.91	2.92	2.43	2.42	2.33	2.12	2.20	1.89	2.00	2.08	1.36	2.67	2.29
>1000	2.47	3.24	2.98	2.29	2.67	2.43	2.05	2.00	2.13	2.71	1.16	2.83	2.75
Total	1.55	2.45	2.14	1.89	1.71	1.81	1.90	1.58	1.94	1.75	1.28	2.16	1.80

Table 4.9 Relative Importance of Each Source: Number of Sectors in Which Source is in "Top Five"

NACE	Sources	Number of Sectors	The Five Sectors in which Source is Most Important (NACE)				
			1	2	3	4	5
4.1	Within enterprise	29	72	70	45	23	30
4.2	Within Group	2	24	30	32	15	26
4.3	Material and component suppliers	24	70	51	74	30	31,34
4.4	Equipment suppliers	25	70	51	72	22*	15*
4.5	Clients or customers	28	70*	51*	72	30	32
4.6	Competitors	7	51	30	32	70*	74*
4.7	Consultancy firms	0	70	41	40	23	15,74
4.8	Universities, HEIs	0	70	74	51	45	41
4.9	Governments labs	0	70	51	24	41*	45*
4.10	Technical institutes	0	70	40	30	72	33
4.11	Patent disclosures	0	51	24	33	29	32
4.12	Professional conferences, etc.	9	70	74	45	72	51
4.13	Fairs, exhibitions	23	51	36	30	29	33
	Total number sectors*	29	70	51	30	74*	72*

* with more than 100 observations; some sources appear as joint equal with others in a particular sector

Table 4.10 Relative Importance of Different Channels of Transfer

Country	I,0	Channel							
		(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)
Italy	I	0.18	0.13	0.41	0.07	1.00	0.37	0.42	0.10
	0	0.24	0.30	0.56	0.07	1.00	0.75	0.87	0.08
Germany	I	0.23	0.30	0.59	0.12	0.73	1.00	0.59	0.00
	0	0.27	0.21	0.44	0.05	0.29	1.00	0.49	0.00
Belgium	I	0.51	0.51	0.31	0.20	1.00	0.61	0.56	0.15
	0	0.55	0.47	0.96	0.17	0.37	0.98	1.00	0.03
UK	I	0.48	0.20	0.35	0.19	1.00	0.63	0.69	0.03
	0	0.62	0.41	0.51	0.08	0.49	1.00	0.53	0.02
Luxembourg	I	0.21	0.25	0.25	0.07	1.00	0.61	0.36	0.00
	0	0.14	0.11	0.11	0.00	0.18	1.00	0.57	0.01
Netherlands	I	0.33	0.56	0.56	0.13	0.66	1.00	0.51	0.10
	0	0.57	0.40	0.59	0.11	0.19	1.00	0.35	0.07
Denmark	I	0.29	0.20	0.40	0.11	1.00	0.59	0.35	0.05
	0	0.56	0.14	0.52	0.05	0.57	1.00	0.44	0.02
Norway	I	0.36	0.25	0.55	0.11	1.00	0.46	0.32	0.03
	0	0.56	0.19	0.44	0.04	0.00	1.00	0.27	0.01
Ireland	I	0.49	0.16	0.38	0.17	1.00	0.53	0.46	0.06
	0	0.64	0.57	0.42	0.22	0.46	1.00	0.06	0.03
France	0	0.42	1.00	0.28	0.25	0.97	-	0.59	-
	I	0.95	0.60	0.71	0.13	0.76	1.00	0.39	-

Note: only Belgium (0.03) has an entry under category (ix) and this column has been omitted from the table.

Table 4.11 Inflows to Outflows: Ratio of Responses by Country and Channel of Transfer

Country	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)	(ix)
Italy	1.08	0.62	1.05	1.44	1.43	0.70	0.69	1.70	-
Germany	0.83	1.38	1.32	2.23	2.42	0.97	1.15	-	-
Belgium	0.89	1.04	0.31	1.09	2.58	0.60	0.54	4.28	18.00
UK	0.73	0.44	0.65	2.32	1.90	0.59	1.21	1.17	-
Luxembourg	1.50	2.33	2.33	-	5.60	0.61	0.63	0.00	-
Netherlands	0.64	1.53	1.05	1.28	3.79	1.10	1.60	1.61	-
Denmark	0.57	1.63	0.86	2.25	1.96	0.65	0.89	2.40	-
Norway	0.78	1.58	1.48	3.25	-	0.55	1.41	5.50	0.00
Ireland	1.02	0.38	1.23	1.03	2.89	0.71	1.10	2.45	1.00
France	0.50	1.89	0.44	2.20	1.46	-	1.70	-	-

