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THE FUTURE OF INNOVATION MEASUREMENT IN EUROPE

- Concepts, Problems and Practical Directions

Anthony Arundel (MERIT) with
Keith Smith (STEP), Pari Patel (SPRU),
and Giorgio Sirilli (CNR)

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Anthony Arundel is at MERIT, Maastricht; Keith Smith is at STEP, Oslo; Pari Patel is at SPRU, University of Sussex; Giorgio Sirilli is at CNR, Rome.

STEP group
Studies in technology, innovation and economic policy
Studier i teknologi, innovasjon og økonomisk politikk

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ABSTRACT

The fundamental goal of this report is to provide a menu of survey questions that can provide the best possible indicators of the innovative process. The FIRST three chapters set the stage for the development of these indicators: Chapter 2 reviews current theories of innovation while Chapter 3 provides an overview of the policy context, including a summary of current trends and policy options. Chapter 4 builds on the results of chapters 3 and 4 to construct a framework for the development of innovation indicators.

Chapters 5 to 7 address the need for innovation indicators that can meet the basic needs of theory and policy. Each chapter develops modules of sample survey questions for new innovation indicators. The goal is to provide indicators that can meet the theoretical and policy relevant issues raised in Chapters 2 and 3.

The question modules build upon the experience gained from both traditional indicators and recent surveys. Some of the suggested questions are very similar to those in use in other questionnaires, others are based on a combination of the best of several different questions, while others are completely new. The design of these questions follows basic guidelines for questionnaire design, as summarised in Appendix A.

Several questionnaire surveys were closely evaluated in order to develop the question modules. These include:

- The 1983 Yale survey of American firms.
- The 1993 and 1997 CIS questionnaires, including national variations.
- The 1993 PACE survey of Europe's largest industrial firms.
- The 1994 Carnegie Mellon Survey of R&D units in United States.
- The 1993 and 1996 Canadian Innovation surveys.
- The 1996 Canadian survey of the diffusion of 22 biotechnologies.

These evaluations consist, where relevant, of statistical analyses of the survey data, discussions with experts that have used the data[1], and an evaluation of studies based on these surveys.

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In the interests of brevity, the report also contains four appendices. The goal is to focus Chapters 2 through 7 on theory, policy, and indicators and to place additional detailed material, which may only be of interest to a few readers, in the Appendices. However, much of the material in the Appendices is essential to the design of indicator questions and to the collection of high quality data. The four appendices are as follows:

Appendix A: Guidelines for the Design of Survey Innovation Indicators.
Appendix B: Sampling Methodologies for Innovation Surveys.
Appendix C: From CIS-1 to CIS-2: Problems and Progress.
Appendix D: Summary of Innovation Policies in Ten EU Member States.

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1. INTRODUCTION

It is widely accepted by firm managers, economists, and policy makers that the ability to innovate rapidly is a vital component of the competitiveness of firms and a major cause of economic and social well-being. At the same time, innovation is a risky and expensive process that can suffer from under-funding or lead to technological dead-ends. The complexity of the innovation process means that many things can go wrong. Yet, current anxieties and concerns over innovation in Europe can be reduced to two simple statements:

"European firms have more difficulty than their competitors in turning the fruits of research into innovative products".
Europe fails to provide a fertile ground for the establishment and growth of new technology-based firms.

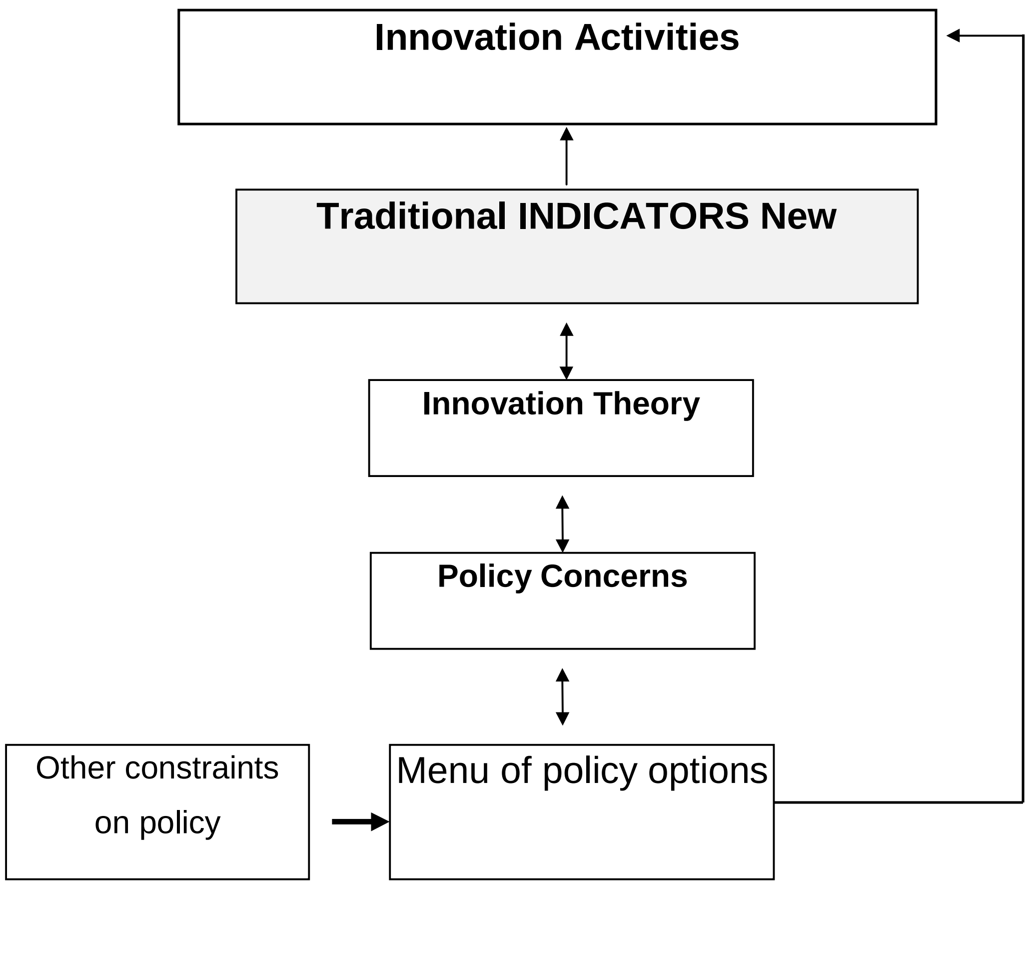
The first statement is a quote from the European Commission's *First Action Plan for Innovation in Europe*. The second is a composite drawn from a large number of discussions of Europe's 'innovation problem'. Although simple and straightforward, these two statements lead to an enormous variety of possible policy responses.

How do we know if these two statements are true, and if they are, how do we determine which policy actions are likely to provide the best solutions? The answer depends on the methods that we use to interpret what is going on in the sphere of innovative activities and then how we translate this understanding into concrete policies. This process is outlined in Figure 1.1.

Innovation indicators provide us with summary measures of the innovative activities of firms. A good indicator must be able to overcome two problems: the complexity of innovative activities and the secrecy that often protects private innovation from outside scrutiny. Many traditional indicators are based on public data that avoids the problem of secrecy because they are either far removed from the locus of innovation or collected for other reasons. These include publicly-available data on patents, scientific publications, and the employment of scientists and engineers. Data on

R&D spending, although only available for 30 years, only provides an indicator of total investment in a limited number of innovative activities. New indicators include both novel methods of analysing traditional indicators and a range of indicators, mostly obtained through surveys of individual firms, that are under development. Many new indicators attempt to open up the 'black box' of innovation and delve more deeply into the actual processes of innovative activities. They include many of the indicators that have been gathered by the first and second Community Innovation Surveys (CIS) of European firms. The first CIS survey[2] obtained data on the innovative activities of approximately 40,000 firms throughout Europe and is the largest survey of its kind to date.

Figure 1.1: The indicator development process



The interpretation and development of indicators depends on our economic, political, and social theories of innovation. This interpretation creates policy concerns, such as the two statements given above. These concerns are then translated into policy

[2] The CIS was coordinated by Eurostat of the European Commission and was inspired by earlier surveys in the Nordic countries, France, Germany and Italy.

actions, although the range of possible actions is constrained by other forces such as competition policy.

Many things can go wrong in the process of developing new policies. The theory could be wrong, the indicator could be inadequate for the task of both testing the theory and providing policy relevant results, or the policy actions could be misguided. In particular, our theories of innovation are often problematic, partly because of a lack of rigorous empirical verification. A period of discovery is required before we can ensure that our theories are workable and that the design and interpretation of indicators matches both theory and the needs of policy.

As an example, innovation policies generally assume that more innovation is always better than less innovation. Although this could be true for society at large, what counts from the perspective of the firm is profitability and survival. Several studies have used new indicators available in the CIS to evaluate ‘leaders’ and ‘laggards’ in innovative activity (Albach *et al*. 1996; Arundel *et al*, 1996). The purpose of these exercises is to identify strategies that make up best practice. Once identified, these strategies could be promoted through policy actions. However, by definition, there will always be leaders and laggards. Furthermore, the laggards might fill important economic roles that are partly responsible for the profitability of the leaders. The policy options are not clear. Should policies try to encourage laggards to innovate more? Is this worthwhile or even helpful? The fact that several studies have found that many firms that do not innovate are as profitable as innovators (Christensen *et al*, 1996; Pattison, 1996) raises serious questions about policies to encourage firms to adopt the strategies used by leaders.

Another example concerns the problematic state of the theory of national systems of innovation. The boundaries between ‘national’, ‘regional’, ‘local’ or even pan-national systems of innovation are unclear. These will partly be determined by the relative importance of national influences on innovation versus other levels of influence. Many of these amorphous influences will vary by industry, raising the possibility of industry-specific systems of innovation. For example, the pharmaceutical sector is believed to highly globalized, with the innovative strategies of firms depending very little on where they are located. Yet, the pharmaceutical sector is still closely tied to national regulatory systems, the publicly-funded medical research infrastructure, and to national differences in funding health care. Our theories of innovation systems cannot, so far, manage the complexity of a sector that is both global in its use of information sources and markets while at the same time remaining closely tied to national infrastructures.

The linkages between theory, indicators and policy are not always transparent. Theory can be used to support programmes that are largely driven by political considerations. An example is the strong bias in the European Framework Programme towards cooperative R&D. This appears to have originated in a politically-driven effort to encourage contacts between firms in different European countries. Yet new theories of innovation that emphasise sharing knowledge and the diffusion of information and capabilities are now used to not only justify cooperative R&D but to call for policies to increase or improve relationships between large firms and subcontractors, producers and users, and collaboration networks (Clark & Guy, 1997). Appropriate indicators are required to determine if these theories are founded in fact.

Another potential problem that could be solved through the development and analysis of appropriate indicators is the growth of innovation and policy ‘myths’. These are theories or hypotheses about innovation that are assumed to be true without ever having been adequately tested. Again, the widespread belief in the multiple benefits of cooperative R&D is a possible candidate for a policy myth. Cooperative R&D *could* be a panacea that will help European firms to turn the fruits of research into competitive products, but we really don’t know. We need good indicators, good theory, and good analysis to determine where cooperative R&D is more efficacious than the alternatives and where it is not.

1.1 The Three Qualities of a Good Innovation Indicator

The development of effective innovation policy requires good indicators to ensure that our understanding of the problem is correct, good theory to both suggest which indicators are needed and to interpret the resulting data, and an effective policy response to identified problems. Essentially, the goal is to tighten the links between innovation and both government and private actions to improve the innovation process.

To help achieve this, innovation indicators should provide information that can meet three requirements:

Directly assist the development and implementation of policy actions. The need for indicators to *directly* assist policy means that the policy significance of each existing and potential indicator needs to be carefully scrutinised. Some indicators could appear to be relevant to policy, when in fact the results could be of little value because political and economic constraints make it highly unlikely that the policy action would ever be implemented. For this reason, the policy value of specific indicators needs to be carefully scrutinised. This requires a good understanding of the policy context, consisting of the existing menu of policy options and the constraints on the potential for developing new policy actions. For example, the current policy context prohibits using tariff barriers to support indigenous new technology firms, although the same goal might be achievable through research subsidies or competitive bidding for government procurement contracts.

Verify innovation theory as part of a continual process of testing and improving theories of innovation. The requirement for indicators to improve our understanding of the innovation process is based on the vital role of theory to interpret empirical data. We need indicators that can be used to verify theory and our beliefs and assumptions about the innovation process. An example is the need for indicators to test our theories about national systems of innovation.

Assist private firms and other institutions to develop and adjust their own innovation strategies. The social and economic value of innovation indicators will be greatly enhanced if they are of direct value to innovators themselves. For example, indicators that identify best practice can help guide firms and public institutions towards more efficient methods. It is particularly important that indicators obtained from surveys of firms or institutions are of value to them. Managers will be more motivated to complete innovation questionnaires when the results offer clear benefits to their firm.

A good indicator should serve as many of these three requirements as possible. This is necessary to keep the questionnaire short while maximising the amount of information that is acquired. The significance of the questions must also be readily understood and lead to direct policy actions. It is of very little help for policy makers if an analysis of indicators comes up with platitudes such as the need to "facilitate the awareness of opportunities and foster the spread of entrepreneurial capabilities". Instead, innovation indicators (and their analysis) need to provide concrete evidence that can be used to design specific policy actions.

1.2 DEVELOPING NEW INNOVATION INDICATORS

A single indicator cannot provide all of the information that is needed, although traditional indicators such as R&D expenditures or patents can serve a variety of purposes. There has also been some success in developing techniques to extract more information out of traditional indicators such as patents. Nevertheless, new indicators are required to meet policy needs and to test innovation theories. Many new indicators have been developed in response to new theories of innovation, as summarised in the Oslo Manual (1992). These indicators have been implemented through surveys.

The CIS provided a first test of a large number of these new survey indicators. The results of approximately a dozen studies using the CIS data (or similar surveys) were presented to the conference, *Innovation Measurement and Policies*, held in Luxembourg in June, 1996. Summaries of each of the conference papers are available in Arundel and Garrelfs (1997).

Unfortunately, very few of the initial analyses of the CIS data provided policy recommendations. Giorgio Sirilli gave a succinct summary of the problem when he commented, in the Concluding Session of the Luxembourg conference, that the results "confirm what we already expected, with no major surprises". Although it is vitally important to empirically confirm expectations, this is not enough. New indicators must be able to provide substantially more useful results.

Part of the problem is due to the fact that the CIS results that were presented to the Luxembourg Conference were based on preliminary analyses. Careful analysis of specific questions, for example on the value of public research, is required before policy relevant results can begin to take shape. Several examples of careful, policy relevant analyses of new indicators have become available after the Luxembourg Conference[3].

In addition, the difficulty in deriving policy-relevant results is partly due to a lack of precision in the CIS questions. The questions were intentionally designed to be relevant to all manufacturing firms - from 10 employees to over 100,000 and across the entire spectrum of manufacturing industries. This general approach to question design meant that there was no room to include detailed questions that are only relevant to specific sectors. As an example, the CIS-1 questionnaire combines standards with other instruments of government intervention, such as taxation and regulations. This makes this question of little use for an analysis of conditions in information and communication technology sectors, where standards can play an essential role.

Problems with the first CIS (CIS-1) were expected, since this was the first large-scale survey of its type. A second survey, or CIS-2, was also developed, with many of the CIS-1 questions altered. CIS-2 was also designed to cover several service sectors. Unfortunately, one of the main goals behind CIS-2 was to make the questionnaire as short as possible. This has led to new problems which will probably require another revision of the CIS questionnaire before a good, workable set of indicators is developed. Furthermore, CIS-2 may not be a suitable instrument for measuring innovation by service firms. Some of the disadvantages of CIS-1 and CIS-2 are discussed in Chapters Five to Seven below. In addition, an extensive discussion of the design of innovation survey questions, sampling techniques, and the problems with CIS-1 and CIS-2 are given in Appendices A, B, and C[4].

1.3 THE LIMITATIONS OF INNOVATION INDICATORS

Innovation indicators, by definition, provide summary measures of complex activities. Most of the new innovation indicators discussed in this report are based on

[3] For example, Arundel & Steinmueller (1998) investigate the policy implications of the CIS question on the importance of patent disclosures as a source of information, using both survey indicators and semi-structured survey techniques.

the use of questionnaire surveys to obtain information of interest. However, there are two main constraints that limit the types of indicators that can be obtained from surveys. First, many innovation activities are not directly measurable. Second, some aspects of innovation cannot be reduced to summary measures.

An example of the first limitation is the different uses of tacit and codified knowledge. Some aspects of codified knowledge can be measured, such as patents, publications, or embodied technology. But, it is very difficult to develop a measure of tacit knowledge or its relative importance to the ability of firms to innovate. Tacit knowledge, by definition, is undefined and firms are unlikely to have internal methods for determining how much of it they hold. This means that tacit knowledge can perhaps only be measured indirectly, for example as a residual once codified knowledge is accounted for. Alternatively, we may be able to define certain information sources as holding more tacit knowledge or more codified knowledge. Informal contacts between firms are more likely to be based on tacit knowledge than subscriptions to trade journals.

The second limitation reflects the complexity of innovative activities. For instance, it is possible to develop indicators for different types of innovation strategies, but it is much more difficult to design workable indicators for the reasons *why* firms use specific strategies. In addition, questionnaires are not suitable for probing complex issues or for delving deeply into conditions that vary enormously from firm to firm. In some cases, specialist indicators can be constructed to solve these problems, but they should only be used in surveys of the relevant firms. Questions for specific sectors or problems, such as for environmental innovation, are developed in the companion IDEA report *Analytical Challenges for Innovation Theory and Policy*. Other examples are given in Chapters Five to Seven below.

These two limitations ensure that there will always be a need for focused case studies and semi-structured interviews that can delve deeply into the complexity of innovation and the reasons why firms adopt specific strategies. Face-to-face

[4] The IDEA group made a large number of proposals on the design of the CIS-2 questionnaire, some of which were accepted. These proposals are explained in Appendix C.

interview techniques will often be required to complement data obtained from innovation indicators and to provide answers to policy questions.

1.4 OVERVIEW OF THIS REPORT

The fundamental goal of this report is to provide a menu of survey questions that can provide better indicators of the innovative process. The next three chapters set the stage for the development of these indicators. Chapter Two reviews current theories of innovation while Chapter Three provides an overview of the policy context, including a summary of current trends and policy options. Chapter Four uses the results of Chapters Two and Three to evaluate several possible frameworks for the development of innovation indicators.

Chapters Five to Seven address the need for innovation indicators that can meet the basic needs of theory and policy. Each chapter develops modules of sample survey questions for new innovation indicators. The goal is to provide indicators that can meet the theoretical and policy relevant issues raised in Chapters Two and Three.

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2. Indicators and Theories of Innovation

Recent theories of innovation are based on two key ideas.

The first is that innovation develops through an evolutionary, interactive process between actors and between different stages in the development of an idea into an innovation. Evolutionary economic theory focuses on the need for experimentation with technically diverse solutions and selection mechanisms to weed out less-desirable technologies. This focus on the benefits of experimentation differs from the emphasis in neo-classical economic theory on market failure and static efficiency. Metcalfe (1995) comments that the effect of an evolutionary perspective is to shift the attention of policy makers “away from efficiency towards creativity, patterns of adaptation to market stimuli, and technological opportunity” (418).

The second key idea is that knowledge and learning play a growing and crucial role in developed economies. The current emphasis on the importance of knowledge is probably influenced by two characteristics of modern society. One is the accumulation of knowledge over time. The available amount of technical knowledge in use today is clearly more than what was available 100 years ago, or even 20 years ago. The second is the rapid diffusion of information and communication technologies not only in industry and services, but also in consumer goods (BP, 1996). Both of these factors, however, do not imply that the need for knowledge is *qualitatively* more important today than it was during other historical periods of major innovation, such as the rapid development of new applications for electrical power between 1890 and 1920 (Tenner, 1997). What could have changed is the rate at which people must learn new skills to keep pace with changes in technology. The result is a marked increase in the importance of learning activities to interpret and make use of information (Edquist, 1997).

The current focus on knowledge, combined with an interactive theory of innovation, has led to the belief that the competitiveness of European firms can be increased by improved knowledge flows - the more and faster the better. The goal is often to introduce policies that support the development of what is frequently called a 'knowledge-based economy'. The *First Action Plan for Innovation in Europe* states that the efficient use of new knowledge depends on three factors: 'the ability to produce knowledge, the mechanisms for disseminating it as widely as possible, and the aptitude of the individuals, companies and organisations concerned to absorb and use it' (p 6). This is very similar to a proposed framework for science and technology statistics under development by Statistics Canada, which focuses on the generation of science and technology, its transmission, and its use (ACSTS, 1997). In both typologies, learning runs throughout all three stages. They also form a basic model of innovation.

This model of innovation, based on three factors, is only one of many ways of looking at innovation. More complex models are probably more accurate, such as Rosenberg's chain link model or the systems approach described by Soete and Arundel (1993). However, the advantage of this simple three-factor model is that it maps easily onto current policy trends. This will be apparent in Chapter 4, which examines various frameworks for innovation indicators that can address the needs of both policy and theory.

The disadvantage of this model of innovation is that the boundaries are artificial. For instance, there is no obvious demarcation line between knowledge creation and dissemination, or between dissemination and absorption. All three activities can occur at the same time and depend on each other for their success. This boundary problem is shared by all interactive models of innovation. It also creates problems for the design and interpretation of innovation indicators. In this respect, it is worth describing more fully what is meant by knowledge creation, dissemination, and absorption and the problems that these concepts pose for indicators.

2.1 Knowledge Creation

Technical knowledge is created by people, or human capital. It spans the entire range from basic knowledge with no immediate commercial applications to very minor solutions to technical problems. Many of our traditional innovation indicators on patents, bibliometrics, human capital stocks, and R&D expenditures capture either the results of knowledge creation (patents and journal articles) or the activities that produce new knowledge (R&D).

The amount of new knowledge that is created should be related to both the number of people working on a problem and their level of expertise[6]. Therefore, a basic indicator for the creation of knowledge is the stock of trained scientists, engineers and technicians and their level of expertise (as proxied through their educational level). It may also be worth gathering indicators for the field of study of employed scientists, such as the natural sciences, engineering, medicine, agriculture, computing, or the social sciences and humanities. R&D expenditures are also a proxy for knowledge creation because the major component of R&D is usually wage costs.

In addition to knowledge held in the minds of people, knowledge can be codified or transformed into information that is stored in products such as scientific papers, patents, instruments, new equipment, and software (David & Foray, 1994). So far, the most common indicators of created knowledge consist of patents and bibliographic studies of scientific papers. A survey can also measure other forms, such as the purchase of licenses, new instruments, or production machinery. The importance of new equipment is highlighted by the results of the first Community Innovation Survey (CIS), which shows that the largest share of the total innovation expenditures of firms is for the purchase of new machinery and equipment.

Recently, researchers have called for indicators for changes in the stock of economically valuable knowledge, including measures of the rate at which know-how becomes obsolete, its rate of replenishment, and the 'imitation potential' (BP, 1996). Patents and scientific papers can be counted from year to year, providing basic measures in the supply of new knowledge over time, although neither provide a measure of obsolescence. Such measures are a potential area for survey research. Changes in the stocks of human capital, such as the supply of new scientists and engineers, can also provide a measure of the future potential for knowledge creation.

2.2 FLOWS OF KNOWLEDGE AND TECHNOLOGY

The focus of a substantial amount of current research on the development of new innovation indicators concerns the flow (or diffusion) of knowledge. Knowledge flows include technology transfer and the flows of know-how, knowledge, and information, including both spill-overs and intentional transfers. They require both a

[6] These types of indicators are extensively discussed in the OECD's Canberra Manual.

channel or route, for example contacts between two scientists from different firms, and a medium, such as a printed article, a patent disclosure, informal discussions, or the movement of a scientist from one firm to another. In addition, knowledge flows are not limited to the exchange of information between firms or institutions. Knowledge flows within large firms that are active in several industrial sectors could play a crucial role in the diffusion of knowledge across disciplines.

Knowledge flows link different sources of new knowledge or technology and its users. David and Foray (1994) refer to these flows as the distributive power of an innovation system, which is its ability to get useful knowledge to firms that are capable of using it. This view stresses the role of “diffuse externalities”, where the capacity of firms to innovate partly depends on their ability to adopt knowledge from other firms and institutions and to recombine this knowledge in new ways. Similarly, Roelandt and Hertog (1996) refer to the *transfer capacity* of an innovation system, or the ability of knowledge-creating agents to spread the results to potential users. Both theories assume that innovation will proceed faster if innovators can benefit from the work of others rather than block each other[7].

