Innovation in Firms

A MICROECONOMIC PERSPECTIVE

OECD *Innovation Strategy*

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Innovation in Firms

A MICROECONOMIC PERSPECTIVE

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Foreword

Innovation matters for growth. Improving our knowledge of firms' innovative behaviour and its determinants is crucial for designing effective innovation policies. Data collected through innovation surveys have been increasingly used to explore a number of questions regarding the determinants, the effects and some of the characteristics of innovation. Nonetheless, with few exceptions, almost all such studies have been conducted at the level of individual countries. While valuable, they do not allow for comparing results across countries. Reasons for not exploiting firm-level data at the international level are mainly legal: access to innovation survey data, as for microdata in general, is restricted by laws that protect confidentiality and secrecy in all countries. As a consequence, microdata from different countries cannot be pooled and because different models and methodologies are used, the results are usually not comparable across countries.

This is why the OECD launched the Innovation Microdata Project in 2006 based on a "decentralised" approach combining a common framework provided by the OECD with the work undertaken by researchers with access to their own country's microdata. It is a pragmatic way to address problems of data access and still provide better information to the policy community. More needs to be done to refine and expand on these results. Innovation surveys can be exploited further, but more promising analysis can be carried out by matching innovation survey data with other firm-level data and administrative records, such as balance sheets, R&D surveys, ICT surveys, surveys of organisational practices, patent records, public support, etc. This would make possible different (and better) measures of productivity and would help to learn more about which policies work and which do not, and to better understand the reasons why similar policies may be more effective in certain countries than in others, all questions that the exploitation of aggregate data can only begin to address.

This volume highlights the findings and challenges of this large-scale endeavour, draws some lessons and identifies some areas for future research. This project was a first experiment and relied considerably on the willingness of researchers to invest a considerable amount of personal time. Without their help and dedication this collaborative effort would not have been possible. It is hoped that this exercise and exchange will have benefited them as well, and that the network of people and the exchange of ideas will continue to flow to the benefit of a better understanding of the links between innovation and economic performance and the role played by policies.

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Innovation in Firms: A Microeconomic Perspective

Introduction

How do we measure innovation?

As the importance of innovation as a driver of economic and social change grows, its nature, role and determinants are receiving increasing attention. Innovation is a broad concept which encompasses a wide range of activities and processes: markets, entrepreneurship, networks and competition, but also skills and organisations, creativity and knowledge transfers. Statistics covering various science and technology activities have been systematically collected by statisticians and researchers for more than 40 years, but only recently has the broader concept of innovation been formalised in a way that makes it possible to gather information about how firms innovate through large-scale statistical surveys. R&D surveys can provide information about some of the inputs to innovation, but have little information on the outputs of these processes, and tend to be more useful for measuring technology-based activities, which are only a subset of what is

The *Oslo Manual* and innovation surveys

To harmonise and ensure the quality of innovation surveys, the *Oslo Manual* was developed by the OECD in 1992. Since then, on the basis of the experience acquired, the *Oslo Manual* has been updated twice; while it was initially designed for firms in the manufacturing sector, it was later modified to include the services sector. At first it dealt with product and process innovations, but it was later extended to cover organisational and marketing innovations. The latest (third) edition of the *Oslo Manual* (OECD/Eurostat, 2005) defines innovation as the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations. This implicitly identifies the following four types:

- *Product* innovation: the introduction of a good or service that is new or significantly improved with respect to its characteristics or intended uses. This includes significant improvements in technical specifications, components and materials, incorporated software, user friendliness or other functional characteristics.

The *Oslo Manual* and innovation surveys *(cont.)*

- *Process* innovation: the implementation of a new or significantly improved production or delivery method. This includes significant changes in techniques, equipment and/or software.
- *Marketing* innovation: the implementation of a new marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing.
- *Organisational* innovation: the implementation of a new organisational method in the firm's business practices, workplace organisation or external relations.

In innovation surveys, firms are asked to give information about inputs, outputs and the behavioural and organisational dimensions of their innovative activities. On the input side, innovation surveys measure a firm's intangible assets, which include, beyond R&D expenditure, spending on training, acquisition of patents and licences, product design, trial production, and market analysis. On the output side, data are collected on whether an enterprise has introduced a new product or process, the share of sales due to significantly changed or new products ("new" can mean new to the enterprise, new to the market or new to the world). Other indicators capture the nature of innovative activities, whether R&D is done on a continuous basis and/or in co-operation with others, as well as categorical data on the sources of knowledge, the reasons for innovating, the perceived obstacles to innovation, and the perceived strength of various appropriability mechanisms.

Innovation surveys were first experimented in several European countries but have since been conducted in many others, including Australia, Canada, all EU countries (where the Community Innovation Surveys [CIS] co-ordinated by Eurostat are in their sixth round in 2008), Japan, Korea, Mexico, New Zealand, Norway, Switzerland, Turkey, as well as in Russia, South Africa and most Latin American countries. The United States is a notable exception, as no official innovation survey based on the *Oslo Manual* framework exists at this time.

included in the broader concept of innovation and often more relevant for manufacturing firms than for those in services. Likewise, patent data are useful for understanding certain innovation-related strategies, but they cannot measure the full extent of innovative activities and suffer from some well-known limitations. Given these constraints, it was felt that new surveys should be developed to collect more information about types of innovation, reasons for innovating (or not), collaboration and linkages among firms or public research organisations, and flows of knowledge, and that new quantitative data should also be collected on the inputs and outputs of innovation. "Innovation surveys" were therefore developed to increase knowledge about innovation in firms with a view to developing effective innovation policies.

Microdata: what more can they tell us?

The OECD already publishes indicators based on aggregate data from innovation surveys such as the share of firms with new-to-market product innovation or the share of firms co-operating with universities. These indicators are very informative as regards the general situation of countries. They make it possible to identify gaps in national innovation systems (*e.g.* the proportion of innovative small and medium-sized enterprises [SMEs] may be smaller than in other countries).

Microdata-based indicators reflect the behaviour of individual firms and firms' heterogeneity. Some firms innovate, others do not. Among those that do, innovation performance is skewed (some are highly innovative, other are less so). Firms differ as well in the types of innovation that they perform (product, process, organisational, marketing). Improving our knowledge of firms' innovative behaviour and its determinants is crucial for designing effective innovation policies. To increase the number of innovative firms, for instance, it is necessary to understand what prevents certain firms from innovating, and among the impediments they face, the types of policies to which they would be more sensitive. Innovation policies that do not take into account the heterogeneity of firms risk missing their main targets. Those that ignore functional relationships that influence innovation at the firm level risk choosing the wrong target (*e.g.* subsidising R&D when the obstacle is market access).

Microdata-based indicators characterise firms by size, by industry, etc. Microdata also allow for combining responses to multiple questions and identifying firms' innovative profiles, which can then be aggregated at the country level. In addition, more sophisticated techniques, such as exploratory data analysis or econometrics, can also be used. The former make it possible to use the data to identify similarities and differences in certain characteristics or certain groups of firms; for instance, an analysis may show that in-house R&D, new-to-market product innovation and patents tend to be associated (performed jointly in the same firms), while process innovation is more closely linked to extra-mural R&D and investment in machinery. The econometric approach allows for estimating functional relationships between variables that may differ across sub-groups of firms; it can show, for instance, that firms that spend more on innovation tend to have a higher innovative turnover and increased productivity and it can qualify relationships across countries or by firm size.

Innovation survey data have been increasingly used to explore a number of questions related to the determinants, the effects and the characteristics of innovation. Some of the topics examined in previous studies include the determinants of innovation, complementarities (in terms of the sources of innovation, knowledge acquisition, etc.), collaboration and co-operation strategies, the effects of innovation on economic variables such as productivity or export performance, and the impact of innovation polices (*e.g.* additionality *vs.* crowding-out effects of government support).

Exploiting the potential of microdata: a comparative project

The *OECD Innovation Microdata Project* was designed to examine a range of issues relating to innovation and firm performance using a common methodology. Research teams in 20 countries used similar data cleaning methods and econometric models on their national data sets to produce harmonised tabulations of results.[1] A series of topics of high policy interest was identified for the project's indicator and the econometric modules. The indicator work covered both standard innovation indicators, as well as more complex indicators of innovation strategies or "modes". The themes selected for econometric analysis (which also entailed the compilation of comparable indicators) included: the determinants of innovation and the impact on productivity; modes of innovation, including non-technological innovation; and the incentive effect of IPR on innovation. Below are some key findings.

The data used in this project come mainly from the 4th round of the CIS (CIS 4), or from national surveys carried during a similar time frame. It was decided to use the "core" CIS 4 coverage in terms of sectors and similar firm size thresholds as a benchmark in order to allow for comparability (countries using industrial classifications other than NACE performed concordances to map as closely as possible to the CIS 4 list of industries).

Beyond simple pointers

Twenty simple indicators were chosen to compare five broad dimensions: technological innovation; non-technological innovation; innovation inputs; innovation outputs; and key policy-relevant characteristics (internationalisation, collaboration, intellectual property rights). The results reveal firms' heterogeneity and reflect countries' structural differences in terms of sector specialisation and size composition. For example:

- The share of firms in each country having developed a product or process innovation ranges from over half of all firms in Austria, Germany, Luxembourg and Switzerland, to less than a third in France, Japan and Norway. Firm size is an important factor: differences among countries are much less pronounced when the focus is only on large firms (250 employees or more).
- The share of firms having introduced a marketing or organisational innovation varies widely across countries, ranging from around 60% of all

firms in Denmark, Germany and Luxembourg to around one-third in the Netherlands and Norway. The shares are quite similar for both service and manufacturing industries (unlike product and process innovations which are more prevalent in manufacturing than in services).