Table 4.12 Spatial Distribution: Purchase and Sale of Equipment (v)

Country		European			Non European		
		National	EC	Non-EC	USA	Japan	Other
I	I	0.68	0.20	0.04	0.03	0.04	0.00
	O	0.44	0.18	0.16	0.05	0.02	0.14
	I/O	2.20	1.58	0.35	0.91	2.69	0.05
D	I	0.68	0.17	0.06	0.05	0.03	0.01
	O	0.47	0.13	0.13	0.13	0.02	0.13
	I/O	3.57	2.82	0.80	1.72	2.00	0.27
Bel	I	0.31	0.47	0.08	0.10	0.04	0.00
	O	0.16	0.34	0.19	0.10	0.01	0.18
	I/O	4.85	3.54	1.08	2.43	7.00	0.00
UK	I	0.46	0.24	0.05	0.14	0.09	0.01
	O	0.26	0.24	0.19	0.10	0.05	0.16
	I/O	3.34	1.93	0.52	2.75	3.50	11.60
Lux	I	0.25	0.68	0.04	0.04	0.00	0.00
	O	0.20	0.20	0.20	0.20	0.00	0.20
	I/O	7.00	19.00	1.00	1.00	-	0.00
Nds	I	0.54	0.35	0.04	0.06	0.01	0.01
	O	0.30	0.34	0.17	0.09	0.05	0.05
	I/O	6.84	3.82	0.85	2.39	1.00	0.67
Dk	I	0.41	0.36	0.09	0.09	0.04	0.01
	O	0.30	0.21	0.31	0.06	0.04	0.08
	I/O	2.63	3.47	0.58	2.80	2.00	0.29
N	I	0.55	0.35	0.00	0.00	0.00	0.10
	O	-	-	-	-	-	-
	I/O	-	-	-	-	-	-
Ire	I	0.27	0.50	0.07	0.11	0.04	0.01
	O	0.29	0.52	0.01	0.14	0.03	0.01
	I/O	2.76	2.76	14.00	2.30	4.00	3.00
Fr	I	0.49	0.33	0.06	0.07	0.04	0.01
	O	0.39	0.18	0.12	0.10	0.04	0.18
	I/O	1.84	2.66	0.71	1.12	1.40	0.09

Table 4.13 Spatial Distribution: Communication With/ Specialist Services From Other Enterprises (Source vi)

Country	European			Non-European			Average ratio I/O
	National	EC	Non-EC	USA	Japan	Other	
Italy	0.64	0.23	0.04	0.06	0.02	0.01	
	0.54	0.21	0.11	0.06	0.01	0.07	
	0.82	0.76	0.27	0.72	1.23	0.14	0.70
Germany	0.59	0.18	0.07	0.09	0.05	0.03	
	0.46	0.15	0.17	0.07	0.03	0.12	
	1.01	1.01	0.73	0.99	1.00	0.68	0.97
Belgium	0.24	0.47	0.09	0.12	0.05	0.04	
	0.23	0.33	0.16	0.12	0.07	0.09	
	0.60	0.87	0.32	0.62	0.38	0.27	0.60
UK	0.63	0.17	0.04	0.08	0.06	0.02	
	0.35	0.24	0.10	0.16	0.06	0.10	
	1.07	0.41	0.25	0.28	0.60	0.13	0.59
Luxembourg	0.24	0.65	0.06	0.06	0.00	0.00	
	0.18	0.68	0.04	0.04	0.00	0.07	
	0.80	0.58	1.00	1.00	-	0.00	0.61
Netherlands	0.47	0.32	0.08	0.10	0.02	0.02	
	0.46	0.27	0.09	0.08	0.04	0.06	
	1.11	1.28	1.05	1.27	0.53	0.40	1.10
Denmark	0.38	0.32	0.14	0.10	0.04	0.01	
	0.34	0.28	0.12	0.16	0.03	0.06	
	0.74	0.76	0.76	0.42	0.80	0.11	0.66
Norway	0.57	0.31	0.00	0.00	0.00	0.11	
	0.69	0.23	0.00	0.00	0.00	0.08	
	0.46	0.74	-	-	-	0.75	0.55
Ireland	0.35	0.46	0.04	0.11	0.02	0.03	
	0.46	0.30	0.03	0.18	0.02	0.01	
	0.54	1.09	0.80	0.41	0.67	3.00	0.71
France	-	-	-	-	-	-	
	0.56	0.25	0.07	0.08	0.01	0.04	
	-	-	-	-	-		-