The theoretical stress on the importance of knowledge flows is not unequivocally supported by the empirical evidence: knowledge flows are not always correlated with the efficiency of innovation. On the positive side, some of the results of innovation surveys show that more innovative firms tend to have more external knowledge sources (Bosworth and Stoneman, 1996). Part of this effect is probably because more innovative firms also tend to be larger and larger firms simply have more opportunities to form external contacts. What we really need to know is the number of external contacts per research employee. Unfortunately, existing survey data only gives us information on the variety of external sources in use. On the negative side, survey research consistently shows that innovative firms rank their own R&D more

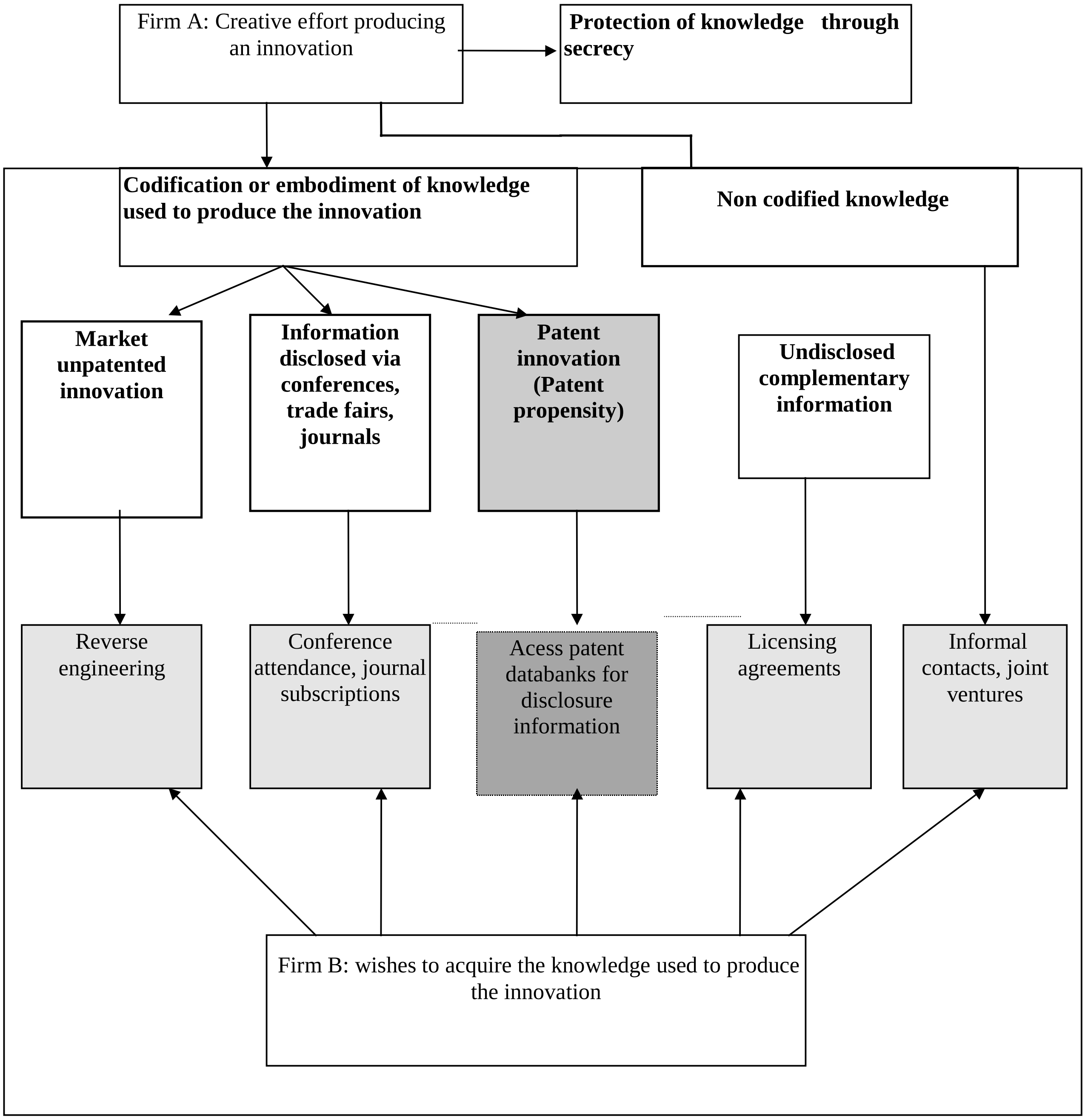
7 David and Foray (1994) suggest that one means of increasing the distributive power is to strengthen the public disclosure aspect of the patent system so that patents act as a clearing house for new knowledge. This would require encouraging firms to patent a much higher percentage of their innovations than they patent today and improving disclosure. The latter would require disclosing complementary information that can be necessary to replicate the invention and improving public access to patent databases. How these changes could be achieved is difficult to imagine, since existing disclosure requirements are already a major disincentive for firms to patent. Something would have to be offered in return, such as broader patents that would reduce the ability of competitors to ‘invent around’. This would reduce the amount of information freely available in the public knowledge pool. The end result could be more public knowledge but greater restrictions on its use.

highly than external information sources (Levin *et al*, 1987). Reverse engineering, which does not require networks or personal contacts, is also found by both Levin *et al* (1987) and Arundel *et al* (1995) to be a comparatively important method of learning about new technological developments.

There are many alternative routes for knowledge flows between firms. The problem with simple indicators for the types of information sources used by firms is that they can fail to capture the complexity of knowledge flows, which are formed by a wide range of influences. One factor which increases this complexity are appropriation conditions. This is illustrated in Figure 2.1, which shows the different routes that can be used by Firm B to obtain information about an innovation developed by Firm A. The specific routes available to Firm B depend on the strategic choices made by Firm A to appropriate its innovation. One option, which is particularly relevant to process innovation, is for Firm A to use trade secrecy to prevent the public release of information. The other options depend on whether or not the information is codified, although the knowledge required to produce most innovations will be divided between codified and non-codified information.

If firm A markets an innovation without patenting it, the methods available to firm B include reverse engineering combined with other possible information sources, such as information disclosed in journals. If firm A decides to patent the innovation, information will be available through patent disclosures, but it could also be available through a wide variety of other sources. Firm A could also intentionally publish information on an invention to prevent a competitor from patenting it. The decision, by Firm A, to patent its invention also opens up additional routes for the flow of knowledge. For example, Firm A could patent a product innovation, but the ability to successfully exploit this innovation could also depend on complementary process knowledge. The patent could encourage Firm A to license the innovation to Firm B, including the necessary ‘undisclosed complementary information’. Alternatively, patent protection could permit Firm A to disclose information in other locations, such as at conferences or in journals.

Figure 2.1: Knowledge production and knowledge flows



A word of caution is required here. Part of the current emphasis on knowledge flows and diffusion could be caused by misreading spill-overs, or the unintended flow of information from one actor to another, as an *intentional* knowledge flow. Furthermore, Geroski (1995) points out that many apparent knowledge flows could, in fact, be coincidental, due to the "more or less independent development of similar answers to commonly perceived problems which a group of competitors all arrive at by drawing on a pool of common scientific knowledge" (112).

Some of the problems with the theoretical assumptions about the value of knowledge flows can be illustrated by an evaluation of collaborative or cooperative R&D. This is one mechanism that can be used by firms to obtain knowledge from external sources. The assumed advantages of cooperative research include a reduction in technological and market uncertainty, cost-sharing, risk spreading, more incentives to invest from reducing appropriability problems, reduced duplication of research, economies of scale, and an ability to combine different expertises. These advantages could partly explain why firms that participate in cooperative R&D have a higher share of new products in their product line than firms that do not take part in cooperative R&D (Nas, Sandven and Smith, 1994).

At the same time, there are many drawbacks to cooperative R&D. It can divert energy and talents (Geroski, 1995). The cost savings to a firm from collaborative R&D could also be reduced by the cost of developing an appropriate ‘receiving mechanism’ to be able to successfully incorporate the results into new products and processes. Economies of scale cannot always be necessary or only the largest firms would perform R&D (Mowery, 1995), while the reduction in duplication could also prevent different research programmes that could develop alternative, and possibly better, solutions to a technical problem. Of interest, studies of the telecom and office equipment sectors, based on preliminary analyses of the CIS data, find that firms that participate in cooperative R&D are *less* innovative than those that do not (Arundel *et al*, 1996; Malerba *et al*, 1996).

2.2.1 Flow of knowledge via human capital

An important factor in the diffusion of knowledge is the movement of human capital. For example, the movement of biotechnologists from pharmaceutical firms to agricultural firms would suggest the transfer of genetic engineering techniques from the pharmaceutical industry to agriculture.

The problem is how to determine when the movement of human capital actually measures a real transfer of knowledge from one discipline or institution to another. Due to widespread restructuring, there has been a flow of scientists and engineers from industry to business services. This would imply a flow of knowledge to services, but some new business service firms only provide services to the industrial firms that created them as spin-offs.

So far, the focus has been on the movement of human capital between firms or institutions. Generally, we need indicators that can tell us when the movement of scientists is significant or not, regardless of whether it occurs within a firm, between firms, or ostensibly between industry sectors.

2.2.2 National innovation systems

A key question is the extent to which the distributive power of knowledge flows depends on regional or national innovation systems (NIS), which include the full range of government and private institutions, including laws governing exchange, governance, and intellectual property rights. Regional or national innovation systems would have a strong role in innovation if local sources of external knowledge are considerably more important than distant sources and if other institutions, for example technology transfer organisations and public research institutes, are essential for the competitiveness of firms, as shown by improved factor productivity, the share of innovative products in sales, and export performance (Roelandt and den Hertog, 1996). Conversely, the innovation system will be relatively weak if firms are able to access information globally and are not dependent on local knowledge sources.

So far, it has not been possible to empirically test the role of innovation systems in a satisfactory manner. The best method is to compare the behaviour of firms in the same industry but in different countries. This technique was used in one study based on the CIS-1 data. Some effect for country was found after controlling for industry and firm-level factors (Calvert *et al*, 1996). Unfortunately, little confidence can be placed in the results because of the poor comparability of the CIS data across countries, pointing to the need for nationally comparable innovation indicators.

Most of our current indicators for the role of a national innovation system in knowledge flows are based on input and output measures of inventive activity, such as R&D expenditures, scientific articles, and patents. Better indicators are needed for the flows of information between different parts of a national innovation system, such as between firms and public research institutions.

Schmoch *et al* (1996) focus on indicators that can link the science base of an innovation system, which is largely due to publicly-funded research in universities and research institutions, with the technological base, as shown by commercialisable knowledge. They propose several indicators based on patents: such as the percentage of patents that come from public research institutions and patent citations of journal articles. These are indicators of the flow of ideas. At the same time, we need to improve our measures of the diffusion of material artefacts. For example, a firm is not always innovating when it purchases new production equipment. Equipment that contains only very minor or no improvements can be purchased to replace current machinery or to expand production.

2.2.3 Speed of knowledge flows

Some of the policy relevant discussion of knowledge flows assumes that the benefits increase with the rate of diffusion of a new technology. As an example, technology transfer policies are often designed to overcome several barriers that could prevent a firm from adopting a new technology[8]. These barriers include a lack of knowledge about the technology or a lack of internal capabilities to use it. However, faster diffusion is not always desirable because the cost of adopting a new technology can often exceed the advantages (Stoneman, 1995). Many firms will be better off waiting for future product improvements, for the price to fall, or for improvements in their internal capability to effectively use the new technology.

The complexity of the possible outcomes of diffusion point to the need for better indicators for diffusion policy. The traditional approach focuses on material artefacts such as new production equipment as the carrier of diffusion (Roelandt and den Hertog, 1996). From the perspective of a knowledge economy, this approach needs to be widened to encompass diffusion through the movement of scientists and ideas, as noted above.

So far, our ability to measure knowledge flows is limited. Clark and Guy (1997) comment that the "increased recognition of the importance of knowledge and organisation has not been accompanied by corresponding advances in our ability to measure these factors". This conclusion is perhaps too pessimistic, since the CIS and other innovation surveys have collected some relevant data that show that all firms use external sources of knowledge. However, it is essential to develop better indicators for knowledge flows in order to determine the conditions under which knowledge flows and external networks are important to innovation and when they could be relatively unimportant. In particular, given the policy emphasis on cooperative R&D, we need indicators of the types of information that firms hope to obtain from other sources and the uses to which this knowledge is put.

2.3 ABSORPTIVE CAPACITY

The concept of absorptive capacity is related to the idea that there is no such thing as a free lunch. Ostensibly, some technical information is freely available to all firms, in the sense that it can be used without paying a fee for the use of the information. However, even freely available knowledge is rarely completely free because of the effort that is necessary to understand and exploit technological knowledge. For example, a firm can readily acquire a competitor's product on the market and attempt to develop a competitive alternative through reverse engineering. Although the purchase price of the product could be relatively small, the cost of imitation could approach the development cost of the original invention (Patel and Pavitt, 1995). Similarly, a firm might be unable to understand and develop the commercial significance of basic research results, although freely available in scientific journals, unless it conducts basic research itself.

The ability of a firm to effectively use external knowledge, ranging from basic research and reverse engineering to the implementation of new production equipment, is called its absorptive capacity. This capacity varies with a firm's experience and the range of its innovative activities.

There are two basic types of absorptive capacity. The first concerns the types of skills and expertise required to adopt and modify technologies developed by other firms. This is often seen as an issue of diffusion, or the transfer of technology from one organisation to another. An example is the purchase of new computer-controlled manufacturing equipment. The ability of a firm to efficiently implement this equipment into its production line depends on its understanding of the advantages and disadvantages of the new technology for its own needs and strategies.

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[8] See Appendix D.

Second, firms can innovate by creative activities to develop new or improved products and processes. Much of this development work can benefit from discoveries that are made by other firms or by publicly-funded research institutes (PRIs) such as universities. The capacity of a firm to use these discoveries depends on its ability to understand them and to assess their commercial applications. For example, a firm cannot include genetic engineering techniques into its research programme if it has no expertise in this field. Any activity that a firm undertakes to deepen and widen its scientific and technological skills will also improve its capacity to absorb new discoveries.

One implication of the need for firms to invest in absorptive capacity to be able to effectively use external knowledge, even when freely available, is that large firms could have an advantage in both the production and use of knowledge. This could occur because the employees of a firm will be better placed to exploit in-house knowledge than other firms (Minne, 1996) and because large firms will already be involved in the types of activities that make it easier to absorb external technologies. For example, there is a strong positive relationship with firm size and the probability that a firm conducts R&D, is involved in cooperative R&D, and uses patent disclosure as a source of technical information (Malerba *et al*, 1996; Arundel, 1997b). In contrast, SMEs could be hampered in their ability to develop and adopt new technology because of a lack of scientific and technical staff or experience. These and other arguments have led to a wide range of policy actions to improve the absorptive capacity of SMEs.

Although the concept of absorptive capacity has received a great deal of attention, there are no widely used indicators for it. One common assumption is that the amount of effort expended on innovation, for instance the amount of R&D spending or employed scientists, is an indirect measure of absorptive capacity. This could be a reasonable assumption for large firms, but we do not know if firms intentionally perform specific activities such as basic research in order to build up absorptive capacity, or if it is largely a by-product of existing innovative activities. More difficult problems develop when looking at SMEs or firms that do not conduct R&D. There are no available indicators for measuring the ability of firms to adopt innovations that were developed outside of the firm.

There is a need for indicators of the prevalence of absorptive strategies. These could include questions on whether or not a firm conducts parallel research projects to try to replicate work done elsewhere, or R&D projects to help it understand discoveries made outside of the firm. Furthermore, we need better information on the capacity of SMEs to use sophisticated technical information such as public research results or patent disclosures. Policies to encourage SMEs to make use of this type of information could be misguided if these firms are incapable of using them.

3. INNOVATION INDICATORS AND POLICY

Although a wide range of government programmes influence innovation, including competition, regulatory, fiscal, educational, and public investment policies, this discussion of the policy context is limited to programmes that are specifically designed to assist innovation.

There are many different ways of classifying innovation policies. For example, Ergas (1987) divides national innovation policies into mission-based and diffusion-based, while Mowery (1985) classifies policies into supply-side programmes to create new knowledge and demand-side programmes to encourage their diffusion. Metcalfe (1995) focuses on three ways that policies can influence the creation of knowledge: public research to supply new technological opportunities, patent legislation and government procurement to provide incentives to innovate, and research subsidies and education to provide the financial and human resources necessary for innovation.

All of these methods of classifying innovation policies are of value, but for the purposes of this report we will follow the three categories of importance to a knowledge-based economy. This translates into policies to create knowledge, to encourage dissemination, and to support the ability of firms to use knowledge developed outside of the firm.

Table 3.1 summarises the range of policies currently used in ten EU member states for each of the three categories[9]. Further details on these innovation policies are provided in Appendix D. Table 3.1 also divides policies into those that concern public research institutes (PRIs) and those that involve private firms. This division is necessary because of the number of policies by member states that concern PRIs. This highlights the central role of PRIs in innovation policy.

One further division is necessary to be able to map this scheme onto existing policies. Some innovation policies are based on general programmes that are

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[9] Information on current programmes is based on summaries provided for 12 EU member states plus Norway to the *EU Ad Hoc Committee on Dissemination, Optimisation and Innovation* and from Wolters and Hendriks (1997).

available to all firms while other policies are targeted to support a specific type of firm or field of research. General programmes include fiscal incentives such as R&D tax credits that are available to all firms that conduct R&D. Examples of targeted policies include programmes to support biotechnology or to help SMEs to innovate.

Table 3.1: **Innovation policies in use by EU member states**

Knowledge creation	Knowledge dissemination	Knowledge use (absorption)
By public research institutes (PRIs)	***By public research institutes (PRIs)***	***By public research institutes (PRIs)***
Maintenance of the teaching, training, and research activities of public institutions such as universities, research institutions, and laboratories. **Financial and passive incentives for PRIs to conduct research of commercial value.** **Targeting of research funds to areas with commercial potential.**	**Entrepreneurial assistance for staff to set up firms to exploit an invention or assistance to patent it and license it to a firm.** **Demonstration centres to provide information on specific technologies.** **Maintenance of a technology transfer infrastructure, including publicly-funded research centres and innovation centres.** **Subsidies for collaborative R&D or programmes to transfer technology between PRIs and firms.**	**Maintenance of research activities in specific fields.**
By private firms:	***By private firms:***	***By private firms***
Subsidies via direct grants or soft loans for in-house research. Often targeted to specific technologies. **Subsidies for collaborative R&D with other firms.** **Tax incentives such as a reduction in payroll tax for R&D personnel.** **Seed finance programmes, including equity and venture capital, to finance start-ups and the growth of small firms.** **Stock market initiatives to provide alternative markets for venture capital investment.**	**Subsidies for firms to contract research out to PRIs.** **Subsidies to adopt innovative technology. These are usually limited to specific technologies.** **Subsidies for collaborative R&D with other firms.** **Visits to or seminars by firms that are examples of best practise.**	**General advice on how to manage innovation, plus individual consultancy to assess how innovation can fit into the firm's business plans.** **Technology feasibility subsidies for evaluating the feasibility of adopting or developing an innovative technology.** **Technology audits to solve specific technical problems.** **Hiring subsidies for scientists, engineers, and technicians.**

3.1 Trends in European Policies to Support Innovation

The last decade has seen a shift in the types of innovation policies that are in use in Europe. These shifts have been motivated by reductions in subsidies to firms for both budgetary reasons and to meet European competition policy, changes in innovation theory, and a search for policies that can improve the ability of the European innovation system to translate research into innovative products. Some, but not all of these changes are apparent in Table 3.1. Five major trends in innovation policy have occurred:

1. Publicly-funded research institutes such as universities and government laboratories are being encouraged (or required) to direct their research efforts to areas that are of interest to private firms.

2. Direct research subsidies to large, individual firms for in-house R&D have been substantially cut-back or eliminated in most EU countries, with the notable exception of France and smaller EU countries such as Ireland and Greece that pay for these programmes with EU structural funds. In most other countries, direct subsidies are limited to targeted programmes to support SMEs or for collaborative research projects.

3. Targeted research subsidies for private R&D for strategic technologies such as micro-electronics or biotechnology has been reduced in favour of general policies. However, targeted funding still dominates the EU Framework Programme and other pan-European programmes such as EUREKA. Contrary to this trend, targeting of research by PRIs has increased.

4. Several governments have developed programmes to create a venture capital market and expertise to provide both seed capital and start-up funds. The intention of many of these programmes is to build a private venture capital market and to phase out public funds, although this has proved difficult in many EU countries.

5. Greater emphasis is placed on the diffusion of technology. In addition to the maintenance of a technology transfer infrastructure, many countries have introduced programmes to improve the absorptive capacity of firms. These include basic educational courses on innovation management and technology

audits, which identify technical problems in the firm and suggest innovative solutions. Most of these programmes are targeted to SMEs.

Several factors stand out here. One is a general shift from policies to supply new technology, for example by public research institutions, to policies to support the diffusion of technology. Many of these policies are not strictly concerned with diffusion *per se*, but with tightening up the link between basic and applied research and commercialisation. These programmes encompass efforts to improve the innovative capacity of SMEs, support for cooperative R&D which is intended to create networks and diffuse information, and programmes to force PRIs to re-position themselves to be closer to industry and to sell their research services to industry. These changes to policy have also had the ironic effect of reducing programmes for firms that are targeted to specific technologies, while increasing targeting for PRIs[10].

Another factor is that the first three of these five trends concern the creation of knowledge. This reflects both the long-standing influence of the linear model of innovation, with its strong emphasis on the supply of new knowledge, and policy efforts to improve the connection between Europe's strengths in basic and applied research and the commercialisation of these discoveries.

3.2 MAIN POLICY QUESTIONS FOR INNOVATION INDICATORS

An evaluation of the existing policies listed in Table 3.1 and the five major trends in European innovation policy points to several main policy concerns that need to be covered by indicators. These are summarised in Table 3.2. In respect to knowledge creation, these are the role of PRIs, collaboration, and financial barriers for start-ups and SMEs. The main topics of interest for the dissemination of knowledge concern the use of publicly funded research by firms, the channels by which new knowledge can be obtained, the vehicles for transmitting this knowledge, and appropriation conditions. The absorption and use of knowledge raises questions on the barriers to absorption and the innovation strategies of firms.

[10] This change in policy for firms reflects arguments, such as those by Mowery (1995), that it is preferable to develop general diffusion-oriented policies to support the flow of knowledge between different actors than to support programmes that target specific technologies or improve forecasting exercises for the selection of technological winners.

Table 3.2 only lists the most important questions of relevance to current policy. New innovation indicators are needed that can help answer all of these questions. In addition, there are many other secondary policies that could benefit from innovation data. An example is the value of patent disclosures as an information source.

Table 3.2: Main policy concerns to be covered by indicators

Knowledge creation	Knowledge dissemination	Knowledge absorption & use
What is the contribution of PRIs to knowledge that is of value to innovation? How important to firms is collaboration compared to other methods of innovation? How do financial conditions influence innovation, particularly by SMEs? What role do appropriation conditions play in the creation of knowledge?	What role do PRIs play in the innovative activities of firms? How will this be influenced by the increased targeting of PRI research? How important is collaboration as a method of disseminating information? What are the main external sources of knowledge and the vehicles for its transmission? What role do appropriation conditions play in the dissemination of knowledge? In particular, to what extent do intellectual property rights block or assist knowledge flows?	How do firms develop an adequate absorptive capacity? What active and passive methods are used by firms to strengthen their ability to adopt externally-generated knowledge? What are the barriers to absorption?

Other questions of relevance to policy concern the ongoing interaction between evolutionary theory and policy options. The emphasis of evolutionary theory on diversity and experimentation suggests a need for diverse policies that are closely targeted to specific conditions. Hofer and Polt (1998) comment on the need for innovation policy to become experimental, such that it “tries out new types of promotion, new types of interaction with policy tools...reorganising itself according to the changed requirements of modern policy formation”. This will be a very difficult goal to achieve, although any success in this direction will also require detailed information on the innovation strategies of firms.

4. A FRAMEWORK FOR INNOVATION INDICATORS

Existing frameworks or guides to the development of innovation indicators, such as the 1992 and 1997 Oslo Manuals, are built on an eclectic mix of new economic theories of innovation and past experience. The latter focuses almost entirely on indicators of in-house innovation, rather than on innovation as a process of diffusion. The Oslo Manuals suggest placing a new emphasis on diffusion processes, but it has been very difficult, in practice, to move beyond a conception of innovation as in-house research, as explained below in Chapter 5.

The problem is how to escape the powerful influence of past trends in the design of innovation indicators. One option is to develop a clearly articulated theoretical framework to guide the design of innovation indicators. Chapters Two and Three above indicate that such a framework should focus on knowledge creation, dissemination and absorption and on issues of value to policy.

A similar approach has been taken by the *Advisory Committee on Science and Technology Statistics* for Statistics Canada (ACSTS, 1997). They developed a simple framework that asks basic questions about each different type of innovation activity: *who* are the actors, *what* is the activity, *where* does it take place, and *why* is the activity initiated?

Table 4.1 summarises a version of the ACTS framework that is built around knowledge creation, dissemination and absorption. On first sight, the framework resembles a linear model of innovation, with knowledge flowing from ‘creators’ to ‘users’. However, the same actor can play all three roles, which is in contrast to the linear model, where there is only a uni-directional flow from creation to use. In addition, the framework permits a close evaluation of the linkages that connect the different types of innovative activity. Unlike the linear model, any point in the framework makes sense as a starting point. For example, a question can focus on a location and ask what types of innovations are being used, by whom, and for what purpose.

Other approaches adopt an actor-based framework, with concentric circles of influence. The firm is usually placed in the centre, with the science and engineering base, or general policy frameworks such as patent law, placed on the periphery. Distributive factors or knowledge flows link these various loci.

None of these attempts to develop a unifying framework are completely satisfactory. The ACTS framework must include a modification to account for the existence of external factors, such as patent law, that influence the innovation strategies of actors such as private firms. Other actor-based frameworks face the same problem and are perhaps less successful in emphasising the linkages between different actors.

Table 4.1: A framework for the development of innovation indicators

	Knowledge creation	**Knowledge dissemination**	**Knowledge use and absorption**
Who	Who creates the knowledge?	Who is the carrier of the knowledge - ie. scientists, patents, journal articles, new equipment.	Who is using the knowledge?
What (How)	What type of knowledge is created?	What specific knowledge is disseminated?	What absorptive capabilities must be present to be able to use the knowledge?
Where	Where is this activity located?	Where are the linkages - where do they start from?	Where is it being used?
Why	What purpose does the knowledge serve?	-	Why is it being used? What purpose does it serve?
External factors	What external factors influence this activity? How do financial factors influence knowledge creation?	What external factors influence this activity?	What external factors influence this activity?