In addition, new "composite" indicators were developed to provide greater insight into innovation processes and help to better address policy needs.[2] How novel is innovation? How open/collaborative is it? Two examples of composite indicators are "output-based innovation modes", which aim to capture firms' novelty and creativity and "innovation status" which reflects firms' relative reliance on in-house and external sources of knowledge. The output-based innovation modes cross three variables from the surveys: Is the product new to the market or only new to the firm? Is the firm's market international or only domestic? Is the innovation based on in-house effort or not? This makes it possible to distinguish several categories of firms, of which the most innovative issue products new to the market, with an international market, based on in-house efforts (a category labelled "new-to-market international innovators"). In this category, the leaders (as a share of innovating firms) are Canada (manufacturing sector), Denmark, Finland, Luxemburg, the Netherlands and Sweden. Firms in Austria, France and Germany, instead, seem to rely more on innovation based on existing products (new to the firm). In terms of innovation status, in manufacturing the great majority of firms that collaborate also engage in in-house innovation, while in services collaboration plays a more central role.

Beyond the distinction between technological and non-technological innovation: a broader set of complementary strategies

While the concepts of technological (product, process) and non-technological (marketing, organisational) innovation are useful from a practical perspective, since the relevant data are readily available, they do not fully recognise that today's firms adopt mixed modes of innovation: certain types of innovation tend to go hand in hand in the same firms and complement each other, while other types tend to be independent or to substitute for each other; certain innovative activities (*e.g.* co-operation or patenting) are more closely related to certain types of innovation than to others. A set of activities or practices which tends to be grouped and implemented together by the same firms is here called a "mode of innovation".

This project applies an exploratory methodology – factor analysis – to innovation survey data to uncover different modes of innovation, and uses cluster analysis to group enterprises according to their use of such practices. This involves identifying a set of variables for measuring innovation-relevant activities and examining which of these variables "hang together" or "load up" so as to identify joint activities (*i.e.* activities often performed together in the same firms) that lead to effective innovation. Such practices are likely to reflect both common conditions across countries and country-specific factors related to national innovation systems and country-specific socio-economic environments.

Four roughly common modes of innovation practices are found in the participating countries. These are interpreted as: *i)* new-to-market innovations based on own and diffused technologies (corresponding in many cases to in-house R&D in conjunction with acquired R&D and to IPR protection); *ii)* marketing-based following; *iii)* process modernising based on embedded technologies (acquisition of machinery, software, etc.) and training of staff; and *iv)* wider innovations linked to organisational and marketing innovations. In general, the highest degree of country specificity appears to emerge in conjunction with modes of innovation linked to new-to-market innovations, while process modernisers and wider innovation patterns exhibit greater consistency across the countries studied here.

Based on the innovation practices identified in each country, enterprises are clustered according to the extent to which they engage in the identified innovation practices. In other words, a cluster analysis groups together firms that exhibit similar values in their factor scores. In almost all countries, one group of firms scores high across all innovation modes. These are firms that engage in all types of innovation activities and combine all innovation modes. Other groups of firms are specialised in terms of their innovation strategies and score high in relation to one specific mode of innovation.

Following the identification of different modes of innovation in the participating countries, the modes are related to firm-level productivity. In addition to assessing productivity levels, broader factors – measures of human capital, conditions of competition and enterprise structure – are also considered. These appear to have stronger relationships with contemporaneous levels of productivity than the innovation practices identified here. Nonetheless, at least one of the summary innovation variables is linked to higher levels of productivity in most countries, and in most cases, a different innovation mode is involved.

Overall, the effects of specific modes of innovation and productivity across countries show no consistent pattern. Different modes of innovation are significantly related to the level of productivity measured at the end of the three-year period covered by the survey. This suggests that, even with the participating countries' data sets constrained to be as comparable as possible, there are major national differences in patterns of competitive and comparative advantage and thus potentially different patterns of response to similar policy instruments.

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Innovation and productivity at the firm level

What are the channels at the firm level that make innovation possible and to what extent can they explain aggregate differences in productivity performance? This question is addressed by estimating a three-step structural model: *i)* the decision of firms to invest in innovation; *ii)* the knowledge production function, in which this investment, together with other inputs, produces innovation; and *iii)* the output production function in which innovation, together with other inputs, is related to labour productivity. Eighteen countries – European, non-European and one major developing economy, Brazil – participated in this part of the project. The analysis uses the same modelling and estimation strategy on comparable innovation survey firm-level data for a similar period (the early 2000s). The results show surprisingly similar and consistent patterns across countries, with some notable exceptions, especially the relationship between innovation policy and investments in innovation. The choice of the variables to be included in the model was dictated by the need to find a minimum common denominator for all countries. For the same reason, the basic model only uses variables available in innovation surveys. This implies that the measure of productivity used, log sales per employee, is a very simple one. In some cases and for some countries, it was possible to extend the analysis to control for other factors such as human capital and physical capital in the production function.

Which firms are more likely to be innovative (*i.e.* to have invested in innovation or to have introduced a product innovation in the reference year)? Results are strikingly similar across countries. In particular a firm that is large and operates in foreign markets is more likely to have reported innovation activity. Being part of a group is positively correlated with the probability of being innovative except in Canada and Norway. It is particularly important in Australia and Brazil, and it is very similar across EU countries.

Which firms invest more in innovation, *i.e.* which firms spend more on the intangible assets, such as R&D, ICT, training, etc., that are inputs in the innovation process? Co-operation is very strongly correlated with innovation expenditure except in Austria and Belgium. Public financial support is also associated with higher innovation expenditure, consistently so in many European countries.

Investing in innovation increases sales from product innovation in all countries except Switzerland. The impact on sales is over 40% in Australia, New Zealand and Norway and ranges from 14 to 35% for the other countries. The analysis provides mixed results on the effect of size on innovative sales.

Product innovation matters for labour productivity: in all countries except Switzerland, and sales from product innovation per employee show a positive and significant coefficient. The magnitude of the impact of sales of innovations on productivity ranges from 0.3 to 0.9, with an average of 0.5, meaning that a 1% increase in firms' innovation sales per employee is associated with an average productivity increase of 0.5%. A negative impact on productivity is found for process innovation: a counter-intuitive result which could be due to adjustment costs or business cycle effects.

The incentive effect of IPR on innovation

Does the patent system stimulate or impede innovative activity? The analysis exploits information collected in innovation surveys to assess the impact of patents on firms' innovative behaviour ("incentive effect"). It focuses on patents, as results for trademarks were not found to be significant. The idea is that since the effectiveness of patent protection varies across industries, comparing the innovative behaviour of firms that benefit from more or less useful protection makes it possible to assess the incentive effects of IPR.

A structural model is estimated, in which firms anticipate the patent premium they can expect from the patent or trademark system when they decide on their innovative effort (the patent premium is the additional revenue that a firm obtains if it actually patents the innovation). The incentive properties of patents are therefore assumed to affect the firms' innovative effort only through this "anticipation channel".

According to the estimates, patents seem to be a significant structural driver of firms' overall innovative effort. There are large discrepancies among countries: patents are important in Belgium and Denmark but seem less so in Finland, Germany and Norway. In terms of the economic significance of the incentive effect, the smallest significant marginal effect is obtained for France and the largest for Denmark. Sample descriptive statistics reveal that the average industry share of patenting firms varies between 8% (Belgium) and 28% (Germany). Therefore, other things being equal, the "incentive effect of patents" would explain between 1.5 and 12 percentage points of the cross-country differences in the shares of firms involved in innovative activities. Since the base is around 50%, this represents a sizeable effect (ranging from 3 to 23% of the total share of innovation-active firms).

In the case of R&D, the estimated structural parameters are always higher than in the previous specification, which means that the R&D component of firms' innovative effort receives the greatest incentive from the patenting system. However, marginal effects are not always higher, which suggests that the average firm is not always able to benefit fully from these incentives. Patents stimulate the R&D efforts of firms in Finland, France, Germany and Norway more than in Belgium, Brazil or Denmark.

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Exploiting innovation surveys: lessons learned

This analytical work has brought to light a series of limitations to exploiting innovation surveys, as currently designed, to address key policy questions. Some conclusions, based on the experience of the research teams involved in this project, are:

Need to better understand why certain firms innovate while others do not

- More detailed information is needed on non-innovators (skills, training staff, etc.). Currently, most innovation surveys filter out non-innovators early in the questionnaire, and thus collect little or no information on them. This makes it very difficult to understand why certain firms innovate while others do not, as the basic information regarding the differences between these two types of firms is not available. Policies aimed at changing non-innovative into innovative firms need such information.
- The variable "obstacles to innovation" is not always very useful for understanding the difference between innovators and non-innovators since responses may either indicate a perception (what they see as a barrier to innovation) or reflect their actual experience. Very often a barrier is encountered only if an activity is undertaken. Firms that engage intensively in innovative activity encounter obstacles along the way, while those that do not innovate, for whatever reason, may not. Questions relating to obstacles may therefore need to be reformulated in order to reveal the actual experience of respondents and the sequence of obstacles to innovation they have encountered.
- More information is needed on the sources of information for innovation (domestic/international), the role of users, and on linkages and collaboration in the innovation process. These topics are mentioned in the latest *Oslo Manual*, but few data have been collected so far.

Need to better assess the effects of innovation on firms' performance

- Survey questions on the effects of process innovation (*e.g.* cost reductions, greater productivity and flexibility, etc.) are needed in order to gain a more complete view of the effect of innovation on the economy. At present, only the share of new products in turnover is covered.
- The effects of innovation are dynamic and become apparent over time. This points to the need for panel data. Part of the sample of SMEs might be maintained in successive surveys so as to monitor the trajectory of innovative and non-innovative firms and the transition from non-innovator to innovator or the opposite. This would require a significant change in most countries' sampling procedures.

- Data from innovation surveys need to be able to be matched to data from other sources. Matched data sets should be constructed and statistical agencies' data access policies should accommodate the needs of users.

Need for better information on non-technological innovation (marketing, organisational)

- As this area only recently entered the core definition of innovation in the *Oslo Manual*, surveys are just starting to include questions on this type of innovation, and little is known at present about the effects of such innovations.