Table 4.14 Spatial Distribution: Right to Use Inventions (Including Licenses)

Country	European			non-European			Average ratio I/O
	National	EC	Non-EC	USA	Japan	Other	
Italy	0.42	0.28	0.06	0.16	0.05	0.02	
	0.35	0.23	0.10	0.09	0.03	0.20	
	1.29	1.33	0.65	1.97	1.77	0.11	1.08
Germany	0.49	0.22	0.07	0.14	0.07	0.02	
	0.29	0.21	0.13	0.13	0.09	0.15	
	1.39	0.88	0.43	0.87	0.62	0.11	0.83
Belgium	0.13	0.38	0.10	0.24	0.11	0.03	
	0.15	0.33	0.13	0.16	0.06	0.16	
	0.76	1.00	0.69	1.33	1.67	0.19	0.89
UK	0.35	0.27	0.08	0.22	0.05	0.03	
	0.25	0.21	0.10	0.21	0.09	0.14	
	1.00	0.94	0.60	0.75	0.43	0.14	0.73
Luxembourg	0.00	0.50	0.17	0.33	0.00	0.00	
	0.25	0.25	0.00	0.25	0.00	0.25	
	0.00	3.00	-	2.00	-	0.00	1.50
Netherlands	0.31	0.34	0.09	0.16	0.06	0.04	
	0.22	0.34	0.13	0.11	0.09	0.11	
	0.90	0.66	0.44	0.90	0.41	0.24	0.64
Denmark	0.32	0.30	0.19	0.13	0.06	0.00	
	0.19	0.22	0.38	0.09	0.04	0.09	
	0.96	0.78	0.28	0.86	1.00	0.00	0.57
Norway	0.47	0.37	0.00	0.00	0.00	0.16	
	0.60	0.20	0.00	0.00	0.00	0.20	
	0.61	1.45	-	-	-	0.64	0.78
Ireland	0.13	0.40	0.08	0.31	0.07	0.02	
	0.14	0.29	0.09	0.24	0.11	0.14	
	0.93	1.41	0.89	1.33	0.64	0.14	1.02
France	0.44	0.23	0.05	0.18	0.07	0.02	
	0.30	0.26	0.09	0.13	0.07	0.14	
	0.73	0.44	0.32	0.68	0.50	0.07	0.50

Table 5.1 "Innovation Too Easy to Copy"

Country	mean score (i)	mean score/ average mean score (ii)
Italy	1.966	0.973
Germany	2.407	1.173
Belgium	1.979	0.934
UK	1.736	0.765
Luxembourg	1.242	0.879
Netherlands	1.000	0.693
Denmark	1.758	0.879
Norway	1.705	0.878
Ireland	1.859	0.881
France	n/a	n/a
Greece	1.872	1.235
Spain	2.400	0.968
Portugal	1.132	1.478
All Countries	1.921	0.970

Table 5.2 "Innovation Too Easy to Copy" - Multivariate Analysis

Variable	Parameter Estimate
Intercept	0.395
Log Employees	0.014
Luxembourg	-0.333
Germany	0.187
Norway	-0.073
Netherlands	-0.526
Spain	0.161
Denmark	-0.082
Ireland	-0.056
NACE 10	-0.311
NACE 14	-0.209
NACE 17	0.034
NACE 19	0.096
NACE 20	0.049
NACE 22	-0.053
NACE 25	0.076
NACE 26	0.042
NACE 28	0.060
NACE 29	0.121
NACE 30	0.102
NACE 31	0.073
NACE 32	0.052
NACE 33	0.078
NACE 34	0.058
NACE 36	0.071
NACE 40	-0.359
NACE 41	-0.226
NACE 72	0.099
Innovation Dummy	0.046
R^2	0.085
F	50.69