Given the problems with unifying frameworks, the approach to developing indicators taken in this report is to continue the eclectic approach used in the Oslo Manual, while retaining a loose framework that follows the need for indicators of knowledge creation, knowledge dissemination, and knowledge absorption. Where relevant, the framework given above in Table 4.1 are used to guide the development of survey questions.

4.1 Indicators For The Who And How Of Innovation

The first two questions in Table 4.1 above concern *who* innovates and what they do when they innovate, or *how* they innovate. The development of new indicators for knowledge creation, dissemination and absorptive capacity depends on a satisfactory answer to these two questions. Developing indicators to answer these two questions is also one of the main functions of new surveys such as the CIS. It has also proved to be very difficult to answer these two questions, once our definition of innovation is broadened to include diffusion. For this reason, these two questions deserves a closer look.

The first problem is how to define what we mean by innovation. The definition that is most widely used by economists interested in technical change derives from Schumpeter, who saw the innovative process as consisting of three sequential stages: invention, innovation, and diffusion. This scheme separates inventive activities from innovation. Innovation is limited to the *commercialisation* of a new product or the implementation of a new process. The advantage of this definition is that it requires new products and processes to be of economic value, as shown by their commercialisation. Inventions that languish on the shelf for years or decades are excluded from consideration.

The Schumpeterian definition of innovation creates two main routes for innovation. First, a firm can innovate by implementing new process equipment that is purchased from a supplier or by selling a new product that it has obtained from another firm. It is important to note that this type of innovation can require *no intellectual, inventive, or creative effort whatsoever*. Second, a firm can also innovate by commercialising new products or implementing new process equipment that it developed through its own inventive activities. In this report, these two aspects of innovation are defined as follows:

- *Adoption or innovation as diffusion*: The acquisition of new processes or products from sources outside of the firm.

- *Inventive effort*: Creative activities by the firm to develop new or improved products, processes, or services.

These two main routes for innovation do not, however, encompass all possibilities. Firms can also innovate through the combination of adoption and inventive effort, for example when a firm expends some inventive effort to adapt new process technologies to fit its own production processes. The diffusion of ideas, knowledge and information also plays a vital role in creative innovation. In total, there are three possible routes through which a firm can innovate: adoption, inventive effort, and a combination of the two.

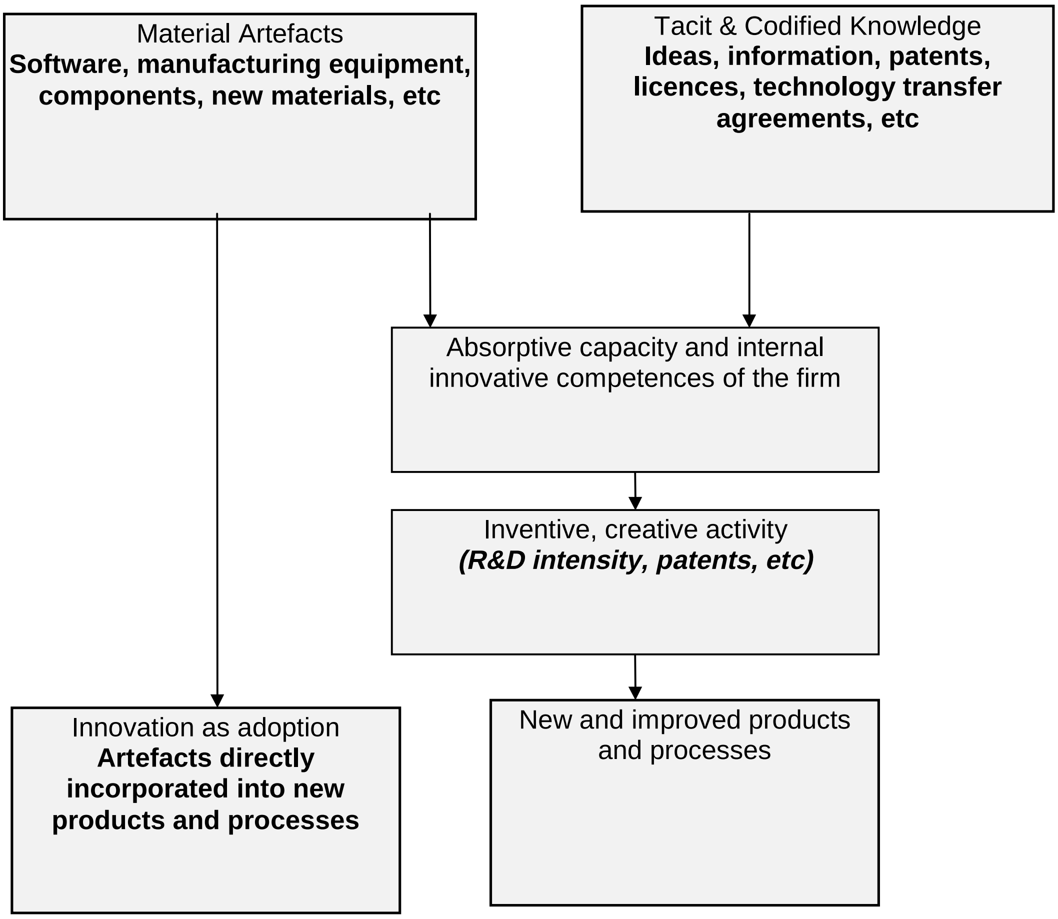
These three possible routes for innovation are described, schematically, in Figure 4.1. The three lines of arrows outline the three ways in which firms can innovate. Traditional indicators focus on the central box labelled ‘inventive, creative activity’. CIS-1 and CIS-2 introduce some indicators, via the expenditure and information source questions, for the box ‘material artefacts’ and the box ‘tacit and codified knowledge’. CIS-2 also contains a key question to differentiate innovation as adoption from innovation as a creative activity, although this question may not be fully successful in separating these two activities. Both CIS-1 and CIS-2 have very few questions that can be used to measure the absorptive capability or the internal innovative competences of the firm.

In addition to indicators that can disentangle the three innovation threads shown in Figure 4.1, there is a need for indicators of the quality or ‘technological significance’ of innovation[11]. The spectrum of innovation ranges from the exceedingly mundane to the exceedingly complex. Therefore, some means of defining the innovative capabilities of firms is also needed.

[11] One means of measuring the quality of innovations is to look at discounted expected returns (BP, 1996). This is probably not possible in surveys at the firm level where each firm can be active in a wide range of innovation projects. Its most feasible application is probably in object-based surveys of individual innovations, as used by Kleinknect.

4.2 NEW INDICATORS AND A WORD OF CAUTION

Figure 4.1: Dimensions of innovation



Chapters Five to Seven below provide question modules for new indicators that can meet the needs of policy, theory, and firms and which follow the framework developed in Table 4.1 and Figure 4.1 above. It is important to stress that these question modules are experimental. The purpose of developing many of these indicator questions is to suggest possible solutions to existing problems with innovation survey indicators and to provoke additional discussion on how survey indicators can be improved. The questions are *not* designed to be used directly in a survey. This would also require further evaluation (as outlined in Appendix A), field testing, and a careful comparison of the field test results with the results of the CIS-2 survey. The latter would be required to determine where the existing CIS-2 indicators are adequate and where the experimental questions provided below provide notable advantages.

Finally, far more questions are provided in Chapters Five to Seven than could possibly be included in a single innovation survey such as CIS-2. Some means of limiting the survey to the most important questions is necessary. Alternatively, some questions could be randomly divided among the sample frame. For example, a random sample of firms could receive questions on appropriation while another sample could receive the questions on the use of publicly-funded research.

5. THE KEY SURVEY INDICATORS: WHO INNOVATES AND HOW

Innovation surveys contain key questions that identify 'who' innovates and 'how' they innovate. The latter consists of measures of the intensity or quality of innovation. Innovation indicators should also be able to differentiate between innovation as adoption and innovation as a creative activity, as defined above in Chapter Four. The next two sections review the available traditional and new survey-based indicators of who innovates and what they do when they innovate. This is followed by a series of question modules on these key issues.

5.1 TRADITIONAL INDICATORS

In its most simple form, the 'how' of innovation can be divided into product and process innovation. The next step is to develop a measure of the quality of innovation. For example, is the innovation a minor adjustment to an existing product, a substantial improvement, or a revolutionary product that is completely new? These two definitions of the quality of innovation, combined with the two categories of innovation as adoption or inventive effort, create six categories. The ability of traditional indicators to provide information for each of these categories is given in Table 5.1.

Table 5.1: Traditional indicators of the 'Who' and 'How' of Innovation

	Innovation as adoption	Innovation as inventive effort
Who: yes or no	-	Applied for a Patent Performs R&D
How: Quality or intensity measure	-	R&D intensity Patent intensity Proportion of employees that are scientists or engineers
How: product or process	-	-

The traditional approach to identifying who innovates concentrates on inventive effort and is based on patents and R&D expenditures. Firms that have applied for a patent or which perform R&D are innovative while other firms are not. There are two main drawbacks to both of these indicators. The first is that they both focus on inventive effort and fail to capture firms that innovate through adoption. This is particularly likely to exclude small firms that often innovate through investment in new production equipment (Evangelista et al, 1997).

Table 5.2: Sales-weighted patent propensity rates by sector for European firms between 1990 and 1992

Sector	ISIC Code	N	Product Innovations	Process Innovations
Mining	10 - 14	11	27.7	32.5
Food, Beverages & Tobacco	15, 16	42	26.1	24.7
Textiles, clothing	17, 18	9	8.1	8.1
Petroleum refining	23	17	22.6	29.0
Chemicals	24	88	57.3	39.0
Pharmaceuticals	2423	32	79.2	45.6
Rubber & plastic products	25	20	33.7	27.6
Glass, clay, ceramics	26	35	29.3	20.2
Basic metals (iron & steel)	27	13	14.6	15.1
Fabricated metal products	28	42	38.8	39.4
Machinery	29	69	52.4	16.3
Office & computing equip.	30	8	56.8	20.9
Electrical equipment	31	26	43.6	21.5
Communication equipment	32	37	46.6	22.7
Precision instruments	33	24	56.4	46.8
Automobiles	34	46	30.0	17.0
Other transport equipment	35	30	31.2	10.9
Power utilities	40	14	29.5	26.5
Transport & telecom services	60, 64	23	20.5	12.4
Other manufacturing sectors		19	-	-
All firms		604	35.9	24.8

Source: Arundel and Kabla, 1998

The second drawback is that both indicators fail to identify all firms that expend some creative effort on innovation. In brief, using R&D as an indicator is biased against firms that develop mechanical innovations, which is often based on design and complex production systems and underestimates innovative activities in small firms[12]. Using patents can partly address the latter bias because small firms have a higher share of patents than of R&D[13] (Patel & Pavitt, 1995). The drawback to patents as an indicator of innovative status is due to intersector variability in the

[12] For example, in a study of firms in Canada, only 30.8% of 448 self-reported innovative firms applied for a tax credit for R&D (Lipsett et al, 1995). This suggests either that many innovative firms are not taking advantage of this programme or that a very high percentage of innovative firms do not perform R&D.

propensity to patent, as shown in Table 5.2, which provides estimates, drawn from the PACE survey, of the percentage of innovations for which a patent application is made. Patents will clearly be much more useful as a measure of innovation in sectors such as pharmaceuticals where 79.2% of product innovations are patented than in basic metals where only 14.6% of product innovations are patented.

A third indicator that has been recently suggested as a measure of innovative activity is the employment of scientists and engineers. Jacobsson et al (1996), in a study of the distribution of scientists and engineers in Sweden, find that although the 25 largest Swedish firms are responsible for 80% of Swedish business R&D, they only employ 30% of the stock of engineers and scientists. Conversely, 37% of the Swedish stock of scientists and engineers were employed by firms with less than 50 employees, although these firms were only responsible for 8% of R&D expenditures by Swedish firms. The wide disparity between firms that perform R&D and firms that employ scientists and engineers suggests that a lot of innovative activity is going on among firms that do not perform R&D. Identifying firms that employ scientists and engineers could also be used to identify innovators. There are two main limitations to this approach: not all scientists and engineers are employed in innovative activities and their employment does not differentiate between adoption and inventive effort.

Recent work suggests that patents can be used as an indicator of the adoption or diffusion of technology. Data on licensing-in can be used to measure the adoption of technology while licensing out can be used as an indicator of diffusion. The disadvantage of both of these measures is that acquiring or selling licenses constitutes only a very small part of the exchange of technologies.

5.2 Current Survey Indicators

Innovation surveys have used a range of methods to identify the who and how of innovation. Some, such as the Yale, Carnegie Mellon and PACE surveys, are limited to R&D performing firms. This means that all of the respondents innovate through inventive effort, but none of these surveys include indicators for the adoption of innovations.

The definition of an innovative firm that is used in the first Oslo Manual defines some firms that do not perform R&D as innovators, but it does not differentiate between adoption and inventive effort. This creates serious problems, as explained below.

Respondents to CIS-1 were asked if their firm had ‘innovated’, in the previous three years by “developing or introducing any technologically changed products (or processes)”. The CIS data, adjusted for differences in sampling and response rates, estimates that 52.9% of all manufacturing firms in 10 European countries innovate (Arundel and Garrelfs, 1997). A careful extrapolation of the CIS results to the total number of firms in specific countries estimates that 39% of Dutch, 39% of Norwegian, 48% of Danish, and 47% of German manufacturing and industrial firms innovate, though the proportion is less in low technology sectors[14].

For comparison, CIS-1 can also be used to estimate the percentage of firms that innovate, based on R&D performance. The comparison is provided in Figure 5.1, which gives weighted CIS estimates of the percentage of firms in seven size classes that perform R&D on a continuous basis and the percentage of firms that innovate using the CIS definition of an innovator[15]. The difference between the two lines equals the percentage of firms that report that they innovate but do not conduct R&D. Almost all large innovative firms also conduct R&D, but the percentage of innovative firms that do not conduct R&D increases as the firms become smaller, clearly illustrating the potential advantages of a survey approach to identify innovative firms. Unfortunately, the CIS survey did not collect data on patents, so it is not possible to include a patent-based estimate of the percentage of innovative firms for comparison.

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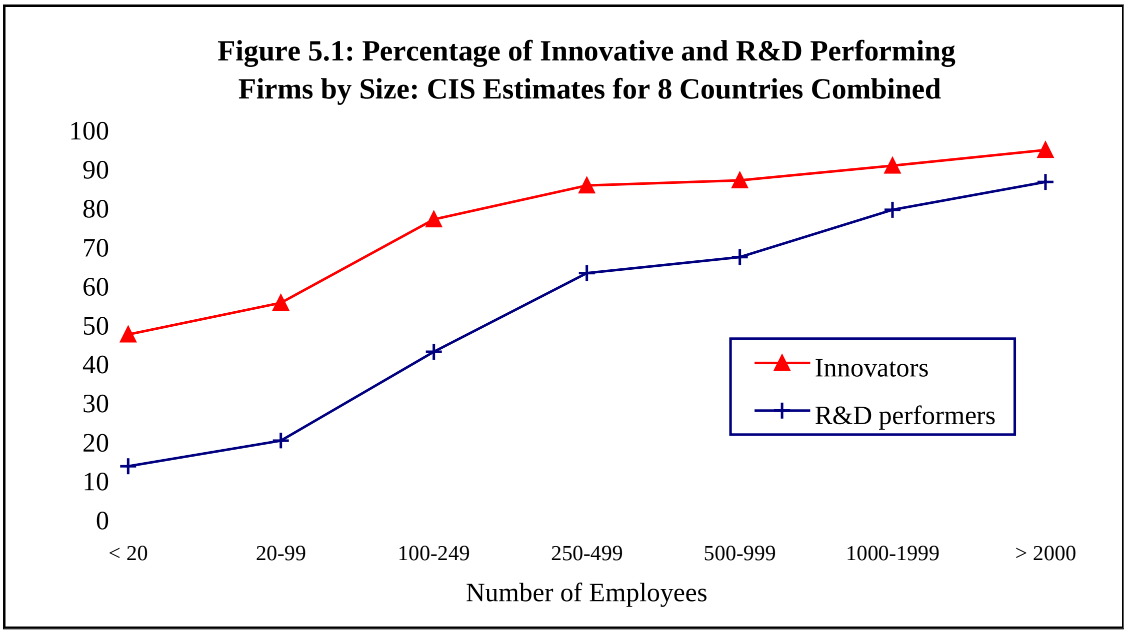
14 Figures obtained via personal communication from Keith Smith of STEP.

15 The estimates in Figure 1 combine responses from Germany, Italy, Belgium, the Netherlands, Luxembourg, Ireland, Denmark, and Norway. Analyses limited to specific countries give similar results.

Figure 5.1: Percentage of Innovative and R&D Performing Firms by Size: CIS Estimates for 8 Countries Combined



Source: Arundel, 1997

The CIS definition of an innovative firm is by no means perfect, since we do not really know what a firm means when it says that it innovates. As an example, what is the difference in the innovative activities of the firms that fall between the two lines of Figure 5.1 compared to the firms that conduct R&D? We don't know, but we are left with the suspicion that an unknown percentage of the firms between the two lines could expend very little inventive effort on innovation, with most of their innovative activity confined to the adoption of innovations, while other firms between the two lines could be more creative than R&D performing firms.

We are also left with a vexing question: Why didn't close to 100% of firms state on the CIS questionnaire that they had innovated? After all, the main CIS question on innovative status includes adoption. This means that a firm that markets a product developed elsewhere is defined as an innovator. For example, a clothing firm that purchases a slightly improved zipper from its supplier and then includes the new zipper into its clothing line is an innovator, since it has introduced a changed product onto the market. One explanation is that many firm managers interpret the question on innovation differently from economists. They could believe that innovation has something to do with inventive effort. At the same time, we cannot interpret the results to refer *only* to inventive effort because an unknown percentage of the respondents will have interpreted the question correctly to refer to commercialisation.

If most firms interpret 'innovation' as requiring some kind of inventive effort, then the estimate that 52.9% of European firms innovate is suspiciously high. Surveys in Canada, Australia, and the United States of manufacturing firms used the same CIS method to identify an innovative firm, but their estimates of the percentage of manufacturing firms that innovate is much lower: 34.8% in Australia (Pattison et al, 1996), 36% in Canada (Baldwin and da Pont, 1996), and 34% in the United States (Rausch, 1997). It is unlikely that either the branch plant structure of the Canadian and Australian economies, which should reduce the percentage of innovators, accounts for an almost 20% spread in the percentage of innovative firms. One explanation is the comparatively high response rates of 80% in Australia and 85.5% in Canada, since the proportion of innovative firms has been shown to be inversely correlated with the response rate (Sandven and Smith, 1997). This is because non-innovative firms are less likely to reply to questionnaires on innovation. This difference does not, however, explain the results for the US, where the response rate is 50%, which is comparable to the CIS average. One possible explanation is differences between the industry structure of the United States and Europe, which can distort results, but we would expect the United States to have an equal or higher percentage of innovative firms than Europe. Another possible, and worrying, explanation is strong national differences in how firms interpret the meaning of the word 'innovate'. These problems cannot be solved without better measures of how firms innovate and, in particular, an ability to separate innovation as adoption from innovation as creative effort.

5.2.1 Summary of CIS-1 survey indicators

Table 5.3 summarises the CIS-1 indicators for the who and how of innovation. At first sight, it appears that the CIS provides a better coverage of the basic indicators than the traditional measures of R&D and patents. However, this is partly deceptive, with some of these indicators working much better than others. For example, the R&D-based measures only give results for firms that conduct R&D, while the quality measure for adoption is limited to firms that purchase or license patents from other firms (CIS-2 improves on the ability to differentiate adoption from creative effort). In respect to the type of innovation, the CIS asks respondents to estimate the percentage of their sales from qualitatively different types of products, but this question provides no information on process innovations. This reduces the value of this question in analyses of the efficiency of innovation (Calvert et al, 1996).

Unlike the traditional indicators, CIS-1 does provide basic indicators for the type of innovation, although only for R&D performers. These firms are asked how much of the R&D budget is spent on product and on process innovation. One possible way of obtaining information for non-R&D performers is to ask firms how much time or effort is spent on different types of innovative activities. This has been recommended by DeBresson (1996). Data on the amount of effort spent by firms on product versus process innovation is of value in studies of the effect of innovation on employment or research on changes over time in the type of innovations that are developed[16]. Research so far shows that, with a few exceptions, most firms expend more effort on product than process innovation. This result could partly be due to a tendency for R&D managers to pay greater attention to product development, particularly if much of process innovation occurs through an incremental and informal process under the control of the production department.

Table 5.3: CIS-1 indicators of the 'Who' and 'How' of innovation

	Innovation as Adoption	Innovation as inventive effort
Who: yes or no	-	Performs R&D
How: Quality or intensity measure	Amount spent on patents and licenses	R&D intensity Share of innovative product sales new to your industry
How: product or process	Purchase of equipment (process adoption)	R&D spending on product and process innovation

CIS-1 lacks indicators that can differentiate between complex innovations such as automobiles and aircraft and single product innovations such as a computer chip. A firm can manufacture complex products by buying in many of the components from sub-contractors. These components could represent a significant innovation to the

[16] Greenan & Guellec (1996) examined the effect of product and process innovation on French manufacturing employment and found that process innovation increases employment in the innovative firm but decreases employment in the sector. Albach et al. (1996), in a study of the European chemical industry, divide firms into product and process innovators and look at factors that influence each strategy. They suspect that a move towards a greater emphasis on process innovation over time could also develop because of a decline in technological opportunities to develop new products.

sub-contractor but only offer a minor improvement to the total product. Therefore, measures of the 'innovativeness' of these sub-components could vary depending on who is asked to assess their value - the sub-contracting firm or the contractor.

As noted above, CIS-1 is also unable to identify firms that only innovate via adoption. This is unfortunate, because the types of strategies that firms use to innovate, and the relative importance of innovation to the survival and growth of the firm, will vary widely depending on the types of inventive and adoptive activities that the firm undertakes.

The lack of indicators for the 'how' of innovation severely limits our ability to benefit from the first CIS survey. For example, the CIS results tell us that very few small innovating firms take advantage of publicly funded research institutions (Arundel, 1997), but we cannot determine if this is because the type of research conducted in these institutions is not relevant to small innovative firms (suggesting perhaps a change in public research priorities) or if these small firms are only involved in adoption or very minor inventions for which any type of publicly-funded research is not relevant (suggesting different methods to support innovation by these firms).

An intriguing exception among recent surveys is the study by Statistics Canada, which asked firms to identify their most important innovation and then to state whether it was a world-first, a first to Canada, or only new to the firm. The results showed that there was very little difference between world-first and other firms in the respondent's perception of the economic performance of their firm, measured by an improvement in profit margins, foreign market share, and domestic market share (Baldwin and Da Pont, 1996). These results suggest that different types of innovation can have similar economic benefits. The implications, for both policy and firms, is that the type of innovation that will be most beneficial probably varies enormously, with no need to encourage all firms to move up the 'innovation intensity ladder' to increasingly complex innovative activities.

The results of these various surveys show that the lack of data on what firms mean when they say that they 'innovate' makes it very difficult to interpret survey data in a way that is meaningful for both policy makers and for firms, who are usually very interested in what survey results can tell them about common practice in their own sector. The severity of the problem is inversely related to firm size, since most large firms conduct R&D and therefore are likely to expend intellectual effort on the development of novel innovations, while the range in the types of innovation conducted by small firms is much more complex. To solve this problem, we need methods to identify different types of innovation among small firms. Furthermore, the intriguing results of the survey by Statistics Canada suggests the need to go further and to identify the actual importance of these innovation activities relative to the constellation of business strategies available to a firm.

5.3 QUESTION MODULES FOR NEW INDICATORS

The second CIS questionnaire (CIS-2) contains three key questions of relevance to the who and how of innovation: the main filter question which defines who innovates, the question on expenditures on different innovative activities, and the question on the percentage of sales turnover due to technologically new, improved, or marginally changed products. The first of these key questions is a major improvement over CIS-1 because it distinguishes between innovation as adoption and innovation as creative effort. However, as discussed in Appendix C, CIS-2 still provides incomplete indicators. There are also several design problems with the filter question which defines an innovative firm and the question on expenditures:

1. The response categories are not fully explained.

2. The definitions are not built into the questions.

3. The filter question to define innovative firms is based on the implementation of significant innovations, with the firm left to decide what constitutes a significant innovation.

4. The filter question occurs very early in the questionnaire, with non-innovators directed to the final question at the end of the questionnaire. This results in a loss of potential information from some of the other questions.

The question modules that are presented below try to solve these problems with CIS-2 and to better encompass the full range of innovative activities. One challenge is to further refine the indicators for innovation as adoption and innovation as diffusion.

The latter also includes indicators for the diffusion of knowledge, which are discussed in Chapter Six.

The question modules are designed to be completed by SMEs or at the division level of large, diversified firms. For the latter, the use of the term ‘firm’ in the questionnaire will refer to the division. This term should be replaced by ‘business line’ or ‘unit’ in questionnaires that are sent to large firms.

5.3.1 Basic questions

An innovation questionnaire must first obtain basic information on the firm’s sector of activity, number of employees, and annual turnover. One of the goals of the sample questions given below is to collect as much information as possible from *both* innovative and non-innovative firms.