Notes

1. Note that not every country participated in all the modules of the project.
2. Composite indicators are defined here as indicators that combine answers to several questions in order to examine a number of policy-relevant factors and better capture the diversity of innovative firms.

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Innovation in Firms: A Microeconomic Perspective

Chapter 1

Innovation Indicators

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1.1. Introduction[1]

Knowledge, research and innovation are of crucial importance for the competitiveness of the modern economy, as well as for high standards of living and welfare. In order to describe and better understand the role of knowledge and its effects, it is vital to have sound statistical information on which to base policy design and evaluation. Indicators to measure research and development (R&D) efforts were first developed and harmonised in the 1960s but it was not until the 1970s and 1980s that researchers started focusing on the development of more complex analytical models and measurement tools to study innovation. In order to understand how innovation occurs and to devise appropriate innovation policies more needed to be known about the process of innovation at the level of individual firms. This led to various experimental surveys in the early 1980s (*e.g.* in the United States, Scandinavia, Italy). Innovation surveys were then developed to increase knowledge about innovation in firms beyond what can be found in other science and technology (S&T) statistics such as surveys of R&D, patent data or bibliometric indicators. The original purpose of these surveys was to obtain data on innovation outputs and on a range of innovation inputs and activities that were not based on formal R&D. This includes collecting information on the types of innovations, the reasons for innovating (or not), the impacts of innovation, collaboration and linkages among firms or public research organisations, and flows of knowledge.

To harmonise and ensure the quality of innovation surveys, the *Oslo Manual* was originally developed by the OECD in 1992. It provides a harmonised framework – including concepts and tools – for undertaking comparable large-scale surveys of this type. While earlier editions of the *Manual* emphasised technological product and process (TPP) innovation, the latest (third) edition (OECD/Eurostat, 2005) extends the scope of these surveys to marketing and organisational innovations and puts new emphasis on the role of linkages (including collaboration) in innovation.

Innovation surveys based on the *Oslo Manual* were introduced in many OECD countries from the early 1990s (the first Community Innovation Survey [CIS] took place in 1993). In recognition that innovation also takes place in developing countries and that their socio-economic structures may affect their innovation activities, an appendix was added in the third edition of the *Manual* with some guidance on how to frame innovation surveys in such countries. Innovation surveys based on the *Oslo Manual* are now conducted in Australia, Canada, all EU countries (where the sixth round of the CIS takes place in 2008), Japan, Korea, Mexico, New Zealand, Norway, Switzerland, Turkey, as well as in Russia, South Africa and most Latin American countries.[2]

1.2. Rationale and methodology

In comparison to R&D-based indicators, indicators derived from innovation surveys have visibly had a lesser impact in the policy-making community (Arundel, 2007). R&D indicators are still the most widely used indicators of innovative activity. There may be a number of reasons for this. First, R&D subsidies play a central role in national S&T policies and therefore call attention to R&D-based indicators. Second, R&D data have been considered more reliable, particularly than early innovation survey data. Third, innovation indicators are less widely accepted and utilised than those relating to R&D and policy makers may therefore find them less useful. Finally, policy makers may not be fully aware of the innovation data available or its potential uses.

The policy use of innovation survey data may also have been hampered by a lack of internationally comparable indicators based on innovation surveys. This has been a serious drawback given strong policy interest in international benchmarking and in the use of indicators as measures of national capabilities. The first high-profile use of internationally comparable innovation survey indicators was the inclusion in 2000 of several indicators from the European CIS in the *European Innovation Scoreboard*.[3] However, there is still no regular publication of detailed and combined results from EU and non-EU innovation surveys.[4]

A second factor that may have reduced policy uptake of innovation survey indicators has been under-exploitation of innovation survey data. Many potentially useful indicators of direct relevance to policy have not been developed. With the exception of the widely used indicator of the percentage of innovative firms, almost all publicly available indicators from innovation surveys are simple indicators of the frequency of responses to a single question, such as the percentage of enterprises that applied for one or more patents, or the percentage of firms by size class that sourced knowledge from universities. Although these indicators can be very useful, they fail to incorporate important factors linked to innovation outcomes. The effect of such factors on outcomes is best addressed through multivariate analysis, but simple cross-tabulations of indicators can often provide an easily understandable picture of the distribution of multiple factors across countries in a way that is highly relevant to policy.

The purpose of this part of the project was two-fold: first, to produce tabulations of internationally comparable innovation indicators for both EU and non-EU countries;[5] and second, to develop new indicators that provide greater insight into innovation processes and help to better address policy needs. A number of the composite indicators build on work in the NIND (Policy Relevant Nordic Innovation Indicators) project, financed by the Nordic Innovation Centre (NICe) (Bloch *et al.*, 2007; Åkerblom *et al.*, 2008).

Although cross-country comparability of innovation surveys based on the *Oslo Manual* is generally good and improving, certain methodological differences may affect comparisons of CIS and non-CIS countries, such as sectoral coverage, size thresholds, length of reference periods, sampling methods and unit of analysis. Differences in survey response rates can potentially also have an influence on international comparisons. Another example is the filtering of innovators/non-innovators, *i.e.* whether firms identified as non-innovators early in the questionnaire are asked to answer subsequent questions (for example, in Canada, only innovators are asked to answer questions on collaboration, but for the CIS, firms that had some innovation activity but did not introduce a product/process innovation could reply). A more detailed description of the methods used in the participating countries is included in Annex A.

For present purposes, it was decided to use the "core" CIS 4 coverage in terms of sectors and firm size thresholds as a benchmark in order to allow for comparability (so countries using industrial classifications other than NACE (Rev. 1.1) performed concordances to map as closely as possible to the CIS 4 list of industries). Unless otherwise noted, the following definitions were used (see also Annex A):

- Sectors covered
  - ❖ Manufacturing: NACE D (divisions 15 to 37).
  - ❖ Services: Core G to K services which include NACE Sections I (Transport, storage and communication), and J (Financial intermediation) and NACE divisions 51 (Wholesale trade and commission trade, except of motor vehicles and motorcycles), 72 (Computer and related activities), and 74.2-74.3 (Other business services).
  - ❖ For Canada and Korea, the data refer to the manufacturing sector only. For Brazil, the data refer to manufacturing and mining only.
  - ❖ Total economy: Manufacturing + Services + NACE sections C (Mining and quarrying) and E (Electricity, gas and water supply).
- Size classes
  - ❖ SMEs: firms with 10-249 employees (5-249 for Australia).
  - ❖ Large firms: 250+ employees.

An additional dimension that is briefly addressed in this chapter is the use of different methods of weighting innovation survey results in order to make them representative for the full population of firms. There is increasing interest in examining alternative methods of weighting innovation data. The main issue is that with standard weighting methods (based on the number of firms), each firm is counted equally, regardless of its size. This may be useful and appropriate for a number of objectives, in particular those focused on firms' behaviour. However, for overall economic impact, standard weights may be a less accurate measure. For example, the economic impact of a product innovation in a large firm will be much larger, other things being equal, than the impact of one in a small firm. This may also be relevant for international comparisons as the distribution of firms according to size varies across countries, in particular as regards firms with over 1 000 employees. This suggests the value of examining alternative measures that take account of firm size, and the most commonly proposed of these is weighting by the number of employees in each firm. In order to gain a more complete picture, all composite indicators presented here were compiled using weights based both on number of enterprises and on number of employees.

1.3. Simple indicators

As part of the project, a list of key indicators of innovation performance and other policy-relevant innovative activities was chosen. Indicators of innovation performance are based on the four types of innovations defined in the latest *Oslo Manual*, and on measures of novelty and diffusion. These concepts are described in Box 1.1.

Table 1.1 gives a list of the main simple innovation indicators which were tabulated (see Tables in Annex 1.A1).

The first five indicators concern product and process innovations, degree of novelty and whether innovations were developed partly or fully in-house (*i.e.* by the firm itself or together with others). Product and process innovations are often considered **technological** innovation, since firms that have product and/or process innovations have implemented new technology (either developed in-house or adopted) into their business. This measure encompasses the implementation of existing (new to the firm) and new technologies, thus capturing both creative innovation and diffusion.

In order to provide additional relevant information on technological innovations, the indicators also focus on individual elements of product and process innovations. Product innovations represent the final commercialisation of innovation activities on the firm's markets, and thus are of policy interest as a separate indicator. Process innovations involve improvements in firms' internal processes, through either the adoption of new technologies or in-house development. In-house process innovations are related to the concept of "user innovations" which has attracted substantial

Box 1.1. **Defining innovation**

The latest (third) edition of the *Oslo Manual* (OECD/Eurostat, 2005) defines innovation as the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations. This implicitly identifies the following four types:

- *Product* innovation: the introduction of a good or service that is new or significantly improved with respect to its characteristics or intended uses. This includes significant improvements in technical specifications, components and materials, incorporated software, user friendliness or other functional characteristics.
- *Process* innovation: the implementation of a new or significantly improved production or delivery method. This includes significant changes in techniques, equipment and/or software.
- *Marketing* innovation: the implementation of a new marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing.
- *Organisational* innovation: the implementation of a new organisational method in the firm's business practices, workplace organisation or external relations.

The first two types are traditionally more closely related to technological innovation (also referred to as TPP innovation). Firms are considered innovative if they have implemented an innovation during the period under review (the observation period is usually two to three years).

Measuring novelty and the diffusion of innovations

By definition, all innovation must contain a degree of novelty. The *Oslo Manual* distinguishes three relevant concepts: new to the firm, new to the market and new to the world. The first concept covers the diffusion of an existing innovation to a firm (the innovation may have already been implemented by other firms, but is new to the firm). Firms that first develop innovations (new to market or new to world) can be considered as drivers of the process of innovation. Many new ideas and knowledge originate from these firms, but the economic impact of the innovations will depend on their adoption by other firms. Information on the degree of novelty can be used to identify the developers and adopters of innovations, to examine patterns of diffusion and to identify market leaders and followers.