Table 5.3 Effectiveness of Different Forms of Protection for Product and Process Innovation (mean score)

Type of Protection	Product	Process
Patent	2.319	1.946
Design	1.933	1.721
Trade secret	2.888	2.832
Complexity	2.684	2.790
Speed of introduction	3.758	2.549
Average all	2.716	2.549

Table 5.4 Effectiveness of Different Forms of Protection, by Country (mean score)

Q9	Country							
	D	B	UK	Lux	Nl	Dk	N	Irl
Product								
(i)	2.663	1.948	2.168	1.833	2.357	2.297	1.656	2.024
(ii)	2.362	1.567	2.023	1.400	1.601	1.673	1.829	1.860
(iii)	3.222	2.946	2.867	2.067	2.686	2.471	2.535	2.832
(iv)	3.326	2.863	2.457	1.867	2.108	1.371	2.219	3.031
(v)	4.099	3.681	3.405	3.578	3.471	2.856	4.055	3.875
Process								
(i)	2.046	1.508	1.76	2.129	1.838	2.584	1.406	2.104
(ii)	1.864	1.236	1.667	1.516	1.327	2.988	1.301	1.888
(iii)	3.015	3.01	2.766	2.548	2.71	2.311	2.644	2.880
(iv)	3.116	2.919	2.52	2.032	2.187	3.836	2.055	2.830
(v)	3.762	2.96	3.24	3.29	3.163	3.411	3.571	3.484

Table 5.5 Effectiveness of Patent Protection, by Country (mean scores)

Q9.1	Country								
	D	B	UK	Lux	Nl	Dk	N	Irl	All
Product									
<50	2.398	1.592	1.946	1.632	2.061	2.061	1.599	1.936	2.05
51-100	2.363	1.795	1.964	2.375	2.422	2.449	1.634	2.015	2.27
101-200	2.468	2.054	2.100	1.727	2.440	2.223	1.662	2.042	2.28
201-500	2.885	1.909	2.367	2.000	2.446	2.352	1.673	2.250	2.47
501-1000	3.047	2.208	2.583	2.333	2.481	2.440	1.692	2.400	2.67
>1000	3.143	2.656	2.706	3.333	2.784	2.429	2.111	3.375	2.95
Total	2.663	1.948	2.168	1.833	2.357	2.297	1.656	2.024	2.32
Process									
<50	1.814	1.333	1.618	1.733	1.638	2.468	1.391	2.084	1.79
51-100	1.775	1.475	1.679	3.500	1.882	2.568	1.444	2.086	1.91
101-200	1.873	1.611	1.600	1.818	1.807	2.524	1.282	2.227	1.89
201-500	2.186	1.485	1.931	3.400	1.886	2.667	1.382	2.075	2.02
501-1000	2.375	1.509	1.750	2.500	2.078	2.64	1.444	2.000	2.14
>1000	2.556	1.906	2.353	4.667	2.514	2.905	1.889	2.375	2.45
Total	2.046	1.508	1.760	2.129	1.838	2.584	1.406	2.104	1.95

Table 5.6 Effectiveness of Trade Secrets, by Country (mean scores)

Q9.3	Country								
	D	B	UK	Lux	Nl	Dk	N	Irl	All
Product									
<50	3.050	2.645	2.857	1.807	2.535	2.354	2.274	2.701	2.70
51-100	3.100	3.026	2.857	2.500	2.641	2.357	2.676	2.854	2.78
101-200	3.115	3.054	2.433	2.091	2.684	2.515	2.465	3.104	2.83
201-500	3.380	2.939	2.933	2.400	2.827	2.630	2.836	3.103	3.05
501-1000	3.403	3.057	2.917	3.167	3.039	2.480	2.923	3.000	3.18
>1000	3.477	3.438	3.529	3.000	2.946	2.429	3.056	2.875	3.35
Total	3.222	2.946	2.867	2.067	2.686	2.471	2.535	2.832	2.89
Process									
<50	2.799	2.647	2.582	2.250	2.520	2.291	2.462	2.745	2.65
51-100	2.878	3.100	2.714	3.000	2.663	2.200	2.528	2.921	2.72
101-200	2.859	3.167	2.500	2.818	2.645	2.194	2.563	3.072	2.72
201-500	3.131	3.121	3.069	3.200	2.836	2.371	2.982	3.269	2.98
501-1000	3.385	3.075	2.833	3.000	3.338	2.720	3.185	3.000	3.25
>1000	3.342	3.406	3.353	4.333	3.270	2.667	3.167	2.875	3.30
Total	3.015	3.01	2.766	2.548	2.710	2.311	2.644	2.880	2.83