The main activity of the firm is sometimes available from a statistical registry. An alternative is to ask for a NACE code by providing a list of NACE categories. This is time-consuming for the respondent. The alternative given here requires the survey agency to code each firm. This is feasible for small to medium-sized surveys (less than 2,000 responses) but could become prohibitively expensive for large surveys.

Please briefly describe your firm's main industrial or commercial activity:

Which of the following categories best describes your firm:

☐ Independent

☐ Majority-owned subsidiary of another firm

☐ Product or research division of a larger firm *country*

Where is the head office of your firm located? ....

Did any of the following occur to your firm between 1997 and 1999?

Your firm was established	☐ No	☐ Yes
Turnover *increased* by 10% or more due to merger or purchase of another firm	☐ No	☐ Yes
Turnover *decreased* by 10% or more due to the sale or closure of part of your firm	☐ No	☐ Yes

What was your firm's total sales turnover in 1999? ....

Percent of this total from:	Sales in the [Netherlands]	........%
	Sales to other EU countries	........%
	Sales to countries outside of the EU	........%
		100%

Please indicate if positive or negative

Percentage change in total sales since 1997	........%
Percentage change since 1997 in exports to countries outside of [the Netherlands]	........%

The next question expands considerably on CIS-2 by seeking information that is of relevance to the absorptive capacity of a firm. The relevant questions concern the number of employees with technical skills and the amount of time spent by these employees on gathering scientific and technical information. One drawback to the version given here is that it does not distinguish between the time spent on product and process innovation. The reason for this is that questions based on dividing up a factor into percentages can only use a maximum of five categories. This is because all categories must be easily divisible into 100%.

How many employees did your firm have in 1999 (full-time equivalents)? ....

Has this number changed since 1997?
☐ No change Increased by ....% Decreased by ....%

In 1999, did your firm have any employees with the following scientific and engineering backgrounds:			If yes, what percent of your employees are in this category?
PhD or Doctoral level in sciences, computing, or engineering	☐ No	☐ Yes	................%
Other university degree in sciences, computing, or engineering	☐ No	☐ Yes	................%
Graduate of a technical institute	☐ No	☐ Yes	................%

If your firm has any scientific or engineering staff, please answer the next two questions. Otherwise go to Question A

What percentage of your total scientific and technical staff in 1999 were hired in the last 3 years? ....%

On average, what percentage of your firm's scientific and engineering personnel's time is spent on the following tasks:

1.Gathering information on scientific and technical developments outside of your firm	................%
2. Developing new or improved products or processes	................%
3. Providing technical or customer support service	................%
4. In-house maintenance of equipment and software	................%
5. Other	................%
	100%

Other questions are worth including at this point to ensure that they are answered by all firms. This includes a question on the firm's objectives. In CIS-2, this question is limited to the objectives of innovation activities, but one problem with this question is that firms appear to give answers for their general business objectives (Arundel, 1997b). More accurate results are probably obtainable if the question is not limited to innovation. One possible question format is to ask about the importance of a list of 'general business strategies to improve the economic performance of your firm'. The options can include strategies that can be met through a range of methods, such as 'to reduce costs' or to 'improve marketing and service' plus options that require innovation, such as to 'introduce new products into existing markets'.

5.3.2 Key question on who innovates

Questions A1 and A2 ask about the three main types of innovation (as adoption, as creative effort, and as a hybrid of the two). These two key questions differ from CIS-2 in not using the terms 'significant innovation' or 'innovation'. The 'no' option is place *after* the 'yes' options to encourage the respondents to read the potential 'yes' categories. An alternative version that forces the respondent to read each option is also given.

A1. Between 1997 and 1999, did your firm introduce onto the market any technically new or improved *products*?

If yes, **Who** developed these products? *(check all that apply)*

- ☐ Other firms or institutes with few or no further technical changes by your firm
- ☐ Other firms or institutes plus technical changes by your firm
- ☐ Mainly your firm

No ☐

A2. Between 1997 and 1999, did your firm introduce onto the market any technically new or improved *processes*?

If yes, **Who** developed these processes? *(check all that apply)*

- ☐ Other firms or institutes with few or no further technical changes by your firm
- ☐ Other firms or institutes plus technical changes by your firm
- ☐ Mainly your firm

No ☐

Alternative version:

A. Between 1997 and 1999, did your firm conduct any of the following activities:

	Yes	**No**
Market a technically new or improved **product** that was developed outside of your firm and which required no further technical changes by your firm?	☐	☐
Market a technically new or improved **product** that was developed outside of your firm *but which required some technical modifications* by your firm?	☐	☐
Market a technically new or improved **product** that contained technical advances that were largely developed by your firm?	☐	☐
Introduce a new or technically improved production **process** that was developed outside of your firm and which required no further technical changes by your firm?	☐	☐
Introduce a new or technically improved production **process** that was developed outside of your firm *but which required some technical modifications* by your firm?	☐	☐
Introduce a new or technically improved production **process** that was largely developed by your firm?	☐	☐

5.3.2 Key Questions on Innovation Expenditures

Questions B to F obtain information on various innovative activities and are designed to replace the set of questions in CIS-2 on innovation expenditures. Several of these questions can be used to measure the quality of the firm's innovative activities.

One of the main disadvantage of the CIS-2 question on innovation expenditures is that it requires the respondent to carefully read a separate box of complex definitions. Much of the time spent by the respondent on this task is 'lost' because no further information, via questions, is acquired. Another disadvantage is that CIS-2 requires the respondent to give a cost figure for the innovative component of several common activities, such as investment in new equipment. This is very difficult, and led to very low item response rates of up to 50% to this question in CIS-1 (Sandven and Smith, 1997). The only solution to this problem that was adopted by CIS-2 was to include a 'no' option. Although this is of value for obtaining responses from firms that do not invest in a particular category, it is less likely to improve item response rates for firms that do invest.

Questions B to F on innovation expenditures solve these problems by including the definitions in the questions (thereby obtaining more information) and by breaking up the activities into more manageable components. In addition, information on the amount spent on innovative activities is obtained through percentages, which is normally simpler for firms to provide than firm cost estimates. For example, the question on investment in new equipment is based on a percentage of total investment in production equipment. This change should increase the low item response rates observed in CIS-1. Another change from CIS-2 is that questions B to F are designed to be answered by *all* firms, instead of only by firms that have implemented a 'significant' innovation.

B. In 1999, did your firm invest in machinery, equipment, or associated software for your production processes? ☐ **Yes** ☐ **No (Go to question C)**

If yes, how how much did your firm invest in these factors in 1999? ....

Approximately what percentage of this total investment was spent on the following factors:

1. Machinery, software, or equipment to manufacture *new or improved* products	....................%
2. Technologically new or improved equipment for *existing* product lines	....................%
3. Unchanged equipment to expand *existing* product lines	....................%
4. Other	....................%
	100%

C. In 1999, did your firm invest in in-house or external training programmes for your personnel? ☐ **Yes** ☐ **No (Go to question D)**

If yes, how how much did your firm invest in training in 1999? ....

Approximately what percentage of this total investment was spent on the following factors:

1. Use of new or improved software and computer systems	....................%
2. Use of technologically new or improved manufacturing processes	....................%
3. Research and technical skills for developing products and processes	....................%
4. Other	....................%
	100%

D. In 1999, did your firm invest in market research and advertising?

☐ **Yes** ☐ **No (Go to question E)**

If yes, how much did your firm invest in marketing in 1999? ....

Approximately what percentage of this total investment was spent on the following factors:

1. Preliminary market research and market tests for new or improved products	....................%
2. Advertising new products	....................%
3. Advertising improved technical features of existing product lines	....................%
4. Other	....................%
	100%

E. In 1999, did your firm purchase or license intellectual property rights, such as patented or non-patented products, processes, or technical know-how, from sources outside of your firm? ☐ **Yes** ☐ **No (Go to question F)**

If yes, how how much did your firm spend on such purchases in 1999? **........................**

Approximately what percentage of this total investment was spent on the following factors:

1. Licenses or rights to use products or components ....%
2. Licenses or rights to use processes ....%
3. Access to technical know-how and expertise ....%
4. Other ....%

100%

F. Did your firm engage in R&D between 1997 and 1999?

☐ **Yes, continuously** ☐ **Yes, some of this time** ☐ **No (Go to question G)**

If yes, did your firm invest in R&D in 1999? ☐ **Yes** ☐ **No (Go to question G)**

If yes, what was your firm's total expenditure in 1999 on R&D? ....

What percentage of this amount was spent on in-house R&D and on R&D contracted out to other firms? In-house .... %
Contracted out ....%
100%

How many R&D personnel did your firm have in-house in 1999 (full-time equivalents) ....

Some of questions B to F may not be worth asking, for example if very few firms invest in the category or if the item response rate is very high. One potential canditate for deletion is question D on marketing, which could be too difficult to answer accurately. Similarly, the CIS-2 question on industrial design is not included above because the definitions are so complex that it is unlikely to obtain accurate responses. Another alternative for reducing the response burden is to split the questions among different samples of firms.

5.3.3 Quality Measures of Innovative Activity

Several of the above questions, such as the basic question on employees, B.1 and B.2, C.3, and question group F, can be used as quality measures of innovative activity. The next group of questions provide additional measures of the quality or technological significance of the firm's innovative activities. The purpose of question

G is to provide an indirect measure of one aspect of how firms innovate: the speed with which firms introduce new products and processes. The answer to this question is important to diffusion research.

G. Compared with your competitors in the European market, how quickly did your firm introduce new or improved products and processes between 1997 and 1999?

New or improved products	☐ much more slowly ☐ more slowly ☐ about average ☐ more quickly ☐ much more quickly
New or improved processes	☐ much more slowly ☐ more slowly ☐ about average ☐ more quickly ☐ much more quickly

Question H follows the quality question in the 1993 Statistics Canada Innovation Survey. An alternative is to ask about the most important new or improved product or process, where 'importance' is defined in terms of economic impact.

H. Think of the most technically advanced new or improved *product* and *process* that was introduced by your firm between 1997 and 1999.

Was this product:	☐ A world first ☐ New to Europe ☐ Only new to your firm ☐ Don't know ☐ No new or improved products introduced
Was this process:	☐ A world first ☐ New to Europe ☐ Only new to your firm ☐ Don't know ☐ No new or improved processes introduced

Questions I and J are simpler (and easier to understand) versions of two related questions in CIS-2. Question I (and the equivalent version in CIS-2) obtains only one piece of data on the quality of innovation, which is the percentage of 'unchanged' versus changed products. This is because there is no quality scale between I.2 and I.3. A new product could be technically less advanced than an improvement, and vice-versa. In contrast, CIS-1 contained a qualitative scale, asking about the percentage of 'incrementally changed' and 'significantly changed' products. The disadvantage of the CIS-1 version is that the interpretation of 'incremental' and 'significant' is entirely subjective. This problem is avoided in question I and in CIS-2, but at a price: the question no longer provides ordinal data on the quality of the firm's innovative activities. For this reason, it is essential for questions I and J to be supplemented by other quality measures, such as questions G and H.

I. What percentage of your firm's total 1999 sales were from the following product categories?	
1. Products that were technically unchanged since the end of 1996	..................%
2. Products with technical improvements made after the end of 1996	..................%
3. Products new to your firm and introduced by your firm after the end of 1996	..................%
	100%

J. Between 1997 and 1999, did your firm introduce technically new or improved products that were both new to your firm *and* to your firm's markets?

☐ Yes What percentage of your firm's total 1999 sales were from these products ....%

☐ No

Neither CIS-1 or CIS-2 include an equivalent to question I for process innovations. This is unfortunate, since a better understanding of investment in new or technologically improved processes is of great value to analyses of the relationship between innovation and employment[17]. Question B above on the percentage of total capital investment in each of three categories (manufacturing new or improved products, technologically new or improved equipment, and unchanged equipment) provides some useful information. However, the question is not ideal since it does not divide equipment for new or improved products into new and existing technologies. It is also based on investment for one year only, which could miss major investments that occurred a year or two earlier.

An alternative version of a question on process innovation is given in Question K. One drawback is the degree of repetition with question B. This means that it may not

[17] See the series of articles on Innovation and Employment in Arundel and Garrelfs (1997), pp 133 - 160.

be practical to include both of these questions in the same questionnaire. In addition, question K could be too difficult for firms to answer correctly, with firms unable to separate K.3 from K.2.

K. What percentage of your firm's total manufacturing capacity in 1999 is due to the following process technologies:

1. Pre 1996 processes that were technically unchanged since the end of 1996	.................%
2. Pre 1996 processes with technical improvements made after the end of 1996	.................%
3. Pre 1996 process technology installed *after* the end of 1996	.................%
4. Completely new process technology installed after the end of 1996	.................%
	100%

A process version of question J above is not provided because firms may not be able to provide an accurate estimate of the percentage of their process innovations that are new to their market. This is because of the widespread use of secrecy to protect process innovations.

5.4 WHO, HOW, AND KNOWLEDGE CREATION, DIFFUSION AND ABSORPTION

The question modules given in this chapter are designed to differentiate the 'who' and 'how' of innovation and to obtain extensive information on innovation as diffusion . The latter goal, in particular, is poorly covered in previous surveys such as CIS, CMS, and PACE.

The 'who' component identifies innovative firms while the 'how' component identifies the quality or intensity of their innovative activites. At the same time, many of these questions contain information of value to the three main policy concerns: knowledge creation, knowledge diffusion, and knowledge absorption and use. Table 5.4 summarizes questions that contain one or more sub-questions of relevance to each of these three areas. Not surprisingly, many of the questions are of relevance to knowledge creation because of the role of in-house innovative activity, which is included in many of the questions on who innovates and how they innovate. In addition, five questions provide information of use to knowledge diffusion, while four are of value to knowledge absorption.

So far, the question series does not include a filter question to direct non-innovators to the end of the questionnaire. Up to this point, a filter is not required since all questions can be completed by firms that do not innovate. As an example, a non-innovator should answer question K.1 above with '100%' and question G on the rate with which the firm introduces product and process innovations with either 'much more slowly' or 'more slowly'. A response from non-innovators to question G would also be of value in establishing a background innovation rate for each sector of activity.

Table 5.4: 'Who' and 'How' questions of interest to knowledge creation, dissemination and absorption

Question	Knowledge creation	Knowledge diffusion	Knowledge absorption
Employees with a scientific and engineering background	*		*
Tasks of scientific and engineering employees	*		*
Percent hired in last three years			*
A1. Introduction of product innovations	*	*	
A2. Introduction of process innovations	*	*	
B. Investment in production equipment		*	
C. Training	*		*
D. Market research and advertising			
E. Acquisition of intellectual property rights		*	
F. R&D activity	*		
G. Speed of introduction of innovations	*	*	
H. Most technically advanced innovations	*		
I. Product sales by innovation type	*		
J. Products new to the firm and market	*		

The first possible option for placing a filter question is after question F. Another option is after question I. The latter is preferred, since it provides more options for checking the validity of the respondent's replies. The drawback for a later placement of a filter question is that it could annoy non-innovators, who might feel that they are asked to complete a large number of irrelevant questions. Alternatively, the questionnaire should work satisfactorily up to this point for respondents that do not innovate through creative effort but which innovate by adopting technology from external sources. Since a high percentage of firms should innovate through adoption, it may be possible to maintain high item response rates for all firms up to the end of question I. Whether or not this is true requires careful checking in field tests.

6. KNOWLEDGE DISSEMINATION AND ABSORPTION

The most frequently used indicators of knowledge dissemination (or diffusion) consist of questions on the importance (or frequency of use) of external and internal information sources. These basic questions are expanded in PACE to include the location of external sources, in CMS to determine the uses to which this information is put, and in CIS-1 to include technology acquisition and transfer and the location of cooperative research partners.

The drawback to many of these questions is that they do not satisfactorily overcome several difficulties: the difference between innovation as diffusion versus innovation as creative effort, the role of internal versus external information sources, an evaluation of the use of the information, and indicators for the role of human capital in information flows[18].

Other than the question on innovation expenditures, CIS-2 contains two questions of relevance to knowledge dissemination: a question on the importance of 12 information sources and a nominal question on cooperation arrangements with seven partner types by five locations. The cooperation question is well-designed and straightforward. For this reason, a question on cooperation is not given below. The question on 12 information sources is also satisfactory, although several improvements are possible, as shown below.

Absorptive capacity is more difficult to measure, partly because a wide range of firm competencies are linked to the ability of the firm to make use of external knowledge, and partly because there is a great deal of overlap between potential measures of absorptive capacity and other innovation indicators. For example, absolute R&D expenditures or the number of employed scientists are both quality measures and indicators of the firm’s capacity to use external information. The main disadvantage of using R&D spending as a measure of absorptive capacity is that it is useless for innovative firms that do not conduct R&D. Both PACE, and particularly the CMS survey, contain other indicators of absorptive capacity. PACE and CMS ask how much effort staff spend on monitoring scientific and technical developments, while CMS contains measures of the number of scientific staff and their area of expertise. In contrast, neither CIS-1 nor CIS-2 contain questions that can measure the absorptive capacity of firms that do not perform R&D.

6.1 KNOWLEDGE DISSEMINATION

One of the problems with the CIS-1 and CIS-2 formats of the question on the importance of information sources is that the question combines both internal and external information sources. This reduces the range of the results for external sources, particularly among R&D performers, because they tend to give much higher scores to their own internal sources than to external sources[19]. One solution is to separate the internal and external sources into two different questions. The disadvantage of separating the two sources when using a subjective scale, as in CIS-1 and CIS-2, is that it prevents a comparison of the relative importance of internal versus external sources. This could be overcome by adding an additional question that provides an overall summary of all internal versus all external sources. Another option that is less repetitive is to use an objective rather than a subjective scale.

An objective alternative to a subjective scale is to use a nominal ‘yes’ or ‘no’ format. However, this substantially reduces the amount of available information because many of these sources are used by a majority of firms. This means that the responses to specific sub-questions cannot differentiate between most firms. For example, Table 6.1 gives the percentage of CIS-1 respondents that probably make at least some use of a selection of seven information sources. Many of these sources are used by over 50% of SMEs, while all are used by over 65% of large firms[20].

[18] The CMS is an exception here. It avoids most of these problems, partly because it is limited to innovation as creative effort.

[19] The overwhelming importance of internal sources and its effect on the range of scores given to external sources is shown in the results of the 1997 SESSI innovation survey in France (Francois and Favre, 1998). In this survey, 46.6% gave a ‘high’ score to the importance of information sources within the firm, compared to between 2.1% and 12.9% for nine external sources. Only one external source comes close to the importance of internal sources, with 31.8% of firms giving a high score to customers.

[20] The Statistics Canada questionnaire on Biotechnology Use adopts a nominal scale, but limits the responses to ‘principal’ sources. However, the limitation to ‘principal’ sources is simply another subjective solution.

Table 6.1: Percentage of innovative CIS-1 respondents that make some use of each information source

Source	Firms with < 500 employees	Firms with ≥ 500 employees
Material suppliers	84.3	91.1
Competitors	75.2	85.2
Consultants	51.0	65.8
Universities	34.4	70.4
Patent disclosures	36.9	74.0
Conferences, etc	69.2	88.9
Trade fairs	80.9	87.0

Excludes firms from the UK, Greece and Portugal. 'Some use' estimated by a response of 'slightly important' to 'crucial' with a response of 1 or 'not important' assumed to represent no use. Part of the latter will use the source, which means that the above use rates are underestimates.

Source: MERIT, 1997

Several other objective solutions to a subjective scale are possible. One option is to ask about the percentage of innovative projects that make use of each source. Examples of the latter for internal and external information sources are given in questions A and B respectively[21]. Since the scale is based on an objective measure, it is possible to make direct comparisons between the value of internal and external information sources[22]. A measure based on 'projects' runs the risk of underestimating the value of a few sources that are essential to a small number of vitally important innovative projects. Nevertheless, the purpose of the question is to measure information *flows*, which should be related to the number and diversity of projects that use a specific source.

Questions A and B could be combined into one question that includes both internal and external sources. They are separated here in order to prevent respondent fatigue from using a very long list of sub-questions. The separation also gives more emphasis to sources within the firm by including more internal choices. This overcomes another problem with CIS-1 and CIS-2, both of which only include two questions on internal sources compared to 10 or more external sources. This creates a

[21] A word of caution is needed here. The subjective scale in CIS-1 works reasonably well, other than the problem of comparing internal and external sources. Whether or not the scale used in questions A and B is better than a subjective scale would need to be thoroughly field-tested.

[22] Questions A and B also use the term 'innovative projects'. This could be replaced, if needed, by a different wording, such as new or improved products and processes'.

bias in favour of the latter, when firms, in reality, find internal sources to be substantially more valuable.

The size of each response category in questions A and B is smaller at the ends (20% range) than in the middle (30% range). This is to help identify the least and most-widely used sources. Many other class widths are possible. It might also be better to use five categories in addition to 'none' in order to create a class that spans the mid-range of 50%.

A. Between 1997 and 1999, what percentage of your firm's innovative projects used technical information from each of the following sources *within* your firm?

	None	**up to 20%**	**20% - 40%**	**51% - 80%**	**> 80%**
Production engineering department	☐	☐	☐	☐	☐
R&D department	☐	☐	☐	☐	☐
Local management	☐	☐	☐	☐	☐
Plant operating staff	☐	☐	☐	☐	☐
Other divisions/subsidiaries of your firm	☐	☐	☐	☐	☐
Corporate head office	☐	☐	☐	☐	☐

Question B includes many of the external sources listed in CIS-2. The most notable change is the addition of 'technical analysis of competitors products'. This requires a change in the category 'competitors' to 'personal contacts with competitors'. This helps to clarify how firms obtain information from competitors, which is not at all clear in CIS-1 and CIS-2. Furthermore, the PACE results showed that reverse engineering (technical analysis of competitor's products) was a comparatively important information source that should not be neglected in innovation surveys.

B. Between 1997 and 1999, what percentage of your firm's innovative projects used technical information from each of the following *external* sources?

	None	up to 20%	20% - 50%	51% - 80%	> 80%
A. Material and equipment suppliers	☐	☐	☐	☐	☐
B. Clients or customers	☐	☐	☐	☐	☐
C. Universities or other higher education institutes	☐	☐	☐	☐	☐
D. Government research institutes	☐	☐	☐	☐	☐
E. Patent disclosures	☐	☐	☐	☐	☐
F. Professional conferences and meetings	☐	☐	☐	☐	☐
G. Trade fairs and exhibitions	☐	☐	☐	☐	☐
H. Scientific and technical publications	☐	☐	☐	☐	☐
I. Engineering and other consultancy firms	☐	☐	☐	☐	☐
J. Personal contacts with competitors	☐	☐	☐	☐	☐
K. Technical analysis of competitor's products	☐	☐	☐	☐	☐

Enter question letter

Which of the above was the most important for suggesting new projects? ....

Which of the above made the most important contribution to the completion of projects? ....

The inclusion of the two extra questions at the bottom of question B (which source suggested new projects and which source helped to complete them) are designed to find out what each external source is used for. This information has many potential uses. For example, it would be of value to the design of programmes to support the innovative capacity of SMEs to know *why* they use government research institutes, patent disclosures, or consultancy firms.

An alternative is to ask a question that directly focuses on the use of information from different sources. An example is given in question C, which uses nominal categories to investigate the purpose of external sources - for instance, to suggest new processes or to aid the completion of a process. Question C cannot, however, be used at the same time as A and B above because it would create too much repetition between questions. Furthermore, question C is relatively complex, since the respondent has to think of the answer to questions on four different uses. This means that the number of external sources should be reduced to a list of the most frequently used sources plus those, such as patent disclosures and public research, that are the most relevant to policy. Another option is to reduce the number of reasons from four to two by deleting separate questions on processes and products.

C. Between 1997 and 1999, did your firm use technical information from each source for the following reasons? (Please check all that apply)

	Never	Suggest new:		Help solve technical problems with:	
	Used	Processes	Products	Processes	Products
Material and equipment suppliers	☐	☐	☐	☐	☐
Clients or customers	☐	☐	☐	☐	☐
Universities/technical institutes	☐	☐	☐	☐	☐
Patent disclosures	☐	☐	☐	☐	☐
Professional conferences/meetings	☐	☐	☐	☐	☐
Trade fairs and exhibitions	☐	☐	☐	☐	☐
Scientific & technical publications	☐	☐	☐	☐	☐
Engineering & consultancy firms	☐	☐	☐	☐	☐

6.1.1 Innovation as Adoption Versus Creative Effort

Questions A and B above (and the versions used in CIS-2) do not distinguish between sources to learn about new technologies that the firm adopts and information sources for the firm’s own creative activities. Questions D and E provide a means of differentiating between the use of information for adoption versus creative purposes.

D. Think of the most economically valuable new or improved product or process technology, developed outside of your firm, that your firm acquired in the past three years. Which information sources did your firm use to learn about this technology?

(Please check all that apply).

A. Personal contacts with competitors	☐
B. Customers	☐
C. Equipment and material suppliers	☐
D. Universities or government research institutes	☐
E. Engineering and other consultancy firms	☐
F. Trade fairs and exhibitions	☐
G. Patent disclosures	☐
H. Professional conferences and meetings	☐
I. Scientific and technical publications	☐
	Enter question letter
Which was the most important source to learn about the existence of this technology?	....
Which was the most important source for learning how to use this technology?	....

E. Think of the most economically valuable new or improved product or process technology that was *developed by your firm*. Which of the following information sources contributed to the development of this technology?

(Please check all that apply).

A. Personal contacts with competitors	☐
B. Customers	☐
C. Equipment and material suppliers	☐
D. Universities or government research institutes	☐
E. Engineering and other consultancy firms	☐
F. Trade fairs and exhibitions	☐
G. Patent disclosures	☐
H. Professional conferences and meetings	☐
I. Scientific and technical publications	☐
J. Technical analysis of competitor’s products	☐
	Enter question letter
Which made the greatest contribution to the development of this technology?	....