In addition, innovation surveys often collect information on the developer of an innovation, *i.e.* whether the innovation is developed mainly by the firm itself, together with others, or mainly by others. This is different from questions on the degree of novelty as enterprises may develop innovations that have already been implemented by others. It therefore indicates how innovative enterprises are, but not necessarily how novel their innovations are.

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Table 1.1. **Simple innovation indicators**

Technological innovation	
1.	Share of firms that introduced a product innovation
2.	Share of firms that introduced a process innovation
3.	Share of firms that introduced either a product or a process innovation ("innovative firms")
4.	Share of firms that developed in-house technological innovations (product or process)
5.	Share of firms that introduced a new-to-market product innovation
Non-technological innovation	
6.	Share of firms that introduced a marketing innovation
7.	Share of firms that introduced an organisational innovation
8.	Share of firms that introduced a non-technological innovation (marketing or organisational)
Inputs	
9.	Total expenditures on innovation [as a % of total turnover]
10.	Expenditure on innovation by type of expenditure (machinery acquisition, external knowledge, R&D, etc.) [as a % of total expenditure on innovation]
11.	Share of firms that performed R&D
12.	Share of firms that performed R&D on a continuous basis
Outputs	
13.	Share of turnover from product innovations [as a % of turnover]
14.	Share of turnover from new-to-market product innovations [as a % of turnover]
Key policy-relevant characteristics	
15.	Share of firms that were active on international markets (outside the home country)
16.	Share of firms that co-operated with foreign partners on innovation
17.	Share of firms that co-operated on innovation activities
18.	Share of firms that co-operated with universities/higher education or government research institutes
19.	Share of firms that received public financial support for innovation
20.	Share of firms that applied for one or more patents (to protect innovations)

interest recently and has been argued to be a major source of new knowledge creation (von Hippel, 2005; Nordic Council of Ministers, 2006).

The final two indicators deal with the distinction between creative activities and diffusion. In-house innovation captures actual development activities which, even for existing technologies, involve more learning and competence building than simple adoption of technologies. New-to-market product innovation isolates inventive activity, *i.e.* the development of products that do not yet exist on the firm's market.

The next group of indicators measures **non-technological** innovation, or the implementation of marketing and organisational innovations. Policy papers increasingly argue for a broad-based approach to innovation policy (European Commission, 2006; OECD, 2005) and a number of analyses have shown the positive role of organisational innovation in productivity growth (Brynjolfsson and Hitt, 2000; Murphy, 2002).

The third group concerns measures of innovation **inputs**. These includes R&D expenditures, but also broader measures of firms' acquisition of embodied and disembodied technology. The distribution of innovation expenditures also provides information on types of innovation activities, the share of expenditures devoted to creative activities, and the outward orientation of investment in innovation (*i.e.* external acquisitions rather than in-house R&D). Also included are the shares of firms with intramural R&D and of those that conduct R&D on a continuous basis. Both these indicators provide measures of the prevalence of firms involved in creative innovation activities, with R&D playing a more central role among those that conduct R&D on a continuous basis.

Quantitative innovation **output** indicators measure the impact and scope of innovation activity. The two indicators presented here measure the output of product innovations in terms of share of turnover: the first measures the share due to any product innovation, and the second the share due to product innovations that are new to the market.

The final group is composed of indicators that focus on aspects of relevance for **policy**. Internationalisation – activity on foreign markets and efforts to access international knowledge – is vital for maintaining competitiveness and is a central policy issue. The two indicators included here are the share of firms active on foreign markets and the share of firms that have collaborated with foreign partners on innovation.

The literature on innovation systems has long highlighted the importance for innovation of external sources of knowledge. Interaction with other enterprises or public research institutions can be valuable throughout the innovation process, from early development to product launch. The more recent concept of *open innovation* emphasises the role of external knowledge in successful innovation (Chesbrough, 2003). This makes co-operation on innovation an important policy objective, and many funding programmes make engaging in collaboration a condition of funding. Shares of firms with any type of collaboration on innovation provide an overall measure of active co-operation.

Co-operation with public research is of particular policy interest as governments strive to improve the return to public research through transfer of knowledge to the business sector. The indicators therefore include the shares of firms that receive public support for their innovation activities.

Finally, intellectual property rights are a widely discussed policy issue. The last indicator shows the share of firms that have applied for a patent.

Simple indicators: main results

This section summarises some of the main results from the analysis of the simple indicators which have included in detail in Annex 1.A1. Despite

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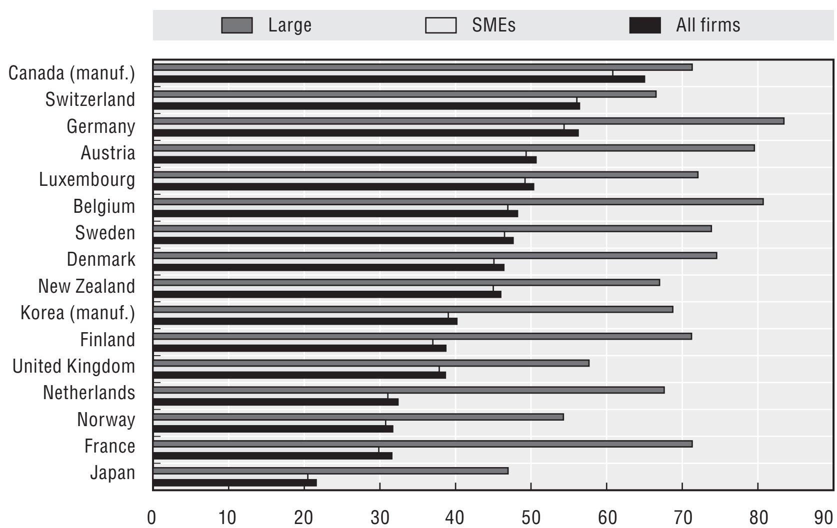
efforts to harmonise the methodology and definitions used to calculate these indicators, cross-country comparisons should be undertaken with caution given that there are differences in both response rates and in the methods used by countries to adjust for non-responses (both at the unit level, and for item non-response).[6]

Figure 1.1 shows the share of firms in each country with a product or process innovation. It ranges from over half of all firms in Austria, Germany, Luxembourg and Switzerland (as well as for manufacturing firms in Canada) to less than a third in France, Japan and Norway. Firm size is an important factor: differences among countries are much less pronounced when the focus is only on large firms (250 employees or more).

Figure 1.1. **Firms having introduced a product or process innovation, 2002-04**[1]

As a percentage of all firms



1. For New Zealand: 2004-05; for Japan: 1999-2001; for Switzerland: 2003-05.

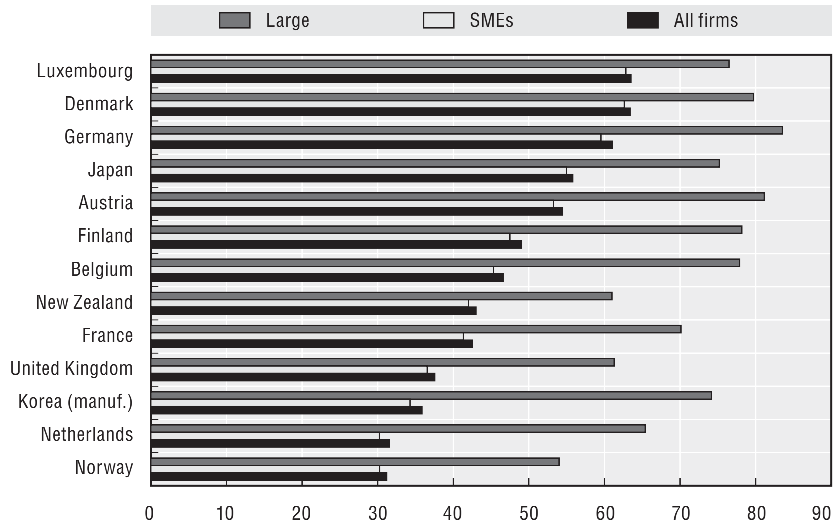
Source: OECD Innovation Microdata Project, 2008.

StatLink http://dx.doi.org/10.1787/545303250144

Figure 1.2 shows the share of firms that introduced a marketing or organisational innovation. There is again wide variation with shares ranging from around 60% of all firms in Denmark, Germany and Luxembourg to around one-third in the Netherlands and Norway. The shares are relatively similar for both service and manufacturing industries (unlike product/process innovations which are more prevalent in manufacturing firms than in services).

Figure 1.2. **Firms that introduced a marketing or organisational innovation, 2002-04**[1]

As a percentage of all firms



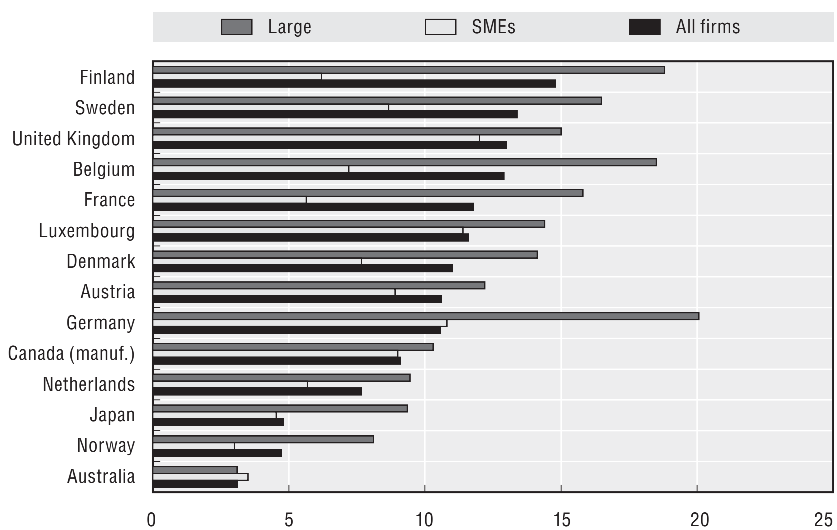
1. For New Zealand: 2004-05; for Japan: 1999-2001.