Table 5.7 Relative Importance of Different Forms of Protection*

Small	(iii)/(i)	(iii)/(ii)	(iii)/(iv)	(iii)/(v)
Germany	1.27	1.35	0.92	3/5
Belgium	1.66	1.84	1.07*	0.79
UK	1.47	1.51	1.14	0.86
Luxembourg	1.11	1.39	1.08	0.54
Netherlands	1.23	1.67	1.32	0.78
Denmark	1.14	1.61	1.93	0.87
Norway	1.42	1.26	1.05	0.57
Ireland	1.40	1.50	0.91	0.71
Large	(iii)/(i)	(iii)/(ii)	(iii)/(iv)	(iii)/(iv)
Germany	1.11	1.32	1.01	0.79
Belgium	1.29	2.11	1.07*	0.88
UK	1.30	1.54	1.28	0.91
Luxembourg	0.90	3.00	1.29	0.69
Netherlands	1.06	1.80	1.10	0.79
Denmark	1.00	1.21	1.76	0.81
Norway	1.45#	1.57	1.57	0.72
Ireland	0.85	1.21	0.96	0.68

*Note: Relative to trade secrets

Table 5.8 Top Five Ranked NACE (1-5) By Form of Protection (i-v)

Product Innovation							Process Innovation					
Rank	(i)	(ii)	(iii)	(iv)	(v)	Av	(i)	(ii)	(iii)	(iv)	(v)	Av
1	29	34	24	34	34	34	32	32	24	32	34	32
2	33	29	29	33	33	33	29	34	34	25	21	33
3	34	31	33	25	32	29	24	33	30	34	19	34
4	32	18	34	32	25	24	33	29	33	19	25	24
5	24	33	15	19	24	25	30	25	19	33	29	29

Note: figures in cells are NACE codes

Table 5.9 Firm Size Effects - Multivariate Results

Form of Protection	Product	Process
Patent (i)	0.0701 (1)	0.0656 (1)
Design (ii)	0.0374 (3)	0.0308 (5)
Secrecy (iii)	0.0473 (2)	0.0598 (2)
Complexity (iv)	0.0302 (5)	0.0398 (4)
Lead time (v)	0.0362 (4)	0.0448 (3)

Table 5.10 Country and Form of Protection - Multivariate Results

Q9	Country						
	B	UK	Lux	Nl	Dk	N	Irl
Product							
(i)	-0.255	-	-0.274	-0.058	-0.092	-0.325	-0.178
(ii)	-0.393	-0.100	-0.439	-0.351	0.316	-0.198	-0.202
(iii)	-0.086	-	-0.463	-0.187	-0.251	-0.176	-0.071
(iv)	-0.157	-0.227	-0.582	-0.497	-0.854	-0.391	-0.075
(v)	-0.088	-0.101	-0.128	-0.172	-0.379	-0.073	-
Process							
(i)	-0.237	-	-	-0.059	0.261	-0.242	0.107
(ii)	-0.328	-	-0.169	-0.261	0.536	-0.254	-
(iii)	-	-	-0.163	-0.113	-0.259	-0.064	-
(iv)	-	-0.122	-0.387	-0.364	0.279	-0.381	-0.063
(v)	-0.304	-	-	-	-0.109	-	-

Table 6.1 Extent of Co-operation Arrangements

Country	Positive Response (i)	Sample		Per cent	
		Innovators (ii)	Total (iii)	(i)/(ii)	(i)/(iii)
Belgium	220	502	748	43.8	29.4
Denmark	246	437	674	56.3	36.5
France	1214	1671	3879	72.6	31.3
Germany	798	2349	2918	33.9	27.3
Greece	63	305	399	20.6	15.8
Ireland	240	732	999	32.8	24.0
Luxembourg	27	93	372	29.0	7.2
Netherlands	699	322	4094	52.8	17.1
Norway	177	401	982	44.1	18.0
UK	86	173	182	49.7	47.2
Italy	248	7554	22788	3.3	1.1
Spain	335	991	2372	33.8	14.1
All Countries	4353	17745	40817	24.5	10.7