Both questions D and E use nominal categories for the importance of each source. This should not result in over 50% of the firms checking each source because the responses are limited to the most 'economically valuable' new or improved product or process.

Question F provides a method of assessing the relative importance of external information sources to a firm's adoptive and creative innovative projects.

F. Between 1997 and 1999, what percentage of your firm's projects to introduce new or improved products and processes would have failed without *key expertise* from outside the firm?

Projects to implement new *process* technologies developed by other firms or institutions	...........%
Projects to implement new *product* technologies developed by other firms or institutions	...........%
Projects to develop new *process* technologies *within* your firm	...........%
Projects to develop new *product* technologies *within* your firm	...........%

Questions A, B, and F above ask the respondent to estimate the percentage of the firm's innovative projects, over a three year period, that meet certain criteria. This may be difficult for large firms that run many different projects. For these firms, more accurate results could be obtained from asking about the percentage of *current* projects.

6.2 ABSORPTIVE CAPACITY

The absorptive capacity of a firm is its ability to adopt new technologies developed by other firms or institutions and its ability to effectively use external information in its own creative activities. These skills are held by the firm's personnel. Therefore, data on the number of scientific and technical employees, their educational backgrounds, and flows of skilled employees, are all potential proxies for absorptive capacity.

Several indicators of value to absorptive capacity are included in the basic question in Chapter Five on the firm's scientific and engineering staff. These include the questions on skill levels, the number of skilled employees hired in the past three years, and the amount of time that skilled employees spend monitoring technical developments outside of the firm. Question C in Chapter Five on investment in training is also relevant to absorptive capacity.

Chapter Seven contains two questions of value for absorptive capacity. The first is the question on obtaining inputs from the public research structure via new scientific and engineering staff. The second, and more important question, asks firms about the contribution of publicly-funded research in nine disciplines to the firm's innovative projects. This question provides a measure of the diversity of technical competencies that are used by the firm. The results would also be of value to theoretical discussions on whether or not firm's knowledge bases are differentiated or highly specific and organised around a limited set of functions.

One additional question on absorptive capacity extends the question, in Chapter Five, on the firm's monitoring activities. This question asks about the motivations for the firms' innovative projects and probes if firms conduct parallel research projects to keep up with new scientific and technical developments. The question is designed for all firms, but it should be more relevant to high technology SMEs and large firms. For this group, it may be possible to change the nominal response categories to the percentage of research projects with these goals.

G. Between 1997 and 1999, has your firm:		
Conducted projects to replicate or build on the results of university research?	☐ Yes	☐ No
Conducted projects to replicate or build on your competitors' innovations or research findings?	☐ Yes	☐ No
Conducted projects to extend your firm's technical expertise into areas that are completely new to your firm?	☐ Yes	☐ No
Abandoned an area where your firm had built up technical expertise?	☐ Yes	☐ No

7. POLICY EXTRAS: APPROPRIATION AND PUBLIC RESEARCH

The preceding two chapters cover the main themes of knowledge creation, diffusion, and absorption. However, it is worthwhile to take a closer look at two areas that influence the innovative activities of firms and where policy plays a vital role: appropriation conditions and publicly-funded research.

Appropriation conditions are one of three external factors that are believed to strongly influence the willingness of firms to invest in innovation as a creative activity. The other two factors are technological opportunities (or the ability to develop a new product or process at a given cost of investment) and demand factors. For example, the probability that a firm will invest in R&D is thought to depend on its ability to recoup (appropriate) the cost of its investment, to find suitable technological opportunities, and to find sufficient consumer demand to be able to cover the cost of its investment (Cohen, 1995). Appropriation conditions are of great interest to policy because one option for appropriation, patents, is entirely dependent on legislation.

Publicly-funded research is believed to play an important role in the creation of technological opportunities by opening up new areas for commercially-profitable innovations. Examples include the computer industry, which was dependent in its early years on military applications, and biotechnology. Public funds, through procurement policies, can also influence demand.

7.1 APPROPRIATION CONDITIONS

Innovation is expensive. Firms try to recover their investments in innovation through strategies that give their new products or services a competitive advantage over the products or services of their competitors. One strategy is to create a lead-time advantage through superior marketing, shorter innovation development times, or frequent improvements to technically complex products (Levin et al, 1987). Another strategy is to use secrecy or intellectual property rights such as patents to prevent other firms from copying the same innovation.

Patents have attracted considerably more academic interest than other methods of appropriating investments in innovation. The fascination with patents, particularly when contrasted with how little attention has been directed towards secrecy[23], is partly due to the fact that a long time series of data exists on patents, whereas secrecy, almost by definition, is invisible. Patents and other intellectual property rights such as trademarks and copyright are also unusual in that they are not a characteristic of free markets but are provided by the state.

The traditional advantage of patents to a firm is its ability to confer monopoly rights. In addition, patents provide several other advantages that could encourage a firm to patent an innovation. A patent can protect a firm against future patent infringement suits, earn license revenue, or be traded via cross-licensing agreements for patented technologies held by other firms. In some circumstances, a strong patent portfolio can increase the market value of a firm.

While patents offer advantages to firms, theoretical and case study research shows that they could also create social welfare losses. The most cited effect is due to excess pricing made possible by the anti-competitive monopoly rights conferred by a patent. Of greater interest to innovation policy is the potential for patents to create barriers to the diffusion of new technologies. The potential social losses from patent barriers will be highest when the patent prevents the diffusion of an enabling technology, or one that is an essential core technology in the R&D projects of other firms or public research institutes. A firm can be prevented from using a valuable enabling technology if the patent-holder refuses a license or charges an exorbitant fee. A firm can also be forced to abandon specific areas of research that are protected by a cluster of patents held by another firm[24].

There are two social welfare justifications for the potential disadvantages of patents, particularly due to the creation of monopoly power. First, the patent system provides an incentive to firms to invest in innovation. Second, in order to receive a patent in Europe, the US and in many other countries, the patent applicant must disclose

[23] There are exceptions, such as the work in process on secrecy by Cohen et al (1997).
[24] There are only a limited number of empirical studies of these issues. Lerner (1995) found that firms are less likely to patent (and presumably invest in research activity) in IPC classes with high patent

enough information about the invention to permit another person or firm that is skilled in the technology to replicate it (Grilliches, 1990). This requirement "encourages the maximum diffusion of knowledge by making it public" (Geroski, 1995) and consequently increases the total amount of publicly available knowledge that can be used in the innovative process. These disclosures can benefit the innovative activities of other firms by giving them information that they can use to develop second-generation products and processes, or to solve technical problems in completely unrelated fields (Comerford, 1991). The emphasis on the benefits from disclosure does not, however, take into consideration the possible effects of patents in blocking the diffusion of key enabling technologies.

7.1.1 Current Policy Issues for Appropriation

Current policy actions within Europe in respect to appropriation conditions focus on encouraging firms to patent a higher proportion of their innovations. This is not necessarily the best policy response, since higher patent rates could interfere with diffusion. Conversely, higher patent rates could assist diffusion if firms made better use of patent disclosures to learn about new inventions. In order to solve these issues, we need better data on the range of appropriation methods available to firms, the relative importance of patents compared to other methods, and the ability of patents to block the diffusion of important inventions.

Good data on some or all of these issues are already available from several innovation surveys: PACE, CMS, and the Yale survey of the early 1980s. These have led to a series of working documents or publications on appropriation conditions and the role of patents[25]. One of the main results is that patents are *not* the most important appropriation method for most firms and in most sectors. Nevertheless, this message does not appear to be getting through to policy makers. For this reason, larger surveys with better coverage of patenting issues are required.

CIS-1 contained a series of short questions on different appropriation methods. Unfortunately, the usefulness of these questions was reduced by the fact that the CIS did not ask respondents about their own patenting activities. Furthermore, CIS-1 did

litigation rates. Arundel *et al* (1997) found that patents blocked the use of enabling technologies in biotechnology, but not in four other high-technology fields.

[25] See Levin et al (1987), Cohen et al (1997), Arundel et al (1995), Arundel and Steinmueller (1998), and Arundel and Kabla (1998).

not contain additional questions that are necessary to round out our understanding of these complex issues.

The question modules given below are divided into two groups. The first group consists of a short number of appropriation questions that could be included in all innovation surveys. The second group includes questions that probe more deeply. These questions should only be sent to a sample of firms and perhaps less frequently - for example every five to ten years.

7.1.2 Basic Question Modules on Appropriation

The primary policy need is a question on whether or not the firm applied for a patent and, if yes, how many technically-unique patents were applied for. These questions provide both an opportunity to link survey results at the aggregate level to patent data and they provide a quality measure for the firm's innovative activities. Firms that apply for at least one patent are highly likely to be creative innovators. The following question modules provide these basic results.

A. Between 1997 and 1999, did your firm apply for one or more patents for a product developed by your firm? ☐ **Yes** ☐ **No (Go to question B)**

1. If yes, how many product patents did your firm apply for over these three years? (Do not double count the same patent filed in different jurisdictions) ....
2. What percentage of your firm's technically new or improved products (developed by your firm and introduced over these three years) did your firm apply to patent? ....%

B. Between 1997 and 1999, did your firm apply for one or more patents for a *process* developed by your firm? ☐ **Yes** ☐ **No (Go to question C)**

1. If yes, how many process patents did your firm apply for over these three years? (Do not double count the same patent filed in different jurisdictions) ....
2. What percentage of your firm's technically new or improved processes (developed by your firm and introduced over these three years) did your firm apply to patent? ....%

Questions A.2. and B.2 provide estimates of product and process patent propensity rates. This gives a basic estimate of the importance of patents to appropriation. Firms (or sectors) that patent a high proportion of their innovations are more likely to find patents to be a valuable means of appropriation. An alternative version of this question is to provide five response categories (0 - 19%, 20-39% etc). This approach was taken in the PACE survey, but high item response rates for the PACE version suggest that a slightly more demanding open format should be feasible.

Firms patent for reasons that have little to do with appropriability, such as to prevent patent infringement suits. Nevertheless, the basic function of patents, as reported in the PACE survey, is to deter competitors from copying the invention. This means that a basic question of this type provides a good measure of the use of patents for appropriation without needing to ask other questions on why firms use patents. Additional questions, as developed below, need only be sent to a limited sub-sample of firms.

7.1.3 Extra Question Modules on Appropriation

Additional questions can explore the relative value of patents to other appropriation methods and acquire a measure of the strength of patents as a means of protecting innovations. An example is question C[26]. Another option is to repeat question C for process innovations. This is not done here because process innovations are often protected through secrecy.

The issue of secrecy is taken up in question D, which is a variant of a commonly-used question on the relative importance of different methods of appropriation. The main problem facing the design of this question is how to anchor the responses to an objective criteria. The CMS version asks about the *percentage* of product and process innovations that were adequately protected by each method. The drawback to this version is that the number of innovations is not necessarily correlated with the value of each protection method. For this reason, question D retains a subjective importance scale[27].

[26] This question is adapted from the CMS survey.
[27] This issue was not solvable through attempts to map the PACE version of this question on the CMS version. PACE uses a subjective scale while CMS uses the percentage of innovations. The results of the two surveys differ, for example CMS finds secrecy to be substantially more important than in PACE. Although this could be due to national differences between Europe and the US, one other option is that this difference is due to the two different measurement scales.

C. Think of your firm’s most commercially important new and improved products that your firm introduced to the market in the past 10 years.

How long did it take another firm to market a competitive alternative to:

1.Your most commercially important *patented* product

- ☐ < six months
- ☐ six months to one year
- ☐ one to three years
- ☐ three to five years
- ☐ > five years

2. Your most commercially important product that was *not* patented

- ☐ < six months
- ☐ six months to one year
- ☐ one to three years
- ☐ three to five years
- ☐ > five years

D. How important are the following methods of protecting the competitive advantages of your firm’s new or improved *products*?

	not important	slightly important	moderately important	very important	extremely important
1. Secrecy	☐	☐	☐	☐	☐
2. Patent protection	☐	☐	☐	☐	☐
3. Frequent technical improvements	☐	☐	☐	☐	☐
4. Lead-time advantages	☐	☐	☐	☐	☐
5. Technical complexity	☐	☐	☐	☐	☐

Question D can be repeated for process innovations.

Question E concerns the reasons why firms decide *not* to apply for a patent. This question has been asked in the PACE and CMS surveys and provides useful information of relevance to patent policy. However, neither PACE nor the CMS provide good coverage of small firms, which could experience markedly different barriers to patenting. In particular, they could find the costs of patenting, particularly the ability to defend a patent, to be substantially more important than large firms. It would be worthwhile including question E in a survey of a sample of small firms, although such a question need not be asked frequently - once every decade would probably suffice.

E. In the last three years, has your firm consciously decided *not* to apply for a patent for one or more inventions? ☐ Yes ☐ No (Go to question F)

If yes, how important were each of the following factors in your decision not to patent?

	not important	slightly important	moderately important	very important	extremely important
1. Application costs	☐	☐	☐	☐	☐
2. Cost of defending the patent against infringement	☐	☐	☐	☐	☐
3. The amount of information disclosed in the patent application	☐	☐	☐	☐	☐
4. The ease of legally inventing around a patent	☐	☐	☐	☐	☐

There are three different ways in which a patent can act as a barrier to the diffusion of a technology. A patent-holder can refuse to provide a license for the use of the technology by another firm or charge a license fee that is too high for some firms. The third way is a threat of a costly infringement suit. This will be justifiable if the threatened firm is actually infringing a patent, but sometimes a threatened firm challenges the validity of the original patent or argues that it is not infringing the patent, requiring a court case to decide the dispute. However, many firms, particularly SMEs, might not be able to afford the court costs and may cease using the contested technology even though a court might decide in their favour.

Question F is a highly experimental question for estimating the prevalence of these outcomes. The question is unlikely to be successful unless it can linked to industrial sectors defined at the four-digit level. This is because patent barriers are probably limited to specific product groups.

F. Has your firm been prevented from using a patented or copyrighted technology for one of the following reasons? (Please check all that apply)

Technology	Threat of an Infringement suit	Refusal of the owner to license the technology	License rights too expensive
1.Product component	☐	☐	☐
2. Software	☐	☐	☐
3. Process technology	☐	☐	☐
4. Technology used in your firm's own research	☐	☐	☐

Another optional question on patents concerns the influence of in-house patent expertise on the patent propensity rate. There is some evidence that firms with in-house expertise on how to apply for a patent are more likely to patent than firms that must use outside consultancy services (Scherer, 1965; Arundel and Kabla, 1998). In addition, firms without in-house expertise could be less likely to search for patent infringement against their own patents. If true, both of these factors could have important implications for the design of policies to encourage firms to patent. Questions G and H below address these issues.

G. Who draws up your firm's patent applications?	
In-house patent office	☐
Patent office of a parent firm or another firm related through ownership	☐
Patent office of a firm with which you have cooperative arrangements	☐
External patent consultancy	☐
Other	☐

H. How frequently does your firm check for infringement against your patents?		
☐ Never or rarely	☐ Semi-annually	☐ Monthly

7.2 PUBLICLY-FUNDED RESEARCH

The proportion of gross expenditures on R&D (GERD) in Europe in 1993 ranged from a low of 27.8% in Ireland to approximately 50% in Norway, Austria, Italy, and Norway (Smith, 1997). This substantial government investment in R&D means that publicly-funded research is important to both policy and to firms that access the results of such research.

The CIS-2 survey contains three questions of relevance to publicly-funded research. Respondents are asked to:

1. Estimate the importance of 'the main sources of information needed for suggesting new innovation projects or contributing to the completion of existing projects'. The information sources include 'universities or other higher education institutes' and 'government or private non-profit research institutes'.

2. Note if the firm was involved in cooperative innovation projects with ‘universities or other higher education institutes’ and ‘government or private non-profit research institutes’ in each of five locations.

3. Note if the firm received any government support for innovation activities.

These questions provide basic coverage of the use of publicly-funded research, both outside of the firm and within the firm. Similar questions are included in Chapter Six. Yet, these questions are unable to explore several issues of interest. This section develops several additional questions of value to policies for publicly-funded research.

7.2.1 Current Policy Issues for Publicly-Funded Research

The main European policy concern in respect to public research is the belief that European firms lag behind their American competitors in their ability to turn basic and applied research, partly conducted by universities and government research institutes, into competitive new products and processes. The solution taken in most European countries is to either directly steer public research funds into areas with potential commercial applications or to provide incentives for public research institutions to shift towards commercially valuable research (see Appendix D). Another policy goal is to increase the relevance of publicly-funded research to SMEs, or, conversely, to encourage SMEs to participate in cooperative research with the public research infrastructure.

Unfortunately, these policy trends are based on insufficient information about the different functions of public research in modern economies. The best policy response will depend on *how* different types of firms benefit from public research. The possible benefits of this research include the following:

1. Creation of new technological opportunities by opening up new fields
2. Training of technical and scientific staff
3. Development of new instruments and technologies
4. Suggest ideas for new products and processes
5. Provide solutions for on-going projects to develop new products and processes

There is some debate over the relative importance of each of these functions of public research. Research by Mansfield (1991), Kleinknecht and Reijnen (1992) and Rosenberg and Nelson (1994) suggests that firms primarily access public research to acquire basic or pre-competitive research results. These research results could be biased, however, by their focus on the linkages between large R&D performing firms and universities. SMEs could be more likely to use technical institutes to help solve problems with innovative projects. This points out the need to ask questions about different parts of the public research infrastructure and to ask why firms access public research or cooperate with public research institutions.

Another issue is the importance of proximity. Research by Pavitt (1994), Dasgupta and David (1994) and Arundel *et al* (1995) indicates that firms place greater importance on the national public research infrastructure than on foreign equivalents. The relative importance of national versus foreign public research can also vary by a range of factors, including the firm's sector, country of location, and size. A better understanding of the factors that influence the importance of proximity is of value to policy decisions over what aspects of the public research infrastructure need to be supported[28].

One complication is that the possible benefits of public research will vary by the field of research. For instance, one firm could hire most its research staff from chemistry departments while at the same time using new discoveries in biology to suggest new products. This points to the need for some results by research field.

Measuring technological opportunities is a particularly difficult issue. One option is to use a measure of a firm's 'closeness' to public research, on the assumption that most technological opportunities are closely linked to the research output of the public research infrastructure (Cohen, 1995). One method of estimating closeness is to measure the importance of different research fields to the firm's innovative activities.

[28] The CIS-2 questions on cooperation with two type of public research institutions are of value here, but firms can also obtain information from public research institutions without active participation in cooperative projects.

7.2.2 Question Modules on Public Research

Basic questions on public research are included in Chapter Six on diffusion. This section provides two additional questions that could be included in sub-sample surveys or in specialised surveys.

Question A provides information on the types of public research outputs that are used by firms in their innovative projects. The question is also divided by region in order to obtain information on the importance of proximity and knowledge flows between regions[29]. The nominal (yes or no) format of Question A means that it is likely to work best for SMEs, since a high proportion of large R&D performing firms will probably check over half of the options. This may be a worthwhile trade-off in order to keep the question simple, particularly since less is known about the use of public research by SMEs than by large firms.

Question B provides details on the use of publicly-funded research by field that can assist the planning of expenditure allocations (although it provides no information on *future* needs). The question is also of possible use in research on technological opportunities. Sectors with high average results for the percentage of projects that draw on publicly-funded research could have greater technological opportunities than sectors where public research is rarely used.

A. Between 1997 and 1999, did your firm obtain the following inputs from universities, government research institutions or labs located in each of four regions?

(Please check all that apply)

	[Germany]	**Other Europe**	**United States**	**Other countries**
Hiring scientific & engineering graduates	☐	☐	☐	☐
New instrumentation or techniques	☐	☐	☐	☐
Ideas for new products	☐	☐	☐	☐
Ideas for new processes	☐	☐	☐	☐
Solutions for product development projects	☐	☐	☐	☐
Solutions for process development projects	☐	☐	☐	☐

[29] Location in Japan is not included because innovation survey research shows that European firms rarely access public research from Japan (Arundel et al, 1995).

There are also several possible alternative versions of Question B. In the example given below, the ordinal scale is anchored in innovative projects, rather than using a subjective scale based on importance. The justification for this particular anchor is that the range of applications of public research (as measured by the percentage of projects that are affected) is a good measure of its economic influence. This contrasts with the intensity with which public research could be used in any particular project. A measure of the range of applications could also be more relevant than intensity for estimating technological opportunities.

B. Between 1997 and 1999, what percentage of your firm's projects to develop new or improved products or processes used the results of publicly-funded research in each of the following fields:

	0%	**1 - 20%**	**21% - 40%**	**41% - 60%**	**> 61%**
Biotechnology (including molecular biochemistry)	☐	☐	☐	☐	☐
Chemistry	☐	☐	☐	☐	☐
Physics	☐	☐	☐	☐	☐
Medical and health sciences	☐	☐	☐	☐	☐
Materials science	☐	☐	☐	☐	☐
Computer science	☐	☐	☐	☐	☐
Chemical engineering	☐	☐	☐	☐	☐
Electrical engineering	☐	☐	☐	☐	☐
Mechanical engineering	☐	☐	☐	☐	☐

8. RECOMMENDATIONS

Innovation surveys such as the CIS provide valuable information on the innovative activities of firms. Nevertheless, many surveys that adopt the CIS approach suffer from several problems:

- A lack of objective measures for innovative activities such as knowledge flows.
- An inability to separate innovation as diffusion from innovation as creative effort.
- A focus on highly innovative firms such as R&D performers.
- A lack of data for non-innovators or weakly innovative firms.
- General questions that fail to capture many issues of importance to innovation policy.
- A failure to adequately survey the innovative activities of large, diversified firms.

This report, and its Appendices, offer solutions to each of the above issues. At the same time, these solutions fall within an approach to innovation, as developed in the Oslo Manuals, that is dominated by a concept of innovation that is based on R&D and creative, inventive effort. There are two reasons for this.

First, an attempt to completely cut the theoretical links to invention, in order to give equal attention to diffusion, would result in a questionnaire that would be unrecognisable to users familiar with the CIS surveys. This would be equivalent to a technologically-advanced product that is a commercial failure because its characteristics far exceed the needs of any potential users.

Second, creative innovation is of fundamental importance. The problem with focusing on diffusion, as noted in Chapter Two, is that rapid diffusion is not necessarily linked to greater profitability, consumer welfare, or consumer satisfaction. A case in point is the slower diffusion of genetically-engineered food commodities such as rapeseed, maize, and soybeans in Europe versus North America. It is highly doubtful that this makes any difference to the profitability of European food products firms or to consumer welfare. The only place where the slow diffusion of genetically-modified plants *does* affect European competitiveness is its impact on the R&D strategies of European firms active in agro-biotechnology.

Given these caveats, the following recommendations can be made for innovation indicator surveys:

1. Wherever possible, the subjective scales used in CIS-1 and CIS-2 should be replaced with objective scales. Chapters Five through Seven give many examples of how this can be done. One option is to use a nominal 'yes' or 'no' scale. Another option is to use an ordinal scale that is anchored in a real measure such as the number of innovation projects held by a firm.

2. CIS-2 contains a strong bias towards innovation as creative effort by its emphasis on 'significant' innovation. This contradicts the Oslo Manuals' emphasis on innovation as diffusion and the growing importance of policies to encourage diffusion and related factors such as the ability of SMEs to 'absorb' new technologies. Innovative surveys need to develop indicators that clearly separate innovation as a creative activity from innovation as a diffusion process. Chapter Five gives several examples of questions that can make this distinction.

3. The CIS, although sent to many SMEs that do not perform R&D, is nevertheless biased towards R&D performing firms. This bias stems from a long tradition in the development of innovation indicators, which has focused on large R&D performing firms, patents, and scientific publications. New techniques that can provide a better measure of the innovative activities of firms that do not perform R&D are needed. One method is to avoid the highly subjective technique of asking firms if they have introduced a 'significant' innovation. This should be replaced by a range of questions that probe the *quality* of the firm's innovative activities.

4. Almost all of the CIS questions are designed for firms that innovate through creative effort. Very little information is obtained for non-innovative firms. Weak innovators could also be more likely to abandon the questionnaire because very few questions are relevant to them. These problems can be overcome by ensuring that many of the survey questions can be answered by all firms. Not only should this increase the amount of information available for non-innovators or weak innovators, but it will ensure that we can provide an excellent definition of the

'innovativeness' of all firms. One result is that we will no longer be able to provide simple estimates of the percentage of 'innovative' firms. Instead, we will have a range of criteria to define innovation.

5. The CIS is designed to be answered by firms of all sizes and in all manufacturing sectors. This is a strength that permits comparisons between many different firms. At the same time, little attention has been given to specialised issues, many of which are of great interest to policy. The CIS approach needs to be combined with smaller, specialised sub-surveys that focus on particular issues.

6. The sampling and survey techniques used in many surveys fail to adequately survey large firms that are active in multiple product lines. As noted in Appendix B, this could seriously distort our understanding of innovative activities by increasing the apparent differences between SMEs and large firms. Furthermore, the current emphasis on sampling at the enterprise level is a false economy given the dominant role play by large firms in creative innovation. Future surveys must sample large firms at the product line or division level.

7. Current innovation surveys fail to take full advantage of the power of computerised survey systems. These permit the construction of specialised questionnaires that contain different questions, depending on the firm's sector of activity and size. Furthermore, these techniques can be used to randomly assign a series of optional questions that focus on specific issues such as appropriation conditions or the role of public research. Chapters Five through Seven provide many examples of questions that could be sent to smaller sub-samples of large-scale surveys. Further examples are provided for environmental indicators in the companion report *Analytical Challenges for Economic and Innovation Theory*.