Source: OECD Innovation Microdata Project, 2008.

StatLink http://dx.doi.org/10.1787/545330160000

Figure 1.3. **Share of turnover from product innovations, 2002-04**[1, 2]

As a percentage of total turnover



1. For Australia: 2004-05; for Japan: 1999-2001.
2. Refers to all firms (not just product innovators).

Source: OECD Innovation Microdata Project, 2008.

StatLink http://dx.doi.org/10.1787/545333484521

Figure 1.3 shows the share of turnover from product innovations. Although the share is modest in most countries (less than 15%), it is around 20% for large firms in Belgium, Finland and Germany.

1.4. Composite indicators

The simple indicators presented above provide a range of useful information on innovation activities and performance across sectors and countries and have often been used as general indicators of innovativeness. For example, the share of enterprises having implemented a product or process innovation is very widely cited. However, as Arundel and Hollanders (2005) argue, these broad indicators fail to fully reveal the wide variation in innovative enterprises, give an incomplete picture of how innovative enterprises are in a sector or country, and may in some cases be misleading in international comparisons. This is because enterprises can innovate many ways. For example, some may be at the cutting edge for their market, developing products and technologies that are truly novel. Others may adopt new technologies developed by others rather than invest in development themselves. Some enterprises' innovation activities may be focused on new organisational practices or marketing methods.

The ability to classify and distinguish different types of innovative enterprises may be of great value for innovation policy design and for further analysis. A clear and detailed view of enterprise innovation can help to identify policy needs and to target innovation policies properly. For example, there is policy interest in identifying the enterprises that actively create new knowledge and in promoting their development. At the same time, to fully capitalise on this knowledge creation, a large share of enterprises must also adopt and implement this new knowledge in their own goods and services.

This section uses **composite** indicators (defined here as indicators that combine answers to several questions) based on firm-level data to examine a number of policy relevant factors as a way to better capture the diversity of innovative firms. Four composite indicators were developed and are presented below:

1. *Output-based innovation modes* which classify innovative firms according to the novelty of their innovations and whether innovation was conducted in house or mainly by others.
2. *Innovation status* classifies firms according to the inventiveness of their innovation activities and whether they engage in collaboration.
3. *Technological and non-technological innovation* examines the combination of product-process innovation with organisational and marketing innovations.
4. *Dual innovators* identifies firms that are active in both goods and service innovation.

Output-based innovation modes

The point of departure here is the classification developed by Arundel and Hollanders (2005), which builds on Tether (2001) and Arundel (2003). Arundel and Hollanders use a variety of CIS innovation variables to characterise four types of innovating enterprises, or "innovation modes". Their classification is based on two main criteria: the level of novelty of enterprises' innovations and the degree of creative in-house activity. The four innovation modes are: strategic innovators, intermittent innovators, technology modifiers and technology adopters (Arundel and Hollanders, 2005).

This indicator has proved useful in increasing our understanding of how firms innovate, but the classification presents difficulties. In particular, the construction of intermittent innovators and technology modifiers is based on various combinations of indicators, which makes it difficult to define them clearly. The classification also relies heavily on inputs, namely R&D (and whether it is continuous or occasional). While R&D is indeed an indicator of creativity, it may in some cases be more appropriate to focus more on output indicators when measuring innovativeness.

An alternative is to base the classification on innovation outputs, implicitly using them as criteria for both novelty and creativity. The emphasis on novelty follows Arundel and Hollanders' classification, but with greater emphasis on output measures, and in particular whether product innovations are new to the market or only new to the enterprise. The "market" is the enterprise's own competitive environment. Hence, a product innovation that is new to the market for an enterprise that operates on international markets may be considered more novel than a product innovation that is new only to the domestic market. On the other hand, a product innovation that is new to domestic markets may or may not be more novel than an innovation that already exists on international markets.

The following classification (Box 1.2) is based on innovative novelty and in-house development and, as for Arundel and Hollanders' innovation modes, it is only based on product and process innovation. Like theirs, this classification is mutually exclusive: enterprises are placed in the highest category for which they meet the criteria. Marketing and organisational innovation, and its combination with product/process innovation, is examined later in this chapter.

Figure 1.4 classifies product/process innovators in all firms according to the five output-based modes. As it shows, there is wide variation in the shares of product/process innovative firms and in the degree of novelty and international orientation.

Canada and Germany have the largest share of product/process innovators,[7] although the breakdown by types of innovation differs widely. In

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Box 1.2. Output-based innovation modes

New-to-market international innovators

These enterprises have introduced a product innovation that is new to international markets and have developed new products or processes in house. Their innovations have the highest degree of novelty; at the same time, in-house development (product or process innovation developed by the enterprise alone or together with others) indicates that these enterprises possess (at least some of) the capability to create novel products.

New-to-market domestic innovators

These enterprises have introduced product innovations that are new on domestic markets, but not necessarily on international markets. These enterprises only operate on domestic markets. As with new-to-market international innovators, innovations are at least partially developed in-house.

International modifiers

These enterprises have some in-house development activities, but product and/or process innovations already exist on international markets (new-to-enterprise product or process innovators). Innovations may or may not be new to domestic markets.

Domestic modifiers

These enterprises only operate on domestic markets. Product and/or process innovations already exist on domestic markets (new-to-enterprise domestic product or process innovators). These enterprises are adopters that are able to adopt and implement the new technologies themselves.

Adopters

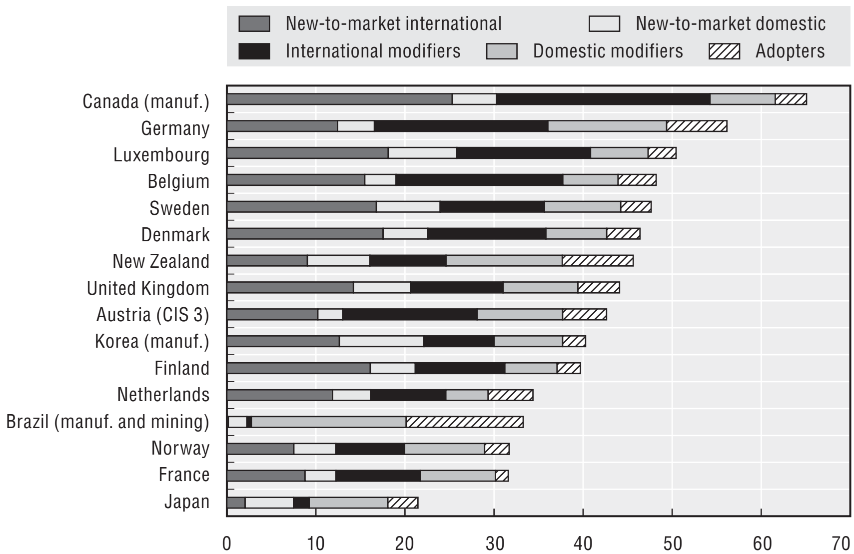
These enterprises have not developed product or process innovations in house, but have had them developed by others. This group thus includes all product and process innovators that have had all their product or process innovations developed externally, regardless of novelty.

terms of new-to-market international innovators, Germany's share is lower than that of a number of other countries. Its high share of innovative firms is largely due to innovation based on existing products and technologies on both international and domestic markets. In contrast, Canada has a high share of new-to-market international innovators and a high share of international innovators overall.

After Canada and Germany, the largest shares of innovators are found in Belgium, Luxembourg, and Sweden. Belgium has a particularly high share of innovators that operate on international markets. After Canada, Denmark and Luxembourg have the largest shares of new-to-market international

Figure 1.4. **Output-based modes, all firms**

2002-04[1]



1. For New Zealand: 2004-05; for Japan: 1999-2001; for Brazil: 2003-05; for Austria 1998-2000.

Source: OECD Innovation Microdata Project, 2008.

StatLink http://dx.doi.org/10.1787/545437206154

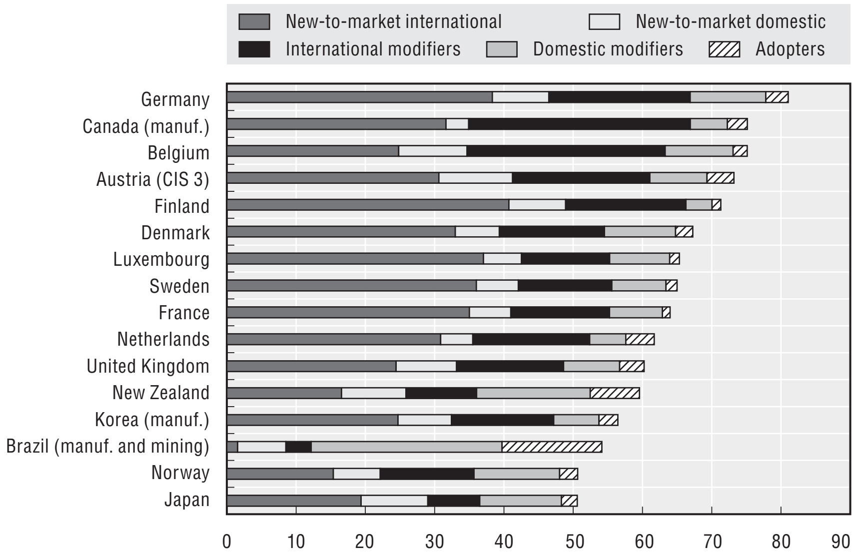
innovators, which represent over a third of their innovative firms. While shares of innovative firms are smaller in the Netherlands, international new-to-market innovators have a relatively high share.

Compared to other countries, Japan has a relatively large share of innovative firms that are new-to-market domestic innovators or domestic modifiers. This reflects in part the size of the Japanese economy and the relatively small share of firms that are active on international markets. New Zealand is much smaller but also has a relatively small share of firms operating on international markets; this is apparent in large shares of domestic new-to-market innovators and modifiers. It also has a relatively large share of adopters. Brazil's profile is markedly different from other countries, with few new-to-market innovators and large shares of domestic modifiers and adopters.