Table 6.2 Existence of Collaborative Agreement by Firm Size

No. Employees	Agreement	Sample	Per cent
<50	993	23748	4.2
51-100	659	7032	9.4
101-200	671	4389	15.3
201-500	876	3330	26.3
501-1000	473	1188	39.8
>1000	681	1130	60.3
Total	4353	40817	10.7

Table 6.3 Extent of Co-operation Arrangements - Firms Providing Detailed Response

Country	Response (i)	Sample		%	%
		Innovators (ii)	Total (iii)	(i)/(ii)	(i)/(iii)
Belgium	193	502	748	38.4	25.8
Denmark	245	437	674	56.1	36.3
France	1015	1671	3879	66.7	26.1
Germany	639	2349	2918	27.2	21.9
Greece	42	305	399	13.8	10.5
Ireland	222	732	999	30.3	22.2
Luxembourg	26	93	372	27.9	7.0
Netherlands	657	1322	4094	49.7	16.0
Norway	176	401	982	43.9	17.9
UK	86	173	182	49.7	47.2
Spain	335	991	2372	33.9	14.1
All countries	3594	17745	40817	20.2	8.8

Table 6.4 Extent and Nature of Co-operation Arrangements: Spatial Distribution

Partner	European				Non European			Total
	Regional	National	EC	Non EC	US	Japan	Other	
Clients	1235	754	261	257	120	102	195	2924 (21.6)
Suppliers	1436	853	252	219	95	75	165	3095 (22.8)
Related enterprises	493	528	186	53	83	111	-	1454 (10.7)
Competitors	247	168	61	59	28	51	-	614 (4.5)
Joint ventures	67	77	27	21	6	33	9	240 (1.7)
Consultants	726	240	102	71	12	18	72	1241 (9.1)
Government labs	523	140	81	15	0	6	55	820 (6.0)
Research institutes	238	113	105	20	0	12	54	542 (4.0)
Higher education	990	245	111	75	12	15	312	1760 (13.0)
Industrial labs	287	86	9	21	6	12	45	466 (3.4)
Other	195	104	22	36	19	18	12	406 (3.0)
Total	6437 (47.5)	3308 (24.4)	1217 (9.0)	847 (6.2)	381 (2.8)	453 (3.3)	919 (6.8)	13562 (100.0)

Note: Table shows number of firms with cooperative arrangements; row and column percentages shown in parentheses.

Table 6.5 Types of Co-operative Arrangements, by Country (per cent)

Country	B	DK	F	D	GRE	IRE	LX	NED	NOR	ESP	UK
Clients	16	23	32	25	-	20	19	21	16	-	38
Suppliers	18	18	52	18	-	16	19	18	14	-	17
Related Enterprises	14	13	-	14	12	10	19	12	12	17	10
Competitors	4	5	-	7	-	4	5	6	5	-	10
Joint Ventures	4	3	-	-	-	6	5	-	6	-	6
Consultants	4	8	15	5	-	9	5	8	10	16	6
Government Labs	8	9	-	0	-	6	0	11	13	13	5
Research Institutes	7	9	-	-	28	9	9	4	11	-	7
Universities HEI	19	8	-	22	61	12	14	12	10	11	10
Industrial Laboratories	3	0	-	7	-	4	5	3	0	10	3
Other	0	12	-	0	-	0	1	5	1	26	10

Notes (- indicates no return, 0 indicates nil return)

Table 6.6 Spatial Distribution of Co-operative Arrangements (per cent)

Country	European				Non-European		
	Regional	National	EC	Non EC	US	Japan	Other
Belgium	27	38	5	5	2	2	20
Denmark	0	27	60	6	2	4	0
France	60	2	5	8	3	1	0
Germany	52	15	6	6	2	3	15
Greece	33	24	0	0	0	0	42
Ireland	39	32	4	7	3	0	11
Luxembourg	37	48	14	0	0	0	0
Netherlands	49	24	6	5	2	2	10
Norway	60	28	0	0	0	11	0
Spain	67	24	0	0	0	0	0
UK	53	24	4	11	3	4	0