So far, almost all of the effort to develop innovation survey indicators has focused on the design of survey questions and the need for comparability between EU member states. This is not an entirely successful strategy because the design of survey indicators goes hand in hand with sampling methods. It is time to expend an equivalent amount of intellectual energy on sample design and to take advantage of the ability of computers to permit more sophisticated survey strategies.

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APPENDIX A

GUIDELINES FOR THE DESIGN OF SURVEY INNOVATION INDICATORS

The ability of a questionnaire to obtain useful innovation indicators depends on the care with which the questionnaire is designed. This requires a two-stage process. The first stage is the development of the questionnaire. Several questionnaire design guidelines are useful to minimise errors at this point. However, no questionnaire is perfect. This means that a second stage is required to evaluate the questionnaire and suggest further improvements.

The second stage consists of an ongoing, interactive process between the design of innovation indicators and the analysis of survey results. For example, experience gained during the analysis of the CIS-1 results has been used to assist the development of the CIS-2 questionnaire. In turn, the analysis of CIS-2 will lead to further modifications and improvements that will be incorporated into future innovation surveys. This process is not never-ending, however. At some time the experience gained with the design of indicator questions will lead to a robust and useful questionnaire.

The first section of this Appendix gives basic guidelines for the initial questionnaire design[30]. These are used to guide the design of the question modules given in this report and in the companion report *Analytical Challenges for Innovation Theory and Policy*. The second section provides guidelines for subsequent evaluations.

A.1 GUIDELINES FOR QUESTIONNAIRE DESIGN

The ability of a questionnaire to obtain useful information depends on the care with which the questionnaire is designed. There are three pivotal issues to consider in the design of a questionnaire: the design of each question or question group, the measurement scale that is used for different question types, and the overall structure of the questionnaire.

[30] There are very few sources from the economics literature on innovation surveys. The two most widely used sources are the 1992 and 1997 Oslo Manuals, but neither of these give careful attention to good questionnaire design. The Sage series of monographs on statistics includes a volume on question design which provides some useful guidelines. Although designed for health surveys, the first four chapters of Streiner and Norman (1996) provide useful discussions of measurement scales and other technical issues.

A.1.1 Basic Rules for Question Design

A.1.1.1 Indicator Questions Must be Simple and Unambiguous
There are four main rules for the wording of questions:

1. Each question should be written in simple, unambiguous language. As a rule of thumb, each sentence should not exceed 20 words and the simplest feasible vocabulary should be used. It is essential that the question does not contain poorly defined or ambiguous words.
2. While maintaining simplicity, the question must be fully explained. ‘Telegraphic’ reduced forms to save space should be avoided. The respondent must not have to guess the meaning of the question.
3. Each question should contain only one question. Care must be taken to avoid questions that actually contain two or more elements. Filter questions should be separated from the main question.
4. Each question should be discrete and not overlap with another question. This is particularly important when respondents are asked to evaluate a range of options.

Although each of these four main rules of question design appear to be obvious, meeting them is often exceedingly difficult in practice. As an example, CIS-2 suffers from ambiguous definitions of product and process innovation. The respondent is asked if their firm has introduced any technologically new or improved products. A technologically new product is defined as one ‘whose technological characteristics or intended uses *differ significantly* from earlier products’ (my emphasis). What constitutes a significant difference is not adequately explained, leaving the respondent to decide.

A.1.1.2 Questions Must be Operational and Appropriate
The data produced by surveys must be robust. Questions outside of the knowledge or experience of the respondent should not be included. For example, questions on the strategic behaviour of competitors or conditions in the firm’s line of business will produce less reliable results than questions about the respondent’s own firm. Similarly, it is very difficult to design “what if” questions or questions about the future, such as the direction of technological change. Questions with either ‘correct answers’ or which allow firms to give answers that will influence policy in the direction that they want should also be avoided. An example of the latter is the question “Do government regulations increase the cost of innovation to your firm?”

A.1.1.3 Build Definitions Into the Question
A well-designed questionnaire should build definitions into the question, rather than including several additional pages of explanatory material. This is because a sizeable

fraction of the respondents will not read the explanations. Furthermore, it takes time to read definitions. A more effective use of the respondent's time is to turn the definitions into questions. In this way additional information can be gathered while explaining the material to the respondent. One objection to this is that it increases the length of the questionnaire. However, this is based on the false premise that a four-page questionnaire with two pages of explanations is a four page questionnaire. It is not. It is a six page questionnaire.

A.1.1.4 Anchor Subjective Questions Where Possible

Subjective questions that ask the respondent's opinion, for example on the importance of suppliers as a source of technical information, can provide information that is not possible to obtain in other ways. At the same time, subjective questions create many problems in interpretation. Wherever possible, opinion questions should be linked to a measurable quantity. This problem is discussed below in section 1.2.4.

A.1.1.5 Carefully Define the Unit of Observation

Small, independent firms generally have clear boundaries. Therefore, questions on the firm's innovative activities are unproblematic. In contrast, organisational complexity increases with firm size and for firms that are subsidiaries of other firms. A question on the innovative activity of a 'firm' or 'enterprise' could be very ambiguous for complex firms. At one extreme, a respondent could interpret the question to refer to the entire firm, including subsidiaries in other countries and completely different product lines within a diversified firm. At the other extreme, a respondent could interpret the question to refer to one unit within a large, diversified firm, such as a single manufacturing plant. It is crucial for questionnaires to carefully define the unit of observation that the respondent should have in mind when answering the questions.

The problem of how to define the unit of observation cannot be solved through careful questionnaire instructions alone. In addition, an appropriate sampling methodology is required for large, multi-divisional firms. These sampling techniques are described in Appendix B.

A.1.2 Measurement Scales

Innovation indicators can use nominal, ordinal or continuous measurement scales.

A.1.2.1 Nominal Scales

Nominal scales, such as checklists or simple 'yes' or 'no' responses, can provide unambiguous answers to many questions. For example, a yes or no answer for the use of a list of information sources will provide reliable information on the percentage of firms that use a specific source. Whether or not information obtained in this way is of value depends on two other conditions.

First, the value of a nominal scale depends on our *a priori* knowledge about the likely distribution of responses, and second, on the dispersion of the responses by groups of interest. It could be very interesting to discover that 95% of firms do not search patent databases, but of little interest to discover that 95% of firms state that 'a lack of finance' is a barrier to innovation. The results for the latter question indicate that the question requires more detail in order to obtain interesting and useful data. In general, nominal scales are most useful if there is a large disparity in answers across factors of interest, such as firm size, sector of activity, or by innovation strategy. When there is little difference, it is best to replace nominal scales with an ordinal scale that provides a greater dispersion in the responses or to refocus the question on a narrower range of activities.

A.1.2.2 Ordinal Measurement Scales

Several options are available for questions that use subjective scales. One is to use a Likert scale with a neutral centre-point: 'no opinion' can form the centre of a scale ranging from 'strongly disagree' to 'strongly agree'. Another option is to use a uni-directional scale, as in CIS-1, that ranges from 'not important' to 'crucially important'.

Most innovation surveys use uni-directional subjective scales rather than Likert scales.

Ordinal scales can still suffer from the same problem as nominal scales if most responses cluster around one of the two ends. The solution is either to drop the question (it provides few results of interest) or to revise it so that there is a greater diversity of responses.

Number of scalar points: There is ongoing debate over the optimum number of points to use for an ordinal scale: three, four, five, or seven points are all options used in innovation surveys. CIS-1 opted for a five-point scale while CIS-2 uses a three-point scale[31]. The number of points used is likely to have little effect on the ability of the respondent to answer the question, but it could have a substantial effect on the data analysis. This needs to be kept in mind when developing the questionnaire.

Given advanced statistical software packages, there is no significant advantage in using a three, five or seven-point scale. Although a three-point scale is easier to

[31] During the development of CIS-2, Eurostat argued that a three-point scale had several advantages over a five-point scale: it would increase the item response rate and improve the reliability of the statistics, partly by smoothing cultural differences and partly by reducing the size of the confidence interval (Akerblom, 1996). Neither of these advantages hold up to scrutiny. Item response rates for the five-point subjective questions in both CIS-1 and PACE generally exceed 90% or 95% for many questions. This means that any improvement in item response rates will be marginal. Second, the reduction in the confidence interval for a three-point versus a five-point scale is an artefact (recognised by Eurostat) of a larger number of responses per response category, while there is no evidence to support a 'smoothing' of cultural differences.

analyse than a longer scale, the latter can always be recoded to produce a shorter scale. However, a longer scale has considerable analytical advantages that are due to the subjective character of ordinal scales.

The use of a subjective ordinal scale assumes that there is an unknown reference point for the ‘importance’ of a factor, such as an information source. This reference point, known only to the respondent, could be absolute, or it could be based on the importance of a specific information source compared to all other information sources listed in the same question group. Either way, the responses should be internally consistent so that an information source that is ‘crucially important’ will be more important than another source that is of ‘moderate’ importance.

In contrast, there is no common reference point between one respondent and another. We do not know if respondent A’s rating of ‘crucial’ is equal to respondent B’s rating of ‘crucial’ or to B’s rating of ‘moderate’. This problem cannot be solved when using subjective ordinal scales. Fortunately, there is one solution that is based on the internal consistency of responses for the same respondent. For example, assume that the highest score given by respondent A is ‘crucial’ and that this score is given to the importance of universities. The highest score given by respondent B is ‘moderate’ and it also applies to universities. This means that both respondent A and B reply that universities are their *most important information source*, although they each use a different point on the subjective scale.

Analyses of the most important information sources (or the least important) can provide valuable results that are unaffected by inter-respondent variability. It does not matter if respondent B has in mind an importance scale that is identical to that used by respondent A, or not. We can still determine the percentage of respondents that find universities to be their most important source and compare this percentage to other sources. Comparing these results with the percentage of respondents that reply that a source is ‘very’ or ‘crucially’ important is also a good test of the robustness of the subjective responses.

The reliability of results based on the ‘most important’ response declines with the number of sub-questions. For example, CIS-1 contains questions for 13 information sources. This means that there will be several ties, or more than one source that receives the highest score given by the respondent. Ties can be easily divided in the calculation of the percentage of respondents that state that a given source is the most important, but the results decline in reliability as the number of ties increases. The probability of multiple ties is inversely proportional to the number of points on the scale. For this reason, a three-point scale is less useful for calculating the percentage of ‘most important’ responses than a five or seven point scale. On the other hand, a seven-point scale could prevent ties when there is actually very little difference in the importance of two information sources. The final choice of the number of points to use is subjective, but a four or five-point scale is probably better than a three-point scale.

A.1.2.3 Continuous Measurement Scales

Many factors, such as patents, expenditures on different types of activities, or the percentage of products that have been significantly changed in the past three years, can be measured on an interval or percentage scale. The fact that something can be measured on a continuous scale does not, however, mean that the respondents are capable of fully using such a scale. For example, most respondents reply to a percentage scale by giving answers that are rounded off to 5%. This can be clearly illustrated by using the results of the PACE survey, which asked the respondents to estimate the percentage of their R&D personnel's time that is spent on five different activities, including 'developing new or improved processes' and 'developing new or improved products'. Results are available for 671 firms. Of these, 87.3% filled in a percentage ending in 5% or 10% (i.e. 25% or 30%) for process innovations and 85.8% used a 5% or 10% category for product innovations. This is over four times the expected percentage.

Results such as these show that continuous measurement scales are not necessarily more reliable than a well-defined ordinal scale. At the same time, a continuous scale could place a much greater burden on the respondent and lead to a low item response. It is therefore worthwhile to give careful consideration to the use of continuous scales and the alternative option of using categories. For instance, a categorical scale for expenditures could use categories such as zero currency units, 1 to 1,000 units, 1000 to 5,000 units, etc.

The major difficulty with using categories is determining the category dimensions, which will depend both on the question and on the types of respondents. As an example, a question on the number of patent applications should use different category boundaries for small firms than for large firms because small firms apply for far fewer patents than large firms. These categories can be designed so that they can map onto each other, as shown in Figure A.1. These categories permit analyses for both small and large firms combined using three categories: 0 patents, 1 - 25, and over 25.

Figure A.1: Category dimensions

Number of employees	**Categories for the number of patent applications**				
less than 500 employees	0	1 - 5	5 -10	11 - 25	> 25
More than 500 employees	0	1 - 25	26 - 50	51 - 100	> 100

Different category boundaries, although rarely used in innovation surveys, are feasible if Computer Assisted Telephone Interview (CATI) techniques are used or if computer-customised questionnaire printing and mailing techniques are available.

A.1.2.4 Linking Subjective Questions to Objective Criteria

All subjective questions introduce problems of comparability between respondents, although these can partly be overcome through analytical techniques such as calculating the percentage of respondents that give their most important rating to a specific sub-question. Nevertheless, the goal of good questionnaire design is to replace subjective questions with objective anchors. This is not always successful for two reasons. First, solving the problem by replacing an ordinal scale with a nominal scale can result in an unacceptable loss of information. Second, many questions of interest are fundamentally based on the respondent's subjective evaluation. Under these conditions, many of the available techniques for anchoring a question can simply replace one type of subjectivity with another.

The nominal shift: The simplest technique for avoiding subjectivity is to replace an ordinal scale on the importance of a factor with a nominal, yes or no scale. This technique was used by Statistics Canada for many of the CIS-1 questions, including the questions on impediments to innovation. Statistics Canada asked firms to check any of a list of eight factors with 'particular significance to your firm as impediments to your innovation programme'. Conversely, CIS-1 asked the respondents to evaluate, using a five-point scale, the 'relative importance' of a list of 'barriers to innovative success'.

There are two main disadvantages of a nominal scale. The first, which has been discussed above, is that it may not provide very useful information if most firms check a specific factor. Second, a nominal scale conveys no information on the relative importance of a group of sub-questions.

Both of these problems can be partly solved using two techniques. First, the main question can be divided into two questions that provides more detailed information. This both decreases the percentage of firms that check a specific category and obtains more useful information. Second, the question can ask about the most (or least) important factor. An example is given in Figure A.2. The solution is not perfect, particularly for common factors. The example given in Figure A.2 is more likely to succeed because it applies to a specialised use of information sources - those of value to environmental innovation.

Figure A.2: Information sources (1)

What are the principal information sources used by your firm to learn about environmental problems and their technical solutions? (Please check all that apply)

	Problems	Technical Solutions
A. Your firm's R&D department	☐	☐
B. Your firm's production department	☐	☐
C. An affiliated firm (parent firm, etc)	☐	☐
D. Universities	☐	☐

Which was the most important source for learning about environmental problems? ....
Which was the most important source for technical solutions? ....

The advantage of the nominal format in giving a clear yes or no answer can also be incorporated into an ordinal, subjective format. This is shown in Figure A.3, where the question 'not used' is added[32]. This solves uncertainty over the meaning of a 'not important' response: is a factor not important because it has been tried and found wanting or is it not important because it has never been tried?

Figure A.3: Information sources (2)

How important are the following information sources to your firm's innovation projects?

		Importance if used		
	Not used	**Slight**	**moderate**	**very**
Competitors	☐	☐	☐	☐
Universities	☐	☐	☐	☐

Anchoring a subjective question: The other alternative is to replace a subjective ordinal scale with an objective scale. Several examples are given in Figure A.4. The first question uses a standard subjective format, with the respondent given five response options varying from 'not important' to 'extremely important'. The second and third questions are rephrased to anchor the responses to an objective criteria - time frequency in question two and innovation projects in question three. The importance of universities will clearly increase with the frequency of use or with the percentage of innovation projects that use information obtained from this source.

Figure A.4: Information sources (3)

1. How important are universities as an information source for your firm's innovative activities?

Not important	slightly important	moderately important	very important	extremely important
❑	❑	❑	❑	❑

2. How often does your firm obtain information from universities for your firm's innovative activities?

Rarely or never	semi-yearly	monthly	weekly	daily
❑	❑	❑	❑	❑

3. What percentage of your firm's innovation projects use information obtained from universities?

below 10%	10 - 40%	41 - 60%	61 - 90%	over 90%
❑	❑	❑	❑	❑

[32] This technique was suggested by the IDEA group and incorporated into CIS-2.

These methods of anchoring subjective questions still have drawbacks. The most important is that we do not know if there is a significant gain in accuracy or understanding from replacing the first question format with the second or third. This is because the increase in the precision of the response can be counter-balanced by a loss of information. For example, over 90% of a firm's innovation projects could use information from universities, but the remaining 10% of projects could be of vital importance. Not all projects are of equal value. The same respondent might have replied 'slightly important' if given the first question format.

The choice of a subjective or anchored format depends on conditions (do we believe that respondents know how many innovation projects they have?) and the pros and cons of more precise information versus a loss of generality. In some cases a subjective format could be more useful, particularly when it is combined with a nominal component, as in Figure A.3.

A.1.3 Questionnaire Structure

Considerable thought must be given to the overall structure of the questionnaire. The goals are to maximise the questionnaire response rate and the amount of information obtained, and to provide handles that can indirectly link the results to other data sources. In addition, several features of the questionnaire structure, such as the placement order of questions, can influence the results.

A.1.3.1 Questionnaire Length

There is extensive debate over the length of a questionnaire. This issue risks turning into a fetish, with considerable effort put into reducing length at almost all costs. The danger is that concern over length can considerably reduce the value of the results, which will waste more human effort than a longer questionnaire. There is no point asking firm managers to reply to a questionnaire if essential questions are missing or if the questions are not fully explained in order to save space.

Experience with *voluntary* questionnaires shows that response rates of 80% or higher are achievable with short, one or two page questionnaires that are faxed to the recipient. However, this option is only feasible for specialised innovation surveys. General innovation surveys, such as CIS or PACE require longer questionnaires. The question is how long can a questionnaire be before the response rate drops precipitously?

The answer to this question is that the response rate does not decline monotonically with the length of a questionnaire. Instead, there is a rapid drop-off as the number of pages increases from one to between four and six pages, followed by a long, slow decline afterwards. This means that there is very little difference in the expected response rate for an eight versus 10 or 12 page questionnaire. Once the threshold of four to six pages is passed, an attractive layout and well-designed questions will probably have a greater effect on response rates than the number of pages. In addition, the problem for longer questionnaires, once the respondent has decided to reply, lies more with respondent fatigue and a decline in the quality of responses. This emphasises, again, the importance of well-designed questions.

A.1.3.2 Maximising the Amount of Information Obtained

All innovation surveys have a ‘target’ audience of innovative firms for which the questionnaire is most relevant. Firms that are not within the target audience are often immediately excluded through filter questions. This is unfortunate. Innovation surveys should try to maximise the amount of information obtained from non-target firms. Even though many of the answers from non-target firms could consist of ‘no’ or ‘not relevant’ responses, these results are still useful. They provide a clear picture of the activities of non-target firms and could also uncover some activities of relevance among this group.

The questionnaire for environmental technologies (see the companion report) adopts this approach. The goal is to obtain as much information as possible about non-target firms that do not use environmental technologies. For this reason, filter questions are delayed as long as possible until the second half of the questionnaire.

A.1.3.3 Provide Links to Other Data Sources

The ability to interpret indicators obtained from surveys can be increased by providing links to other data sources. For example, a simple yes or no question on whether or not a firm applied for a patent can permit comparisons between analyses of patent data in a specific sector and survey data, although the comparisons will only be possible at the sector level.

A.1.3.4 Logical Question Order

Questions should be grouped in a logical sequence. This is a well-understood principle that is rarely a problem in questionnaire design. More problems develop from question order, which can influence the results. For example, there is a small bias towards giving higher importance scores to the first sub-question in a question group than to the following questions. It may be worthwhile to place sub-questions with an expected high score in the middle or end of a series of sub-questions.

Many questionnaires are designed to place difficult or confidential questions at the end in order not to discourage the respondent, which could reduce questionnaire response rates. This could be a worthwhile strategy for confidential questions, but a better tactic for difficult questions is to redesign them to reduce their difficulty.

A.1.3.5 Number of Sub-questions

Some research suggests that the answers to subjective questions suffer from respondent fatigue when there are large number of sub-questions, as shown by an increase in item non-response and by decreasing scores. One option is to reset the respondent's 'subjective importance metre' back to zero by dividing a long list of sub-questions into two or more main questions, each with a shorter number of sub-questions. The decision of where to divide the question depends on logical groupings and policy or other needs.

A.2 Guidelines For Questionnaire Evaluation

The guidelines given above are used in the initial design of a questionnaire. Once drafted, the questionnaire needs to undergo an ongoing evaluation process, both before and after the survey, to uncover additional errors. The evaluation should proceed through three stages that use three different types of information:

1. The first stage is based on a careful evaluation of the draft questionnaire to look for logical errors, repetitive questions, and other flaws. This should occur before the survey is implemented. Basic errors can also be discovered through a pilot survey.
2. The second stage is based on response analyses of the results of a completed pilot or full survey. The purpose is to detect questions with very poor item response rates or which provide very little information.
3. The third stage, which is the most difficult, is based on identifying relevant results from analyses of the data. These analyses can identify problems such as missing questions that were not foreseeable during the development of the questionnaire.

A.2.1 Questionnaire Evaluation

Each questionnaire needs to be checked to identify logical inconsistencies, repeats of the same question in a slightly different form or overlap between questions, multiple queries within one question, ambiguity, and omissions.

A.2.1.1 Logical Inconsistencies

These are among the most difficult errors to identify. A real example from an otherwise excellent survey outside of Europe is shown in Figure A.5.

Figure A.5: Question logic

What was your firm's domestic and world-wide sales in 1996:

		Don't Know
Domestic	______________________	❑
World-wide	______________________	❑

At first sight, this appears to be a well-designed question that also includes the category 'Don't Know'. The problem was not discovered until some of the early responses were checked. The total for 'world-wide' was interpreted by some firms as including domestic sales and by other firms as *excluding* domestic sales. The question was not logically consistent, with both interpretations being equally valid.

Correcting this error required expensive telephone calls to all of the respondents to clarify the meaning of their answers.

A.2.1.2 Repeating or Overlapping Questions

This is a common problem that occurs when multiple sub-questions are used. Two or more questions can ask about the same thing in a slightly different way, or there can be considerable overlap between them. Although this is not a serious error, it wastes the respondents' time and adds no new information. A real example is from a question that contained 21 sub-questions on barriers to the acquisition of a specific technology. Two consecutive questions asked about the importance of 'internal resistance to the technology' and 'worker resistance'. The latter is either a sub-class of the former or identical to it, depending on the definition of a 'worker'.

A.2.1.3 Multiple Queries Within One Question

Questionnaire design usually involves a trade-off between length and accuracy. In the interests of keeping a questionnaire short, there is a strong incentive to combine factors that appear to be related. This can result in meaningless results if the factors are not related or considerably reduce the value of the responses if each of the combined factors is of real interest.

A good example is one of the sub-questions on the barriers to innovation in CIS-1. The sub-question asks the respondents to evaluate the importance of 'legislation, norms, regulations, standards, taxation'. This question makes both mistakes - it combines unrelated factors and combines several factors of real interest. The factors are unrelated because they can have opposite effects on innovation - each factor can have either positive or negative effects, depending on the circumstances. Furthermore, since all five of these factors are set by government (which is the only thing that they have in common), they can be directly influenced by policy. This suggests that each is of real interest and deserves a separate question.

A.2.1.4 Ambiguity

Ambiguity in the meaning of a question is perhaps the most serious problem for question design. Some questions which are immediately understandable to the designer of the questionnaire, or to economists, may be confusing to the respondents. Other questions contain ambiguity because of the difficulty in finding a non-ambiguous version of phrasing the question. An example of the former is the use of terms such as 'mother', 'daughter' or 'sister' enterprises. An example of the latter is the use of the phrase 'significant innovation', where the meaning of 'significant' is left undefined.

A.2.1.5 Omissions

Sometimes very useful questions are simply omitted through oversight. An example from CIS-1 is the absence of a question on whether or not the firm applied for a patent. The PACE questionnaire omitted a question on the number of employees.

Some oversights can be discovered by writing dummy computer programmes to analyse the data, but this is rarely done before the survey is implemented because of the amount of time required.

A.2.2 Response Analyses[33]

Three simple analyses of survey responses can provide useful information for the design of innovation indicator questions.

A.2.2.1 Item Non-response Rates

Calculating item non-response rates (the percentage of respondents that do not answer a question) provides useful information on the willingness of respondents to answer each question. There are several causes of low item response rates. Each cause suggests different solutions, all of which can improve the quality of the innovation indicator.

1. *The question asks for information that the respondent can only provide with difficulty.* This often occurs for questions using a continuous measurement scale, such as the number of employees working with a specific technology or the amount spent on purchasing licenses. There are two possible solutions. The first is to send the question to someone in the firm who is most likely to know the answer. Unfortunately, this solution can increase costs if multiple respondents within the firm are required and it can decrease response rates if the same questionnaire is sent to different people within the same firm, which increases the probability that the questionnaire will be lost to follow-up or 'forgotten'[34]. The second solution is to provide response categories, as described above, rather than using a continuous scale. Complex subjective questions can also suffer from this problem. For example, the PACE survey contains a simple question that asks about the importance of six information sources and a complex version of the same question that asks the respondent to assess the importance of each source in four regions. The listwise response rate for the simple version (the percentage of respondents who answered all sub-questions in the group) is 95.9%. In contrast, the listwise response rate for the complex version falls to 82%.
2. *The question is confusingly written or unclear.* This requires a rewrite of the question. Unfortunately, many respondents will take a guess at a poorly-constructed question. Problems might only show up during data analysis, such as during a check for logical inconsistencies (see below).