Figure 1.5 shows output-based modes for all firms weighted by employment. This provides a better measure of overall economic impact and takes account of cross-country differences in firm size. The figure, which reflects the shares of employees in product/process innovative firms, shows large increases in innovative shares compared to those in Figure 1.4. As might be expected, almost all of the increase is for firms operating on international

Figure 1.5. **Output-based modes, all firms, employment weights**

2002-04[1]



1. For New Zealand: 2004-05; for Japan: 1999-2001; for Brazil: 2003-05.

Source: OECD Innovation Microdata Project, 2008.

StatLink http://dx.doi.org/10.1787/545453266714

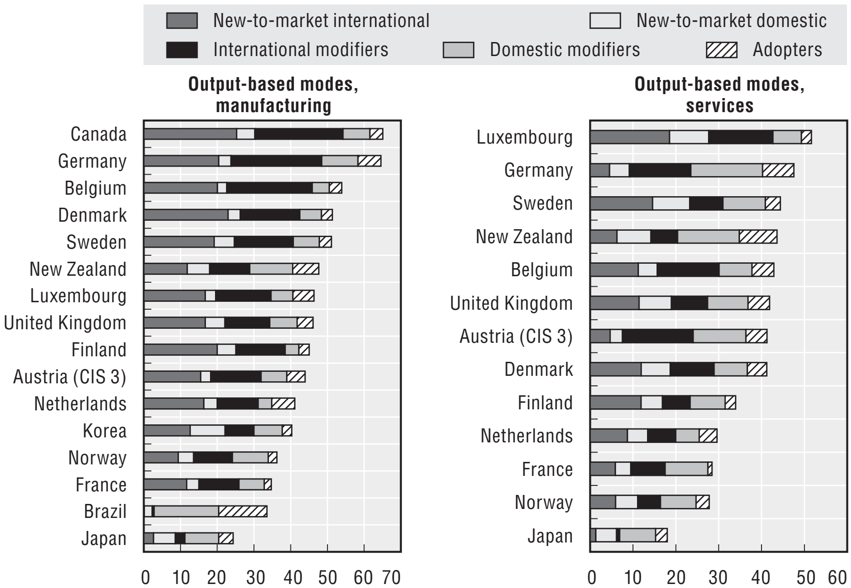
markets (both new-to-market international and international modifiers). For most countries the increase is of the order of around 50%. However, the increase is much larger in Brazil, Finland, France, Japan and the Netherlands, with a doubling of innovative shares for France and Japan and it gives Finland the highest share of new-to-market international innovators.

Figures 1.6 and 1.7 highlight sectoral differences by showing output-based modes for both manufacturing (including mining and quarrying) and services. With the exception of Luxembourg, shares of product/process innovative firms are significantly smaller in services, with differences of around 10 percentage points in most countries. Most of this difference concerns new-to-market international innovators, for which shares are much lower in services. This is particularly true for Austria and Germany. For services, shares of new-to-market international innovators are highest in Luxembourg, followed by Sweden.

It is argued that globalisation is an important driver of innovation activities, owing to increased knowledge transfer, international competition which pressures firms to innovate, and the opening up of new markets that increase potential gains from innovations. The output-based innovation modes can be used to examine the role of market orientation. Figure 1.8 shows

Figures 1.6. and 1.7. **Output-based innovation modes**

2002-04[1]



1. For New Zealand: 2004-05; for Japan: 1999-2001; for Brazil: 2003-05.

Source: OECD Innovation Microdata Project, 2008.

StatLink http://dx.doi.org/10.1787/545461280041

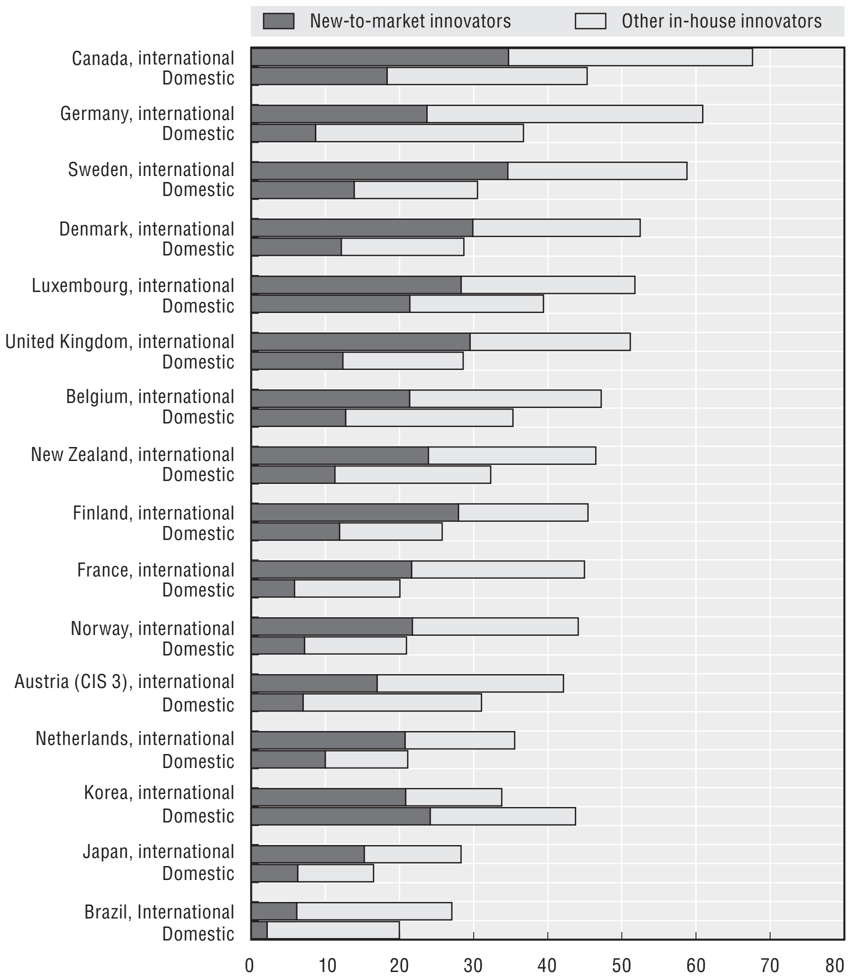
the shares of in-house innovative firms[8] operating only on domestic markets and of those operating internationally. With the exception of Korea, there are substantially higher shares of innovative firms among firms operating internationally than among those operating on domestic markets only. For France and Norway, shares are more than twice as large for firms that operate internationally. Furthermore, most of the difference in shares of innovative firms is for the new-to-market innovators. In most countries, a much larger share of innovators operating internationally have introduced new-to-market innovations than of those operating on domestic markets only. This suggests that exposure to international markets has a strong positive effect on firms' incentives to develop novel products.

Innovation status

Inventive or creative activities and diffusion are two important dimensions of innovation. Arundel and Hollanders (2006), as part of their work on the *European Innovation Trendchart*, develop an indicator to classify innovative enterprises on these two dimensions. Inventive in-house activities (which are denoted here as "formal innovation") are defined here by in-house R&D or a patent application. Diffusion (or "collaboration" in the broad sense)

Figure 1.8. **In-house innovators for domestic and international markets**

2002-04[1]



1. For New Zealand: 2004-05; for Japan: 1999-2001; for Brazil: 2003-05.

Source: OECD Innovation Microdata Project, 2008.

StatLink http://dx.doi.org/10.1787/545547151807

is present if enterprises' innovations were developed with or solely by others or if they engaged in active co-operation on innovations.[9] This indicator also reflects discussions with policy makers in which formal innovation activities and collaboration were mentioned as being relevant to innovation policy.

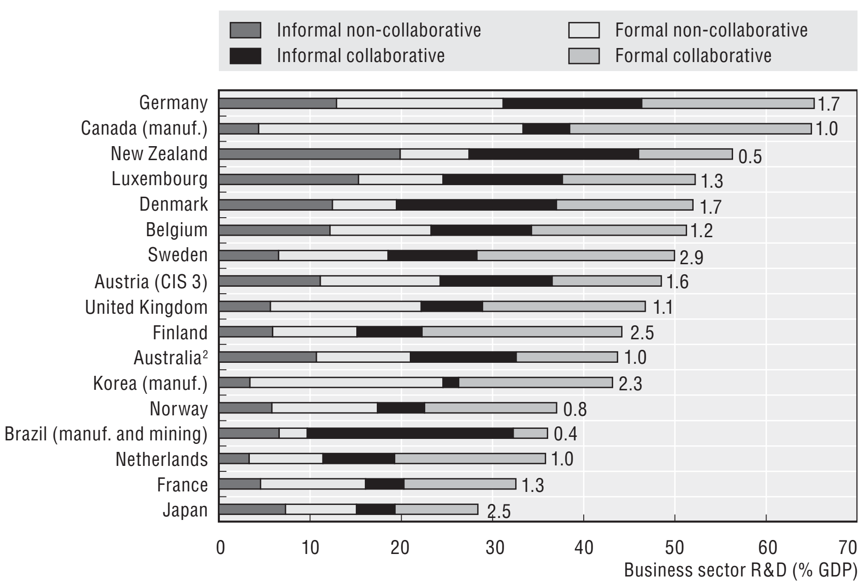
Innovation policy is concerned with promoting both formal innovation activities and collaboration. Formal innovation activities, such as R&D, are important for developing novel products and processes, new competences and new knowledge that can diffuse to other firms. By combining these two dimensions, four types of firms were identified:

- **Formal collaborative innovators** both carry out in-house creative activities and rely on diffusion in their innovation activities.
- **Formal non-collaborative innovators** carry out creative in-house activities, but do not actively access external knowledge.
- **Informal collaborative innovators** do not carry out creative in-house activities but actively access external knowledge.
- **Informal non-collaborators** do not have inventive in-house activities, nor do they actively access external knowledge.

An increasing amount of attention has been paid to the role of non-R&D innovation (NESTA, 2007; European Commission, 2008). To examine this, Figure 1.9 shows the distribution of firms active in innovation among the four categories and highlights the share engaging in formal and informal innovation and whether or not they collaborate.

Figure 1.9. **Innovation status, all firms**

2002-04[1]



1. For Australia and New Zealand: 2004-05; for Japan: 1999-2001; for Brazil: 2003-05.
2. Figures for Australia include firms with fewer than ten employees, and the reference period for the Australian 2005 Innovation Survey is two years rather than three. These differences can be expected to have a downwards impact on the share of innovation-active firms.

Source: OECD Innovation Microdata Project, 2008.

StatLink http://dx.doi.org/10.1787/545554241041

Korea and Canada (manufacturing only) have the highest share of innovators with formal innovation, followed by Finland, France, the Netherlands, Norway and the United Kingdom which have around 70% with formal innovation. Shares are smaller in the other countries, and under half in Australia, Brazil, Denmark, Luxembourg and New Zealand. If these figures are compared to business-sector R&D intensities (as a share of GDP) for 2005 (OECD, 2007), there are some surprising results. Countries such as France, the Netherlands, Norway and the United Kingdom have relatively low business R&D intensity (less than 1.5% of GDP), but high shares of innovative firms with formal innovation. In contrast, Japan and Sweden have significantly higher R&D intensities, but somewhat lower shares of firms with formal innovation. Similarly, Denmark's R&D intensity is relatively high, yet it has among the lowest shares of innovative firms with formal innovation (42%).

There may be several reasons. First, it appears that Finland, France, Norway and the United Kingdom have fairly large shares of firms that are active in formal innovation, but relatively few of these are highly R&D-intensive. The opposite appears to be true for Denmark.[10] Second, high shares of informal innovators may reflect greater emphasis on non-R&D forms of innovation. Finally, the possibility that some of these differences are due to differences in responses across countries cannot be ruled out.

Figures 1.10 and 1.11 focus on collaborating firms (in manufacturing and services), by type of innovation (formal/informal). In manufacturing, Germany has the highest share of such firms, with a large share engaging in formal innovation. Across countries, the great majority of manufacturing firms that collaborate engage in formal innovation. Overall the share of collaborators with informal innovation is much higher in services, with well over half of collaborating firms engaging in informal innovation in Australia, Austria, Denmark, Germany and New Zealand.

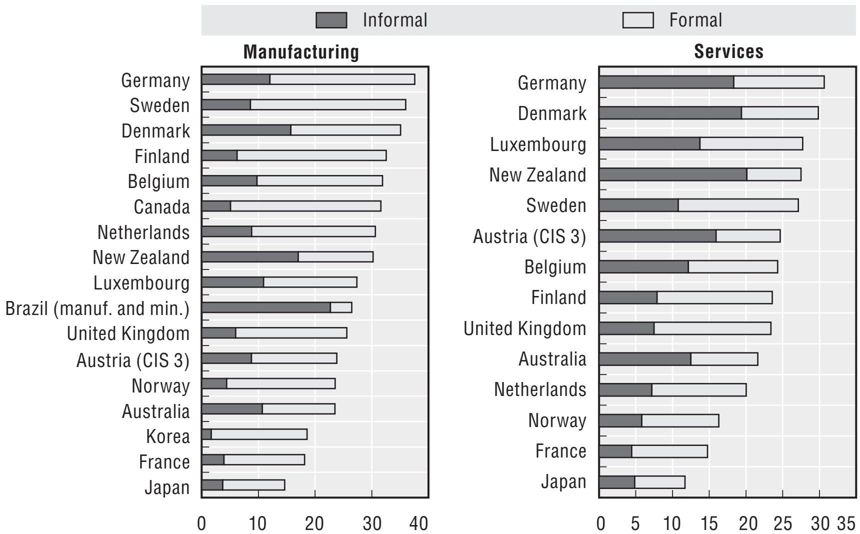
Dual innovators

Service innovation, or the development of new services, is not restricted to the services sector. "Traditional" manufacturing enterprises appear to be shifting an increasing share of their activities towards the production of services (Howells, 2004). However, statistical data on this trend and its scope are lacking, and there has been little analysis of innovation processes for developing services in manufacturing enterprises. The development and delivery of services may pose a whole new set of challenges for manufacturing enterprises, in terms of knowledge, organisational practices and distribution channels.

A special feature of the CIS 4 survey as compared to earlier innovation surveys is that it separates product innovations into goods and services. This makes it possible to identify service-innovating enterprises across industrial

Figure 1.10. and 1.11. **Share of firms collaborating on innovation**

2002-04[1]



1. For Australia and New Zealand: 2004-05; for Japan: 1999-2001; for Brazil: 2003-05.

Source: OECD Innovation Microdata Project, 2008.

StatLink http://dx.doi.org/10.1787/545565256172

classes in both the manufacturing and service sectors. It also allows for identifying enterprises that are active innovators in both goods and services, although it does not give information on whether the innovations are integrated or separate.

"Dual innovators" refers to enterprises that have implemented both a good and service product innovation. An analysis of dual innovators can help provide a picture of how prevalent service innovation is in manufacturing enterprises (and conversely, the prevalence of goods innovation in the services sector).

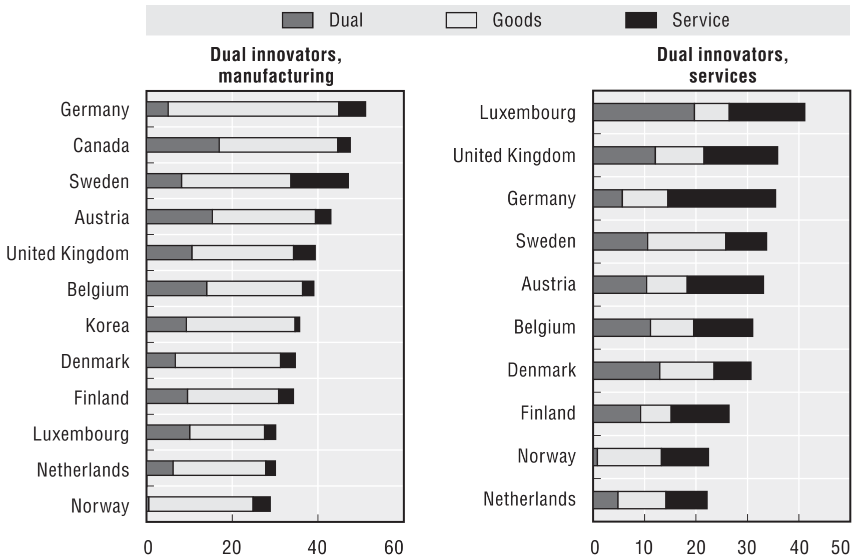
Figures 1.12 and 1.13 show the shares of firms that have implemented goods innovations, service innovations or both. As can be seen, significant shares of firms have implemented both goods and service innovations in both manufacturing and services. Within services a large share of product innovators have implemented goods innovations only; this is less apparent in manufacturing (except in Sweden).

Technological and non-technological innovation

The *Oslo Manual* definition of innovation includes four subtypes: product, process, organisational and marketing. An examination of simple combinations of innovation types may be useful for investigating a number of issues, particularly the prevalence of marketing and organisational innovation

Figure 1.12. and 1.13. **Dual innovators**

2002-04



Source: OECD Innovation Microdata Project, 2008.

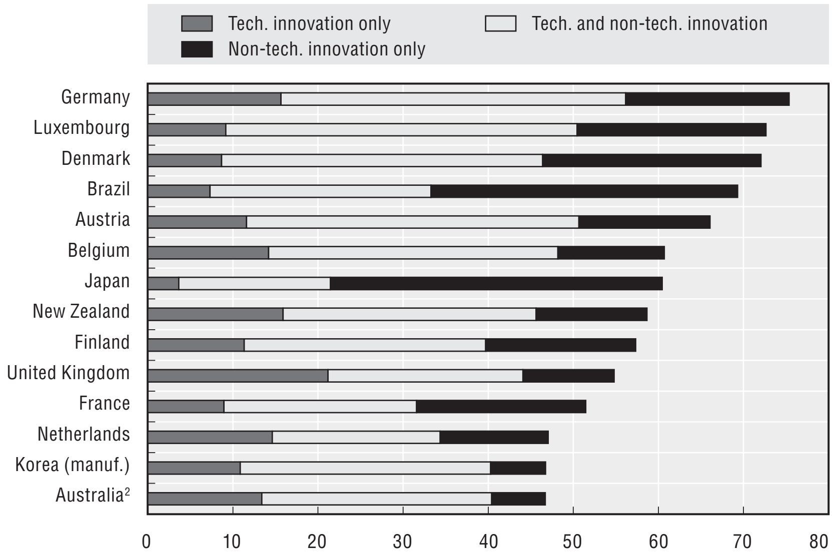
StatLink http://dx.doi.org/10.1787/545605152247

among product and process innovators. Product and process innovations are often considered technological innovations while marketing and organisational are thought of as non-technological. This interpretation is not always correct. For example, many product and process innovations, particularly in services, may not involve technology, while marketing or organisational innovations can include a technological component. Nevertheless, for ease of discussion, this simplification is used to classify enterprises into four groups:

- Technological innovators (product and/or process innovation only).
- Non-technological innovators (marketing and/or organisational innovation only).
- Technological and non-technological innovators.
- No innovations implemented.

Figure 1.14 shows technological and non-technological innovators for all firms. Japan has the largest share of non-technological innovators, followed by Brazil. In terms of overall shares of those with non-technological innovations (*i.e.* non-technological innovators and technological and non-technological innovators), Luxembourg and Denmark have the highest shares. There is a relatively low share of firms with technological innovations only; this

Figure 1.14. **Technological and non-technological innovators, all firms**
2002-04[1]



1. For Australia and New Zealand: 2004-05; for Japan: 1999-2001; for Brazil: 2003-05.
2. Figures for Australia include firms with fewer than ten employees, and the reference period for the Australian 2005 Innovation Survey is two years rather than three. Both these differences can be expected to have a downward impact on the share of innovation-active firms.