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[33] There are two different types of non-response analyses. The first concerns the reasons why respondents did not reply to the questionnaire at all (questionnaire non-response). The second concerns the reasons why a respondent did not reply to a specific question (item non-response). Both types of analysis are necessary, but this report focuses on item non-response because it is more important to the design of innovation indicators.

[34] The PACE survey included an analysis of the causes of questionnaire non-response. Passing the questionnaire to someone else in the firm was the cause of 17.4% of these non-responses (Arundel *et al*, 1995).

3. *The question is of no interest to the respondent.* This is a more serious problem for the questionnaire response rate than for item response rates. A large number of questions without any relevance to the respondent is likely to reduce the probability that the respondent replies at all to the survey. The best solution is to ensure that the questionnaire starts with questions that are applicable and of interest to all respondents. Preferably, almost all questions should be written in way that they can be answered by the vast majority of respondents. Another solution is to refine the selection of the respondents, so that firms that are not relevant to the survey are not included in the sample frame.

4. *The question asks for confidential information that the respondent is reluctant to provide.* The best solution to this problem is to use categories for continuous data, as described above in section 1.2.3.

What counts as a 'low response' rate depends on the question type. As a rule of thumb, item response rates for ordinal and nominal questions should exceed 90% and average 95% or higher. Item response rates for questions that ask for continuous information, such as the amount spent on R&D, should exceed 75% in a voluntary questionnaire.

A.2.2.2 Question Reliability

The reliability of some questions can be checked against independent sources. For example, the PACE survey asked respondent's if their business unit was independent or part of a larger firm. A check for reliability, using published information about the unit, showed that the question completely failed to provide dependable information. Half of all respondents for foreign subsidiaries incorrectly stated that their unit was an independent firm.

A.2.2.3 Check for Logical Inconsistencies

Questionnaires usually contain opportunities for internal checks for logically inconsistent answers. The results can be used to suggest changes to the design of specific questions. An example is from the PACE survey. One question asked respondents about the importance of seven methods for learning about research conducted in public research institutes while another question asked if the firm obtained the results of public research in four regions using each of these seven methods. Firms that reply that a method is 'very' or 'extremely' important should also reply that they obtained results from at least one region using this method. In general, the percentage of logically inconsistent results (method very important but no results obtained using the method) is low, ranging from 1.3% to 7.7% of the responses, with one exception. A logically inconsistent rate of 21.1% was found for 'temporary personnel exchanges'. This high rate suggests that this method is poorly understood by the respondents - or that they are used for something other than obtaining research results.

A.2.3 Intensive Data Analysis

Many problems with innovation indicators cannot be identified without intensive analysis of the data. An analysis of the CIS-1 data on barriers to innovation, for example, showed that the questions could have been measuring the state of concern or anxiety over a barrier, and not the real effect of each barrier (Arundel, 1997b). Another intensive analysis project on the importance of patent disclosures was hampered by the failure of CIS-1 to ask if the firm had applied for a patent (Arundel & Steinmueller, 1998).

A third CIS analysis project on the importance of licensing-in technology had to be abandoned because of a fatal ambiguity in one of the CIS questions. The relevant question asks the respondent to 'estimate the percentage share of total current innovation expenditures' attributable to the 'acquisition of patents and licenses'. The analysis of this question produced several peculiar results. The cause was traced back to the question itself. The intent of the question was to ask respondents how much their firm spent on acquiring the rights to *outside* patents and licenses. However, an unknown percentage of the respondents also interpreted the question to refer to how much their firm spent on patenting their own, *in-house* inventions. This problem made the question useless as a measure of license flows. The ambiguity in the meaning of this question was neither obvious nor detectable until the detailed analyses.

Such experience with data analysis needs to be assembled and used to identify poorly formulated questions, missing questions, and questions that provide little useful information. Many similar problems were identified by the various institutes that analysed the CIS-1 data, but there was no systematic method to assemble information on these problems. Fortunately, the tenders for the analysis of CIS-2 have built-in a request for critical evaluations of the CIS-2 indicators.

A.3 CONCLUSIONS

Good questionnaire design is essential to the goal of obtaining reliable innovation indicators through surveys of firms. This requires a continuous, interactive process between the design of innovation indicators and the analysis of survey data. Examples of this process are given in Appendix C, which discusses the IDEA group's contribution to the design of the CIS-2 questionnaire.

APPENDIX B

SAMPLING METHODOLOGIES FOR INNOVATION SURVEYS

Innovation surveys must be able to obtain comparable data from very dissimilar firms. The variation among firms along several variables can create enormous difficulties for surveys. These include:

- The enormous variation by size, measured by sales or the number of employees.
- The range of activities. Some large firms such as Siemens are active in more than three industries, defined at the two-digit NACE level.
- The number and types of sites where innovation can occur. In some firms all innovative activities are concentrated at the head office, while in other firms different types of innovative activities occur in a range of locations, such as at central R&D laboratories, production sites, diversified and specialised research facilities, etc.
- Differences in who is responsible for specific management functions.

In the ideal firm, all relevant functions are located in the same place, one person is responsible for all relevant management activities, and the firm is only involved in one, narrowly-defined manufacturing or service activity. Most small firms with less than 50 employees meet these ideal requirements. In contrast, the amount of deviation from the ideal increases as the firm becomes larger.

Many surveys, including the CIS in several European countries, collect data at the enterprise level, which is the smallest legally-incorporated entity. Although this is appropriate for small firms, it reduces the ability to collect accurate information on the innovative activities of large firms that are divided into several divisions or which have multiple establishments.

The current focus on sampling at the enterprise level has its roots, as with many indicators, in the activities of large R&D performing firm with a centralised R&D laboratory. This model does not suit current conceptions of innovation, where innovative activity can occur at many levels within the firm and involve both diffusion and creative effort. We are unlikely to obtain suitable indicator data without better sampling techniques for large firms. This issue is therefore crucial to the design of innovation indicators.

B.1 SAMPLING TECHNIQUES FOR LARGE FIRMS

It would be of great value to have a better understanding of the relationship between firm size and 1) the proportion of firms that have more than one establishment and 2) the proportion of firms that are active in more than one sector. This information could be used to determine the cut-off point for sampling at the enterprise level versus at a more detailed level within the firm. Given current knowledge, this point probably occurs somewhere between 500 and 1,000 employees, although it could fall as low as 200 in some countries or in some sectors.

Adequate coverage of large firms is essential since they account for a large proportion of creative innovation by European firms. For example, in 1991, the 12 largest industrial firms in the UK accounted for 44% of all business expenditures on R&D (BERD) in the UK and industrial firms with sales over one billion ECUs accounted for a minimum estimate of more than 77% of all UK BERD. The situation in France is similar. Data from INSEE show that 75 firms account for over 80% of all BERD in France.

This concentration of R&D among very large firms means that a clear picture of innovation in Europe cannot be obtained without capturing the innovative activities of these firms[35]. This creates a problem for survey design, since the organisation of innovation by large firms is very complex. Not only do these firms span several sectors, but they organise their R&D in a number of different ways. Some maintain central R&D laboratories that are active in many different product lines, while others have decentralised their R&D by business line. This makes it difficult to develop a sampling strategy that can adequately cover the innovative activities of large firms.

In practice, the requirement of CIS-1 to survey at the enterprise level creates further complications, because it means that firms that have set up separate legally-defined divisions (for example, the Daimler-Benz group) will be sampled several times, while other firms with divisions that are not legally separate (for example Philips) will be sampled only once[36].

[35] Of course, R&D spending does not capture all innovative activities and many SMEs without formal R&D expenditures can also innovate. Yet, without evidence to the contrary, we suspect that the types of innovations developed by firms that do not conduct R&D involve less creative effort than those developed by firms that do conduct R&D. The innovative activities of non-R&D performers could be more oriented to minor, incremental product and process innovations or focused on diffusion issues - such as the adaptation of innovations developed elsewhere. Though these activities are essential and need to be captured by innovation indicators, the source of most major and minor innovations is likely to be concentrated in firms that perform R&D.

[36] The sampling method for large firms in CIS-1 varied by country. The CIS survey in Germany sampled at the division level for very large firms, while France stuck to the enterprise rule. Renault was apparently sent only two questionnaires, because the truck division had been set-up as a different legal entity, but the many other R&D divisions of Renault did not receive questionnaires.

Possibly the best method for surveying the innovative activities of large firms is to attempt to sample at the line of business or product level. Firms such as Siemens, Unilever, and Philips, to take only a few examples, have over 10 lines of business each. This conflicts with the design of CIS-1 to survey at the enterprise level, which means that only separate, legally incorporated firms can be surveyed.

B.1.1 Basic Sampling Requirements

A solution for sampling large firms should meet the following two goals:

1. Capture the full range of innovation activities, including diffusion and creative effort.
2. Obtain information, at the minimum, for each two-digit sector of activity for the firm.

A failure to meet the first goal will result in poor comparability between large and small firms. For example, sending one questionnaire to the R&D manager of a large firm will result in an emphasis on innovation as creative effort, even if many of the firm's divisions expend more effort on innovation as diffusion. A failure to meet the second goal will result in errors in sector-level analyses for all sectors where the firm is active. For example, assume that a firm is active in two sectors, A and B, but that the firm is classified by the survey as only active in B. The results for sector A will be distorted by the failure to include this firm, while the results for sector B will be distorted by including activities that only belong to sector A.

Another powerful reason to sample at the division or plant level in large firms is due to the link between the collection of indicator data and its interpretation. As noted in the *Guide*, indicators are not neutral. Their structure can influence both our understanding of innovation and the policy response. Many innovation surveys have found that innovative capabilities or strategies, such as the use of external information sources, increases with firm size[37]. Yet, is this effect simply due to the fact that large firms have more employees, which increases the number of opportunities to innovate or to use external information sources? We don't know. It could be that the divisions of large firms behave very similarly to independent firms of the same size. If true, this would mean that the techniques that we use to collect innovation indicators are distorting our understanding of the innovation process.

None of the innovation surveys to date meet both of the two goals given above. For example, Table B.1 summarises the sampling method, advantages, and disadvantages of four innovation surveys that used different sampling techniques. The CIS emphasis on

[37] These include the PACE survey (Arundel et al, 1995), analyses of CIS-1 (see the collection of studies in Arundel and Garrelfs, 1997), a British survey of SMEs (Cosh *et al*, 1997) and a recent French survey on innovation capabilities (Francois, 1998).

sampling at the enterprise level is the least successful technique for sampling large firms, but each of the other surveys suffers from disadvantages.

There are two main drawbacks to the alternative survey methods summarised in Table B.1. First, sampling R&D performing divisions, as in the PACE and CMS surveys will be less likely to capture good data on innovation as diffusion. Second, the techniques used by PACE and Statistics Canada to sample multiple divisions in the same firm often fail because the firm refuses to complete multiple questionnaires. In PACE, this problem was most severe for firms that centralised their different R&D activities in the same location.

Table B.1: Review of Survey Sampling Methods for Large Firms

Survey	Sampling method	Advantages	Disadvantages
CIS-1	Large firms sampled at the enterprise level	Simple sample design, adequate for small firms	Does not meet either of goals 1 or 2
PACE	Large R&D performing firms sampled at the R&D division level. Information on R&D divisions obtained from annual reports and telephone calls to the firms. The number of R&D units surveyed increased with the size of the firm.	Obtains results for different sectors of activity	Focus on R&D performers limits the study to creative innovation. Less likely to obtain multiple responses from firms that centralise their different R&D activities in one location.
Statistics Canada[1]	Samples at the level of the site of activity, which includes individual manufacturing plants and head offices	Permits excellent coverage of innovation as diffusion and obtains results for different sectors of activity	Many firms object to completing a questionnaire for each location and provide only one blended response which serves for all locations Generalised questionnaires may not be appropriate for many locations
Carnegie Mellon Survey	Used the DART list of R&D laboratories to sample all research laboratories of multi-sector firms[2].	Provides good coverage at the sector level and of creative innovation.	Success depends on the accuracy of the source list. Focus on R&D performers limits the study to creative innovation.

[1]. Survey of biotechnology use.

[2]. Similar lists are available for Europe, such as the 1997 Bowker-Saur *European R&D Database*, although there is some concern that this database misses a high percentage of R&D laboratories.

B.1.2 Proposed Sampling Methodology for Large Firms

The experience gained from the four surveys listed in Table B.1 suggests a composite sampling strategy for large firms. This strategy is not perfect, but it should improve on the CIS methodology. Its success would also be improved by using different questionnaires (or at least some different question groups) for divisions that largely innovate through diffusion.

The main requirement is to sample at the division level for both R&D laboratories and manufacturing plants. Both should be included to obtain complete coverage of the range of both diffusion and creative innovative activities. Information on each firm's divisions can either be obtained from a central statistical office (if this type of information is available, as in Canada), or from alternative sources. The latter include the Bowker-Saur *European R&D Database* and the annual reports of the firms, which usually list all product divisions and major subsidiaries.

An objection to this approach is the expense of trawling through annual reports and other sources to look for divisions. This is definitely more expensive than sending one questionnaire to the head office. But, the expense should be kept in perspective. The CIS already samples a large fraction of small firms, many of which scarcely innovate. In contrast, many of the divisions of large firms far exceed the size of small firms and many of these divisions are active innovators. The problem is that we think of these divisions as minor parts of a much larger firm, when we should view them as semi-independent innovators with their own strategies and problems.

There are several options to overcoming a refusal, on the part of the firm, to provide multiple responses. One option is greater customisation of questionnaires. Another option is to sample manufacturing plants or R&D laboratories. The disadvantage of a sample is that it could miss very important R&D laboratories. A sample is probably best suited to manufacturing plants, while surveys of R&D laboratories should include all labs in different geographical locations.

B.2 Minimum Firm Size

The minimum firm size to include in an innovation survey presents few problems, although it has attracted more discussion among CIS researchers than the problems with large firms. The debate over the minimum firm size to include in an innovation survey ranges between a lower cut-off of 1 employee to a higher cut-off of 20 employees. Somewhere between 10 and 20 employees is probably the optimum. The disadvantage of surveying smaller firms is that it increases the survey costs by including a large number of very small firms, many of which will not innovate. They are also less likely to reply to the questionnaire than larger firms.

B.3 Conclusions

The failure of many innovation surveys to sample large firms at the level of the division, R&D laboratory, or manufacturing plant could have severe consequences for our understanding of innovation. This, in turn, could lead to innappropriate policy responses. Techniques for sampling large firms are available, although they are more complex and expensive than the methods used to sample small firms. Also, a period of experimentation with how to best survey large firms will probably be required. However, the pay-offs in terms of a better understanding of innovation are potentially huge.

APPENDIX C

FROM CIS-1 TO CIS-2: PROBLEMS AND PROGRESS

The Community Innovation Survey (CIS) provides a good example of the difficulties and problems that are encountered in the development of innovation indicators. The CIS has suffered from two sets of problems: the design of the sampling methodology and the design of the survey questions. Sampling methodology issues are discussed in Appendix B. This Appendix is limited to a brief discussion of the problems with the CIS-1 questionnaire, followed by a more extensive review of the rationale behind the revisions to the questionnaire for CIS-2, including the role of the IDEA Group in these changes. The final section discusses possible remaining problems with CIS-2.

C.1 PROBLEMS WITH CIS-1

CIS-1 developed out of experience with innovation surveys in the United States and in the Nordic countries. It was also a cooperative effort based on contributions from a large number of academics and institutions such as Eurostat of the European Commission and the OECD. These experts developed a standard version of the CIS questionnaire[38].

The CIS-1 questionnaire has been criticised for poor question design, low item response rates, and unreliable results. Although these criticisms are valid for some of the CIS questions, such as question 13 on total current expenditures on innovation or question 14 on product life cycles, the results for many other questions have been of great value and have produced useful results for innovation policy. This needs to be kept firmly in mind in a review of the problems with CIS-1.

CIS-1 contains three core questions that have been retained in CIS-2:

1. A set of filter questions that separate innovative from non-innovative firms.
2. Expenditures on six innovative activities in addition to R&D.
3. The percentage of sales due to innovative products.

[38] For political expediency, each participating government was responsible for implementing the CIS in their own country. One result was that national organisations or statistical agencies altered the standard questionnaire to meet their own requirements and each country was free to use a different lay-out. The following types of changes to the standard CIS questionnaire were made by one or more of the participants: deletion of standard sub-questions within a question group, addition of questions to the question group, deletion of entire question groups, addition of new question groups, changes to the measurement scale (i.e. from an ordinal to nominal scale), and minor changes to the wording of some of the questions. The combination of differences in lay-out and differences in the questionnaire reduce the comparability of the responses from the first CIS. In some cases, even minor differences such as a change in lay-out or a change in scale can have substantial effects on the comparability of the results. Nevertheless, this discussion of the CIS is limited to the standard CIS questionnaire released by Eurostat.

There are problems with the first two of these three key questions. In addition, there are six general problems with CIS-1:

1. CIS-1 is too long and some of the key questions are difficult to answer. This could be one factor in the low questionnaire response rates in countries, such as Germany, where completion of the questionnaire was voluntary.
2. Some questions do not meet the criteria for good design, as given in Appendix A[39].
3. Interpretation of a 'not important' response is ambiguous. It could mean that the firm has no experience with the factor or that it tried the factor and found it to be of no importance.
4. Several of the questions are very difficult[40], which reduces the confidence which can be placed in the results.
5. Useful questions, such as on the firm's patenting activity, are missing.
6. The results for some of the subjective five-point questions hover around the mean of 'moderately important' or have a very low variance and skewness. This suggests that the question is unable to differentiate between different types of firms and adds little new information.

Point six above is most serious for the group of questions on the objectives of innovation. The average absolute value of the skewness for these 18 questions is 0.72, compared to 0.85 for the 13 questions on information sources. There is also less variation in the means for the 18 objective questions than for the 13 information source questions. Analyses showed that many innovation goals are considered of importance by a high proportion of all firms. For instance, 85% of the CIS respondents stated that increasing market share was a 'very' or 'crucial' goal of innovation. The popularity of several of the objectives suggests that the question is measuring the firm's general business goals rather than its innovation goals alone (Arundel, 1997).

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[39] To start, the key question which defines an innovative firm leaves too much of the definition of an innovator to the discretion of the respondent. These problems are discussed at length in Chapter Five. Another example is the question on whether the firm transferred out any new technologies through the 'mobility of skilled employees'. This is ambiguous because such mobility could be intentional (i.e. sending an employee on a temporary assignment to a subsidiary or cooperative partner) or undesirable, as when a skilled employee leaves to take up employment with another firm. Question 6 asks if the firm acquired new technology via 'communication with specialist services from other enterprises' and question 7 asks if the firm transferred technology via 'communication with other enterprises'. The meaning of both of these questions is a puzzle.

[40] Examples are question 10.c which asks for the percentage of R&D expenditures related to product and process innovation, question 13 which asks for an estimate of total innovation expenditures (not just R&D), including a breakdown among six activities; and question 14 on the distribution of sales by product life-cycle stage. Questions 6 and 7 on the acquisition and transfer of technology provide a matrix for six regions, which is too many.

Table C.1 lists further examples of CIS-1 subjective questions (all using a five-point ordinal scale) for information sources and barriers to innovation that provide little information on differences between firms. Either a very low or very high percentage of firms that find a factor of importance is not necessarily a problem. It only becomes a problem *if* there are no firm characteristics that are linked to the exceptions. For example, the majority of firms do not find patent disclosures to be an important information source, but there is very strong relationship between the importance of patent disclosure and firm size. For this and other reasons, the question on patent disclosure provides useful information.

Table C.1. CIS-1 Information and barrier questions with a low information content

Question	Problem	Possible Advantages
Information sources		
4.3 material suppliers 4.4 equipment suppliers	Close to normal distribution in responses, little difference between the two questions	Identifies the importance of this source, but the two versions can be combined
4.7 consultants	Low mean and variance, very few firms find this source of importance	Importance could increase over time, some exceptions
Barriers to innovation (innovators only)		
12.6 Lack of skilled personnel	Low variance and skewness, very few cite as important	Information on skilled personnel is of great importance to policy. Merits further refinement
12.10 Resistance to change in enterprise	Very few firms give a high rating to this barrier	
12.13 Lack technological opportunity	Very few firms give a high rating to this barrier	

C.2. DEVELOPMENT OF CIS-2

A series of meetings and calls for comments between October 1996 and January 1997 led to the CIS-2 questionnaire. The major goal of the experts involved in developing CIS-2 was to make the questionnaire much easier to answer in a bid to improve response rates and international comparability. To meet this goal, the questionnaire was shortened and specific questions were made easier to answer.

The IDEA group received a copy of each of the several suggested revisions of CIS-2, beginning in October, 1996. The IDEA group submitted several comments and suggestions for a revised CIS over these months[41]. This section outlines some of the major problems with these revisions that were identified by the IDEA group and submitted to Eurostat (the agency responsible for coordinating the development process). Some of the suggestions made by IDEA were incorporated, in part, into

CIS-2[42]. Other suggestions were not accepted. The following overview of the comments made by IDEA focus on problems that have not been fully resolved or which are crucial to good questionnaire design.

C.2.1 The First Key Question: Innovation as Diffusion or Creative Effort

Both CIS-1 and CIS-2 closely follow the Oslo Manuals; the 1992 edition for CIS-1 and the revised edition for CIS-2. The Oslo Manuals provide both a theoretical and practical basis for new innovation indicators. One of their main strengths is an emphasis on innovation as diffusion. This contrasts with the theoretical basis for traditional indicators such as patents or R&D expenditures, which focus on innovation as a creative, inventive activity.

CIS-1 defined an innovative firm as one that ‘developed or introduced any technologically changed products’ (or processes) during 1990 to 1992. The October, 1996 version of CIS-2 followed the revised Oslo Manual in defining an innovative firm as one that ‘introduced any technologically new or improved product (or process) on the market’ between 1994 and 1996.

The main change is that CIS-1 includes ‘developed’, which suggests creative effort, while the revised version only refers to ‘introduced’. The emphasis therefore changes from creative effort to diffusion activities that could require no intellectual effort or non-obvious thought (and learning) on the part of the firm.

The result is an unsatisfactory emphasis on innovation as diffusion. This can be traced back to the revised Oslo Manual. For example, page 41 of the revised manual states that a textile firm that introduces a new anorak with a "lining with improved characteristics" is innovating. This is fine as long as it is recognised that this is innovation *as diffusion*, because no intellectual effort whatsoever is required of the textile firm to replace one lining fabric with another. Similarly, a computer assembler that replaces a hard disk with a faster one with more memory, both of which are manufactured as a complete unit by a supplier firm, is innovating through diffusion but not through creative effort.

There is no argument here with the importance of both innovation as diffusion and innovation as creative effort. However, these two aspects of the innovative process can refer to very different types of activities and be undertaken by very different types of firms. In addition, at the same time that both CIS-1 and the first version of CIS-2 use a definition of an innovative firm that includes diffusion, both CIS questionnaires are *heavily weighted toward innovation as creative activity*. Very few of the questions are

[41] Major submissions were made on October 14, 1996; October 16, 1996; November 21, 1996, December 4, 1996; December 22, 1996 (via the Dutch representative, Niels Lanoy); and January 21, 1997.

[42] The IDEA group does not claim that its suggestions led, on their own, to any specific changes. A large number of experts were involved in developing CIS-2 and many of them made similar comments as the IDEA group.

relevant to a diffusion-based innovator. We can look at this problem through an evaluation of how three hypothetical firms would interpret the questionnaire.

Firm A manufactures and markets in Europe a new product that it obtained from its American parent firm. All product and process development occurred in the United States. Firm A is highly unlikely to find any of the CIS questions of relevance to itself, but it should count itself as an innovator, based on the CIS definition, and reply to all of the questions on sources, obstacles, R&D activities, etc. Nevertheless, firm A might assume that it is not an innovator and leave these questions blank or not answer at all.

Firm B slightly adapts products or processes that it has acquired from elsewhere. These very minor adaptations make it an innovator. Again, very few of the questions are relevant to this firm.

Firm C innovates by putting its own effort into the process of creating new product and/or process innovations. It also obtains new components from other firms that it includes, without modification, into its own product line. The manager reads all of the CIS questions on obstacles, sources of information etc. How does he/she interpret these questions? It is highly unlikely that any consideration is given to components that are 'new to the firm' but developed elsewhere. Instead, he or she will interpret the CIS questions as referring to the firm's own creative activities.

These examples raise two important questions. First, can the revised CIS definition of an innovative firm be altered to identify both innovation as diffusion and innovation as creative effort? Second, can the CIS questionnaire be changed to investigate both diffusion and creative innovation?

In response to the first question, the IDEA group suggested a new version of the key question to identify an innovative firm, as shown in Figure C.1. The purpose of this version is to be able identify firms that innovate almost entirely through diffusion (option 1) and to identify firms that largely innovate via diffusion but which expend some creative effort (option 3).

The revised version of this key question also permits a better interpretation of the responses to the other CIS questions, *if* the respondent only fills in one of the three options 1, 3, or 4. (The second option is not relevant to this discussion). Multiple options would make it more difficult to interpret the responses, since we would not know if the answers to the question on information sources, for example, referred only to option 4 or to a combination of options 4 and 1.

The problem raised by the second question above - how can the CIS be changed to investigate both diffusion and creative effort, would require changes to or additions to specific questions. The IDEA comments on CIS-2 did not go very far into this problem. One option would be to ask a series of questions about the firm's most commercially important innovations and to define the type of innovation using the three options given in Figure C.1.

Figure C.1: Modes of innovation

An innovation is a technologically new or improved product or service that is marketed or a new process that is implemented within the firm. Between 1994 and 1996, has your firm: (please check all that apply)

	Type of Innovation		
	Product	**Process**	**Service**
1. Introduced an innovation that was developed elsewhere and which required no or only minor modifications	☐	☐	☐
2. Worked on the development of an innovation that has not yet been commercialised or which has been abandoned	☐	☐	☐
3. Introduced an innovation that was mostly developed elsewhere but which required further development by your firm	☐	☐	☐
4. Introduced an innovation developed largely by your firm	☐	☐	☐

C.2.2 The Second Key Question: The Intensity of Innovative Effort

A second major problem with the October revision of the CIS concerns the intensity or quality of the effort expended on innovation. A method of differentiating firms by the intensity of their innovative efforts is of importance to many policy issues, such as the types of firms that use public research or technical support programmes. As should be apparent from the above discussion, the basic CIS definition of an innovative firm is very broad and should include many firms that innovate very little.

The second key question, on the amount spent on various innovative activities, provides one method of measuring intensity. It should also be able to measure the intensity of innovation as diffusion, since it asks how much is spent on investment in new equipment and on the acquisition of patents and licenses. Unfortunately, the question suffers from one severe drawback: item non-response rates approach 50% in many of the sampling strata. This suggests that the question is simply too difficult for most firms to answer.

Another intensity measure is the amount spent on R&D (either in absolute terms or as a percentage of sales), but this measure does not work for firms that do not conduct R&D[43].

[43] Other intensity measures are the CIS-1 questions on the percentage of significantly changed products plus the percentage of products that are completely new to the firm's industry. However, these questions will be unable to differentiate diffusers from creative innovators without including a question such as listed in Figure 1. Furthermore, these questions miss process innovators.

Several options were proposed by IDEA to obtain alternative intensity measures. One option is to collect a description of and data on the firm’s most important innovation. ‘Importance’ can be defined in several ways, such as the firm’s most commercially successful or technically advanced innovation. The technical description could be used as a measure of the innovative intensity of the firm, although this would require the description to be coded into ordinal categories of innovative significance by an expert in the field. It is very unlikely that Eurostat or any of the member states would do this. An alternative is to collect information on the novelty of the selected innovation, as suggested in the October revision and used, to great success, in the 1993 Statistics Canada Innovation Survey. This approach was not retained in the final version of CIS-2.

C.2.3 Use of a ‘not relevant’ Versus a ‘no’ Category

The October revision suggested using a ‘not relevant’ category for many of the subjective questions. The goal was partly to solve ambiguity over the meaning of an 'insignificant' response, which could mean either that the firm has direct experience with the factor but it was of no value or that the firm has never used the factor. IDEA argued that the best way of capturing this information is to ask it directly, rather than use 'not relevant', which could be misinterpreted. This can then be followed by a scale of importance for those who answered 'yes'.

IDEA also cautioned against using a 'not relevant' or yes/no option for the CIS questions on factors hampering innovation. These questions concern the actual strategies of the firm itself. The results do not require some familiarity with the question category, as with other questions on external sources of information.

C.2.4 Other Changes

The IDEA group suggested other changes throughout the revised CIS questionnaire. These concerned general information on the firm, innovation objectives, information sources, R&D cooperation, innovation expenditures, factors hampering innovation, the advantages of a three, four, or five-point subjective scale, and the use of open questions. Many of these comments concerned matters of good questionnaire design, such as minor changes in wording to reduce ambiguity, and were incorporated into CIS-2. The details of these comments are not given here. Instead, the next section discusses potential problems with the final version of CIS-2. Many of these problems were identified by the IDEA group during the CIS-2 development process, but were not accepted by the expert group responsible for the final design of CIS-2.

C.3 POSSIBLE PROBLEMS WITH CIS-2

The following discussion is based on the March 5, 1997 version of the core CIS-2 questionnaire. National versions of CIS-2 could differ from this standard version. Only the most problematic features of CIS-2 are discussed below. Minor problems such as wording or question order are not covered.

C.3.1 Definition of an Innovation

The main filter question in CIS-2 defines innovative firms. Innovators complete the entire questionnaire while non-innovators only respond to the question on factors hampering innovation. The CIS-2 version of this key question contains two problems. First, the definitions are not included in the question itself but in separate boxes, although good layout design can overcome much of this problem. Second, and more seriously, CIS-2 defines an innovator as a firm that introduces a *significant* technological change. For example, the CIS-2 definition states:

> ‘A technologically new product is a product whose technological characteristics or intended uses differ significantly from those of previously produced products...A technologically improved product is an existing product whose performance has been significantly enhanced or upgraded”.

This is a marked departure from CIS-1, which does not limit the definition of an innovative firm to those who introduce significant innovations.

There are several good reasons for limiting innovators to significant innovators. One is that it can possibly improve response rates, since firms that scarcely innovate will no longer be required to answer the entire questionnaire. Another reason is to provide a better idea of what self-reported innovative firms actually do. However, neither of these two reasons can justify the additional problems raised by the CIS-2 definition.

First, the definition of a ‘significant’ innovation is highly subjective. A ‘significant’ innovation to a small metal fabricating firm could be of no consequence to a mid-size manufacturer of machine tools. Second, CIS-2 defines ‘significance’ in terms of technical qualities, with an unstated concept of some degree of technological advance. This conflicts with the current economic understanding of the importance of minor incremental improvements. A minor improvement to a product or process could have substantial economic benefits to a firm, while an innovation that represents a major technical advance could have little impact.

One solution to this problem is never to use the term ‘innovation’ at all and to use the questionnaire to passively obtain measures of the quality of the firm’s innovative activities. This would require a significant departure from the technological trajectory of innovation surveys[44]. An alternative is to retain a very broad definition of innovation, as used in CIS-1, and combine it with questions that can differentiate diffusers and creative innovators (as in Figure C.1 above) and with questions that obtain information on the quality of the firm’s innovations.

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[44] Such a questionnaire was developed with Niels Lanoy of the Dutch Central Bureau of Statistics and submitted to the CIS-2 expert group. Not surprisingly, this trial questionnaire did not receive an ecstatic reception.

C.3.2 Diffusers versus creative innovators

CIS-2 includes a simpler version of the question proposed by IDEA (Figure C.1 above) to identify diffusers and creative innovators. The CIS-2 version asks who developed the firm's new or improved products or processes:

1. Mainly other enterprises or institutes
2. Your enterprise and other enterprises or institutes
3. Mainly your enterprise

The simpler wordings in each CIS-2 category are probably sufficient, but there is some concern that the CIS-2 version will miss firms that make slight modifications to the products or processes of other firms or institutions.

C.3.3 Resources Devoted to Innovation Activities

Another key CIS-2 question asks the firm if it engaged in seven different activities, including R&D. If yes, the respondent is asked to estimate the expenditures on the activity. The question mixes R&D, for which the firm will have good expenditure data, with activities that are very difficult for a firm to accurately cost. This problem was identified in CIS-1. For example, most firms are unlikely to be able to accurately estimate the amount that they spend on 'training directly linked to technological innovations' or on the 'market introduction of technological innovations'. The concern is that the request for 'soft' figures for many categories could spillover into the request for R&D data. Furthermore, the questionnaire repeats itself by asking if the firm 'engaged in R&D between 1994 and 1996?'. The question on R&D expenditures should be removed from the first list and included in the second reference to R&D.

The earlier versions of this question included the category 'patents and licenses'. This was changed by the final version to 'acquisition of other external technology linked to product and process innovations'. The change is unfortunate, because it is not obvious that it includes patents, software, and licenses. Furthermore, the question has become a catch-all for unspecified and unknown acquisitions.

C.3.4 Other Concerns (listed in order of their appearance in CIS-2)

Independent status of the enterprise: CIS-2 asks if the firm is independent or 'part of an enterprise group'. Based on experience with PACE, these two categories are not defined carefully enough to prevent errors, particularly by subsidiary firms stating that they are independent.

Main activity: The main activity of the firm is obtained by asking the respondent to fill in their firm's 4-digit NACE code. This will not work for large diversified firms that are involved in several sectors. It would also be of use to have the respondent write in their main activity in order to be able to check for coding errors.

Changes to turnover: The question on significant changes to the enterprise should include the limitation of a 'change affecting turnover at least 10%' in the sub-question rather than in the main question.

Information sources: The questions on internal sources (within the enterprise, within the enterprise group) should be placed in a separate question.

Factors hampering innovation: This question is radically altered from the CIS-1 version. The CIS-2 version follows some of the suggestions of the IDEA group and asks if each factor led to one or more of three outcomes for an innovation project: seriously delayed, caused its cancellation, or caused an innovation project to not even be started. Some preliminary analyses so far for France and Germany indicate that the revised version is much more useful than the CIS-1 version[45]. The main concern with the question format is that it is telegraphic. It does not clearly explain the use of the three outcome categories.

C.4 CONCLUSIONS

CIS-2 contains many improvements over CIS-1. It is shorter, includes a 'no' option that avoids ambiguity in many questions, is simpler to answer, and should provide considerably more useful results for the factors hampering innovation. Nevertheless, several problems still remain with CIS-2. Three major remaining problems are the definition of an innovative firm, the limited ability to differentiate diffusers from creative innovators, and the continued difficulty of the question on the amount spent by the firm on different innovative activities.

Several of these issues are taken up in the main report in Chapters Five through Seven**.** However, although the CIS format can continue to be 'tweaked' to improve the type of information that it can obtain, the format itself could prove to be a barrier to acquiring useful information on the diffusion of innovations. This is ironic, since one of the main functions of the two Oslo Manuals is to stress the importance of diffusion and minor improvements. For this reason, Chapters Five through Seven also try to go beyond the limitations of the CIS format in order to better meet the goals of the Oslo Manuals.

[45] Georg Licht, ZEW, Mannheim, Personal communication. Francois and Favre (1998) report results for France. Economic factors are important to all three outcomes, while other factors, such as a lack of qualified personnel, mostly delay projects, rather than cause them not to be started or to be abandoned. This differentiation of the effects of economic versus other obstacles to innovation is of great value to policy, since it gives a much better idea of the types of obstacles that seriously hinder the ability of firms to innovate.

APPENDIX D

INNOVATION POLICIES IN 13 EUROPEAN MEMBER STATES

This appendix provides a brief overview of public policies in the majority of EU member states in three innovation policy areas: knowledge creation, knowledge dissimination, and the absorption and use of externally developed knowledge. The overview is based on summaries of relevant innovation policies in most member states that were written by national members of the EU *Ad Hoc Committee on Dissemination, Optimisation and Innovation* in late 1996. The national summaries do not cover all policies in each country and therefore some relevant policies for each theme may be missing. The amount of detail provided in each summary also varies. Additional information is obtained from a recent MERIT report on Science and Technology policy for six countries: Belgium, Finland, the Netherlands, Ireland, France, and Germany (Wolters and Hendriks, 1997). Unfortunately, information is not available for Italy, Luxembourg, and Portugal.

Many policies have more favourable rules for SMEs. The upper boundary for an SME is frequently lower in smaller countries than in larger countries. For example, the boundary is 250 employees in Finland, 200 in Belgium, but 500 in France.

D.1 KNOWLEDGE CREATION

Knowledge creation is supported by policies directed towards Public Research Institutes (PRIs) and policies to support research by private firms.

D.1.1 Knowledge creation by PRIs

The goal of many knowledge creation policies in the last decade has been to improve the rate at which public investment in research is translated into commercially-viable innovations. Two main policy options are in use. The first is to provide incentives for PRIs to conduct research of value to the private sector. These incentives are often designed to influence the activities of universities or institutions where the research agenda has traditionally been determined by academic criteria, rather than by the needs of government or industry. The second consists of financial support for publicly-funded institutions with an existing mandate to conduct research of value to firms.

D.1.1.1 Incentives for PRIs to conduct business relevant research

There are two types of programmes to encourage PRIs to conduct research of relevance to business: subsidies for firms to contract out research to PRIs and incentives for PRIs to direct their research into areas of commercial interest. The latter group includes both programmes that actively direct research into business relevant research and passive programmes that establish the potential for contacts between academic researchers and firms. In addition, several countries offer entrepreneurial assistance to academics who would like to commercialise an invention.

1. *Subsidies for contract research*: Most countries subsidise firms to contract out research to PRIs. These are often described as collaborative or cooperative research programmes, although none of the national summaries specify the amount of joint research that must be undertaken by firms and PRIs. A need for a subsidy is justified by the disadvantages of contracting out research to PRIs. These include concerns over confidentiality, higher risks for the basic and pre-competitive research where many PRIs have their expertise, and a preference for firms to keep more applied and commercial research in-house. The programmes also create new knowledge by developing expertise within PRIs on problems of importance to industry and informing academics about the types of problems that occur in industry.
2. *Targeted research funds*: A few member states have introduced mechanisms to deliberately target academic research funds towards areas of value to industry. The research councils in the UK are responsible for distributing funds for academic research. They use two mechanisms to target research towards areas of value to industry. First, they include representatives from industry who take part in the funding decisions and second, they use the results of the Technology Foresight reports to identify promising technologies with potentially large markets. In the Netherlands, PRIs can receive extra funds for projects that are partly funded by a private firm. Over time, PRIs are required to fund a percentage of their research from private sources.
3. *Passive incentives for PRIs*: Some countries have passive incentives to encourage academics to work on problems of value to industry. These often consist of mechanisms to increase the opportunity for contacts between industry researchers and academics, such as the establishment of science parks adjacent to universities, or liaison offices at PRIs. In Norway, staff are permitted to earn extra income from contract research.
4. *Entrepreneurial assistance*: Many European academics lack the knowledge and skills to develop the commercial potential of a good idea or technical discovery. In response, some PRIs provide assistance for commercial development. This can include help to apply for a patent, to find a buyer for the technology, or to set up a firm to exploit the technology. Norway took a more active approach in a two-year programme that actively sought out research results and evaluated their commercial potential.

D.1.1.2 Strengthening the existing business-relevant research infrastructure

Many member states support institutions with a specific mandate to conduct research of value to industry. The classic example is the Fraunhofer Institutes in Germany.

Many of these institutions are under pressure to increase the commercial relevance of their work, the efficiency with which technology is transferred to firms, and the percentage of their operating costs that is funded by contract research. There are two main types of institutions: those that exist in specific, purpose-built institutions and "virtual" research institutes. The former most commonly conduct applied research but a few also perform basic and pre-competitive research in strategic areas. The virtual institutes are more likely to be involved in basic research. They are presented here as a separate category because most new institutes appear to follow a virtual structure.

1. *Applied research institutes:* These institutions focus on specific industries, usually in low or medium technology sectors such as agriculture or machinery, where the industrial structure is dominated by SMEs. These firms often lack the financial resources or expertise to solve technical problems in-house. The applied research institutes offer SMEs basic technical services for free or for a low fee. Basic and pre-competitive research institutes are usually established in strategic technologies such as biotechnology or micro-electronics where commercial applications are fed by scientific advances.
2. *Virtual research institutes*: In the past, applied or basic research institutes were usually established in new buildings with their own offices and research laboratories. The current trend is to establish 'virtual' institutes that link researchers at several PRIs and sometimes with firms. This results in considerable savings since new buildings are not required. In addition, virtual institutes should increase the efficiency of existing expertise by improving knowledge flows and cooperation. They can also encompass both basic and applied research, since there is no existing 'research culture' that must be overcome.

D.1.2 Knowledge Creation by Private Firms

Policies to encourage knowledge creation by private firms consist of subsidies for in-house research and programmes to encourage new high technology start-up firms and SMEs.

D.1.2.1 Research subsidies

Over the last decade, there has been a decline in the number of national programmes that provide direct grants to support in-house innovation by firms, partly because of concerns that direct grants only displaces private funds, rather than increasing the total amount of private investment in R&D. The approach taken by Germany, Denmark, Finland and the UK, for example, is to limit direct subsidies and to focus on the development of a favourable business environment for innovation. One result is that government support for in-house R&D has shifted in many countries from direct grants towards soft loans. This process has gone the farthest in the UK, which provides no direct grants and only gives soft loans to SMEs.

There are a few exceptions to the trend to move away from direct grants for in-house R&D:

- Less developed economies that receive EU structural funds, such as Greece and Ireland, continue to provide direct grants for in-house R&D, although Ireland is trying to replace direct grants with equity investment.
- Direct grants are still used in several countries to support R&D in strategic technologies. For example, the Netherlands provided direct R&D grants for strategic technologies such as biotechnology. These grants, which are no longer available, were justified by the need to develop Dutch expertise in a pervasive technology with many future applications. France provides substantial direct grants for R&D in strategic areas such as aerospace and electronics.
- Direct R&D grants continue to be widely available for collaborative R&D projects or to support R&D by SMEs. The former is justified by the belief that firms would not finance collaborative R&D without incentives and because collaborative R&D is thought to have strong benefits, in the form of establishing contacts that could create spill-overs and more efficient investment in the future.

There are three main forms of government support for in-house innovation: direct grants, soft loans, and tax incentives. All three are sometimes targeted to specific technologies or types of firms (such as SMEs) that the government wants to encourage to innovate.

1. *Direct grants* are cash expenditures to fund part of the costs of an innovation project. They are usually limited to 50% or less of the costs, with the firm required to finance the other 50%. The major concern with direct grants is that firms will use them to replace private funds for research that they would conduct anyway. For this reason, direct grants are often targeted to areas where firms are less likely to finance innovative projects. For example, Belgium only provides direct grants for basic research, while several countries, including Belgium, have more liberal funding policies for SMEs, which could find it difficult to obtain other sources of finance. France only provides direct grants to SMEs. Norway does not appear to limit the size of firms that are eligible for direct grants, but it gives priority to firms located in the North and to projects that are likely to have substantial export markets.
2. *Soft loans* cover several methods that reduce the true cost of a loan to a firm. These include government guarantees for commercial loans, zero or reduced interest loans, and forgivable loans in the event that a funded project fails. In most EU member states, a soft loan is provided for only part of the cost of an innovation project, while Austria will provide a soft loan to an SME for up to 100% of the cost of a project. Several countries, including France, Germany, the

Netherlands, and the UK, only offer soft loans to SMEs. Other countries provide soft loans to firms of all sizes but give better conditions to SMEs. For example, Finland provides soft loans to a maximum of 50% of the cost of a project in a large firm, but up to 60% for SMEs.

3. *Tax incentives*: Belgium, France, and the Netherlands provide tax incentives for in-house R&D. The Netherlands reduces payroll taxes for R&D personnel while France offers research tax credits. Both are available to all firms that conduct R&D. Belgium offers higher tax rebates for research projects in environmental technology.

D.1.2.2 Programmes to encourage start-up firms and SMEs

A major policy concern is a perceived lack in Europe of new high technology firms and small high technology firms with rapid growth rates, at least in comparison with the United States. There is a general consensus among European countries, with the exception of the UK, that one of the causes of this problem is a lack of private equity funding for high technology start-ups and SMEs.

Most EU member states provide temporary incentives to encourage the development of private sources of venture capital. These temporary measures are intended to help establish private venture capital firms and give them time to develop the expertise required for successful high-risk investment. It is not clear how successful these programmes have been, with critical evaluations of programmes in Austria, Denmark and Spain. The concern is that government incentives have not had a significant impact on the supply of risk capital, with most investment, with or without government subsidies, going to projects of limited risk. One possibility is that the main bottleneck is a lack of good projects in which to invest.

Four approaches are in common use: programmes to provide seed finance, public equity investment, subsidies for private venture capital, and initiatives to establish new stock markets that are similar to NASDAQ in the United States. In addition, France, the Netherlands and Germany are supporting small projects to develop technology assessment techniques that can be used by banks and venture capital firms to assess the market opportunities for a technology.

D.2 KNOWLEDGE DISSEMINATION

Two general types of programmes are used to support knowledge dissemination: technology transfer and collaborative research. The latter also creates new knowledge.

D.2.1 Technology Transfer

Many of the programmes to encourage knowledge dissemination are mediated by a national *technology transfer infrastructure*. There are two main types: regional centres that provide advice on a wide range of different technologies to all firms in a geographic region and institutions that focus on specific technologies. For example, the Netherlands supports both a network of 18 regional innovation centres and is building a new network of 15 Technology Centres, each of which is limited to a specific industry. In many countries, the infrastructure that provides technology transfer also provides other services, such as business advice and assistance with applying for EU research funds. In Finland, the technology transfer infrastructure is closely linked to PRIs and is designed to transfer technology from PRIs to firms. In addition to the maintenance of a techhnology transfer infrastructure, three specific programme types are in use in Europe.

1. *Demonstration Centres* provide information on and demonstrations of the use of specific technologies. The goal is to reduce the risk of their adoption by helping the firm make an informed decision. These centres are usually located at research institutes with the relevant expertise. In contrast, the Greek PEPER programme demonstrates the technical and economic feasibility of a new technology by subsidising a full-scale application in a firm.

2. *Best practice* programmes are relatively common. SME staff visit successful innovative firms in order to learn about best practice in their industry.

3. *Technology transfer subsidies*: A few countries offer subsidies to firms to adopt innovative technology. France provides soft loans to firms that adopt targeted technologies, consisting of electronic components, new materials, and computer integrated manufacturing equipment.

D.2.2 Collaborative research

Collaboration programmes support the transfer of technology by either encouraging or subsidising technical collaboration and networking between firms or between firms and PRIs. A programme in Norway provides a subsidy for one firm to develop a technology for another firm. One of the two firms must be an SME. Belgium, Germany, and Sweden have programmes to create networks between firms on either a geographic or sector basis, although no details are given on how these networks are encouraged. The goal of the Swedish network is to encourage firms to identify their needs for new technology and then request local PRIs to develop solutions. Most countries offer subsidies for collaborative research between firms and PRIs. Many of these programmes subsidise collaborative research in basic or pre-competitive research that will require additional work by a firm to develop a commercially viable product or process.

D.3 ABSORPTION AND USE OF NEW TECHNOLOGY

Policies to improve the absorptive capacity of firms are based on programmes to promote education and learning in order to improve the ability of a firm to innovate.

Many of these programmes are provided by the same institution that supports technology transfer[46].

Many member states list educational programmes to improve the ability of firms to learn about new technologies and how to manage the entire process of innovation. Most, but not all, of these policies are directed specifically to SMEs. A role for government assistance for SMEs is justified by the high cost of acquiring information on new technologies and by a shortage of expertise in how to manage innovation. There are two basic approaches: general programmes to develop the innovative capacity of a wide range of firms and customised assistance to help individual firms identify and solve their own problems.

The general education programmes focus on courses on innovation management. Successful innovation often requires many changes to a firm's organisation and improvements to its management expertise. Support in this area includes both seminars and workshops on general management and programmes that focus specifically on how to manage innovation.

Customised assistance programmes form the heart of government programmes to develop absorptive capacity. They include evaluations of a firm's general management, technology audits, technology feasibility studies, and subsidies to hire recent scientific and technical graduates. Several of these programmes involve visits by a consultant to the firm. A fixed number of days of consultancy are usually provided for free, while the cost of additional days has to be partly paid for by the firm.

1. *Individual Consultancy* is usually provided by expert consultants who assess the firm's technical problems and evaluate how innovation fits in with the firm's management and business plans. An example of the latter is the MINT programme, where consultants evaluate the firm's strengths and weaknesses, look for technical problems, and propose solutions. This requires between 3 and 10 days work with the firm.

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[46] In Sweden, the same agency (ALMI Business Partner) provides both general business advice and assistance with technology transfer, while in other countries, such as Belgium, France and the Netherlands, government funding goes to several organisations that provide different services. The trend is to create 'one-stop shops' where SMEs can go for advice on a range of services such as basic management skills, technology transfer, or how to apply for a patent. The advantage of one-stop shops is that it reduces government costs by eliminating duplication and reduces the firm's search costs to find relevant information. The Dutch government plans to merge two institutions that provide innovation services to SMEs in 1998. The disadvantage of one-stop shops is that it creates a new intermediary, since these shops generally lack the expertise to actually implement the required programme. Germany is changing the design of its technology transfer programmes from using intermediaries (which could be located at one-stop shops) to direct links between a PRI and a firm. They believe that the best results are obtained when there is direct contact between scientists and the firm.

2. *Technology audits* focus specifically on technical problems within the firm and make recommendations on how to solve the problem. Several of these programmes are linked to expertise at a PRI. For example, the TEFT technology audit programme in Norway is focused on finding problems that can be solved by a PRI. The technology audit is followed by a second phase where the PRI is given a subsidy to develop solutions to the identified problem.

3. *Technology feasibility programmes*, such as SMART in the UK subsidise the cost of evaluating the feasibility of adopting or developing an innovative technology. By reducing risk, they provide an incentive for SMEs that innovate very little to innovate or an incentive to innovative SMEs to move into new areas. In addition to evaluating the technology, most programmes require the firm to develop a business plan for the use of the technology.

4. *Hiring subsidies for scientists, engineers, and technicians:* The most commonly cited programme to improve the absorption capacity of firms is a hiring subsidy for technical staff. Most programmes are limited to SMEs and pay up to 50% of wage costs, for between one and three years, to hire one recent university graduate to assist the firm to innovate. In some countries the subsidy is available to firms of all sizes. The subsidy clearly has a dual purpose in that it both provides more job opportunities for recent graduates and helps firms to innovate. Several countries also design the subsidy so that the new employee provides a direct link between their university or technical institute and the firm. In Denmark, the subsidy pays 50% of the cost of hiring a PhD student, who works on a doctoral problem of interest to the firm. The student's university also receives state funding. The Teaching Company Scheme in the UK has gone the farthest in this direction. It subsidises higher education institutions to place graduates in firms to transfer technology during a two year project. Supervision is provided jointly by the firm and the educational institute.