Source: OECD Innovation Microdata Project, 2008.

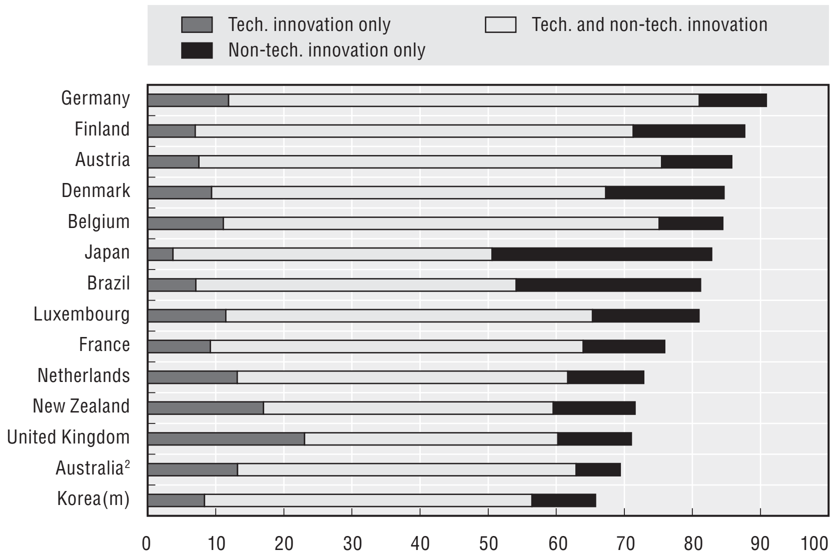
StatLink http://dx.doi.org/10.1787/545638655077

indicates the importance of non-technological innovation, both on its own and combined with technological innovation.

In Figure 1.15, shares are calculated using the number of employees as weights. In general, the impact is less marked than for output-based modes (which are solely based on product/process innovation). Weighting by employees results primarily in an increase in the share of technological and non-technological innovators, a sign that most large firms implement a broad range of innovations, and that shares of innovators with non-technological innovation are more constant across size classes than in the case of product/process innovation. Country comparisons show only a few changes in relative performance, with relative shares increasing for Austria and Finland, and decreasing for Luxembourg.

Figure 1.15. **Technological and non-technological innovators, all firms, employment weighted**

2002-04[1]



1. For Australia and New Zealand: 2004-05; for Japan: 1999-2001; for Brazil: 2003-05.

Source: OECD Innovation Microdata Project, 2008.

StatLink *http://dx.doi.org/10.1787/545735812083*

1.5. Conclusions

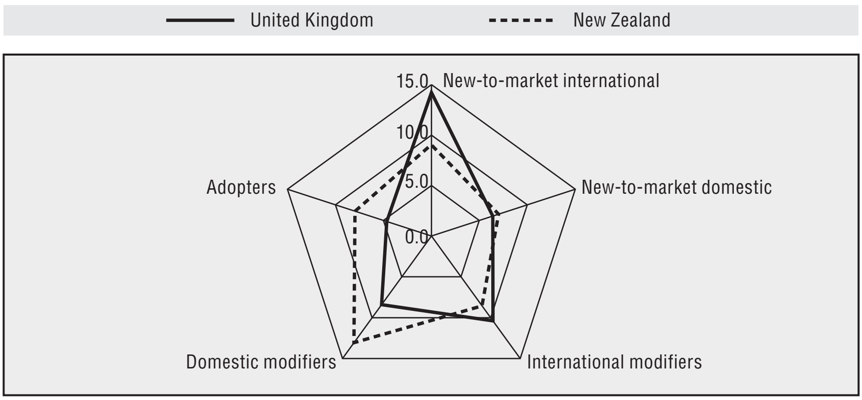
This chapter has presented a number of simple and composite indicators based on data from innovation surveys. It has aimed to address a lack of international comparisons of OECD countries and insufficient exploitation of innovation data for policy purposes. The composite indicators provide a more detailed picture of innovative activities across OECD countries than that provided by a single indicator such as innovation rates (share of product/process innovative firms) and address three broad issues:

- Novelty and creativity: output-based innovation modes.
- Inventiveness and collaboration: innovation status.
- Complementarities in innovation processes: technological and non-technological innovation, as well as dual innovators (firms developing both goods and service innovations, whether in manufacturing or in services).

Such indicators can be used for benchmarking purposes to complement more general indicators such as innovation rates. For example, New Zealand and the United Kingdom with similar overall innovation rates (around 45%) have clearly distinct profiles in terms of innovation modes, with a significantly

Figure 1.16. **Output-based innovation modes in New Zealand (2004-05) and the United Kingdom (2002-04)**

All sectors



Source: OECD Innovation Microdata Project, 2008.

StatLink http://dx.doi.org/10.1787/545745158341

higher share of modifiers and adopters in New Zealand and new-to-market international innovators in the United Kingdom (Figure 1.16).

These indicators only provide a few examples of how data from innovation surveys can be used to identify and examine different modes of innovation. There are a number of possibilities for further analysis. One example is the analysis of open innovation practices (Herstad *et al.*, 2008). In addition, analysis of these indicators could be complemented by econometric analysis of the innovation performance of different types of innovation modes. Finally, other methods can be used to identify innovation modes. One is the use of exploratory analysis (such as factor analysis) to identify the presence of different innovation strategies (see Chapter 2).

This chapter shows that international comparisons of innovation are indeed possible. However, they are subject to limitations. First, innovation surveys are not fully harmonised in all countries, and even harmonised surveys such as CIS can be subject to differences in interpretation by respondents in different countries. While the *Oslo Manual* and EU efforts to harmonise innovation surveys have made great progress in creating internationally comparable data, national differences still exist. On the other hand, differences exist and are accepted in other type of data and such differences in innovation data should not be over-emphasised. Second, statistical measures of the precision of data estimates would greatly facilitate international comparison, by showing which country differences are in fact statistically significant. While this is feasible, it would be time-consuming and is beyond the scope of the present project. Finally, all indicators here are solely

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based on innovation survey data, which greatly restricts the possibilities of analysis. Work to link different data sources, in particular internationally co-ordinated efforts, would be very beneficial. Examples might include linking innovation data to R&D data, structural business statistics, and patent data, among many other possibilities.

Notes

1. This introduction draws in part on an early contribution to this project by Anthony Arundel.
2. The United States is a notable exception, as no official innovation survey based on the *Oslo Manual* framework exists at this time.
3. See European Commission (2008) for the most recent edition.
4. Some editions of the OECD's *Science, Technology and Industry Scoreboard* have included a limited number of such indicators (see for example OECD, 2007).
5. We wish to thank the countries that participated in this part of the project: Australia, Austria, Belgium, Brazil, Canada, Denmark, Finland, France, Germany, Japan, Korea, Luxembourg, the Netherlands, New Zealand, Norway, Sweden, Switzerland and the United Kingdom.
6. Annex A includes some information by country on overall response rates and the methods used by countries to adjust their data (such as non-respondent surveys, or imputation), but this report does not include detailed measures of the statistical precision of each estimate (such as coefficients of variation), which would be needed to assess whether country differences are statistically significant. This is an area to be further explored in follow-up work.
7. Note that results for Canada are for manufacturing only, which tends to have a higher share of innovative firms than within services. Considering the manufacturing sector on its own, shares of product-process innovators are about equal for Canada and Germany. See Figure 1.6 below.
8. Using output-based innovation modes, it is not possible to divide adopters according to market orientation.
9. This is broader that the notion of "co-operation" as measured in the simple indicators, which only measures enterprises engaged in active co-operation and excludes enterprises with innovations developed with or solely by others (see Tables S.17 to S.19).
10. Analysis in the NIND (Policy Relevant Nordic Innovation Indicators) project lends some support to this, by showing that Denmark's relatively high R&D intensity is predominantly due to activities in the pharmaceuticals sector, with much lower R&D patterns, similar to Norway's, in all other sectors (Nilsson and Pettersson, 2008).

References

Åkerblom, M. *et al*. (2008), "Policy Relevant Nordic Innovation Indicators – Final Report".

Arundel, A. (2003), "The Knowledge Economy, Innovation Diffusion, and the CIS", Proceedings of the 21st CEIES Seminar, *Innovation Statistics – More than R&D Indicators*

(Athens, 10-11 April 2003), Eurostat, General Statistics, European Commission, Luxembourg.

Arundel, A. (2007), "Innovation survey indicators: What Impact on Innovation Policy", *in* OECD (2007), *Science, Technology and Innovation Indicators in a Changing World – Responding to Policy Needs*, proceedings of the *OECD Blue Sky II Forum*, Ottawa 25-27 September, OECD.

Arundel, A. and H. Hollanders (2005), "EXIS: An Exploratory Approach to Innovation Scoreboards", Brussels, European Commission, DG Enterprise.

Arundel, A. and H. Hollanders (2006), *2006 European Innovation Scoreboard Methodology Report: Searching the Forest for the Trees – "Missing" Indicators of Innovation, Brussels*, European Commission, DG Enterprise.

Bloch, C. *et al.* (2007), "Development and Analysis of Innovation Indicators in the Nordic Countries Based on CIS Surveys", NIND project report.

Brynjolfsson, E. and L.M. Hitt (2000), "Beyond Computation: Information Technology, Organisational Transformation and Business Performance", *Journal of Economic Perspectives*, 14, 23-48.

Chesbrough, H. (2003), "Open Innovation: The New Imperative for Creating and Profiting from Technology", Harvard University Press, Cambridge, MA.

European Commission (2006), "Putting Knowledge into Practice: A Broad-based Innovation Strategy for the EU", COM (2006) 502.

European Commission (2008), *European Innovation Scoreboard 2007 – Comparative Analysis of Innovation Performance*, PRO INNO Europe/INNO-Metrics, February.

Herstad, S. *et al.* (2008), "Open Innovation and Globalisation: Theory, Evidence and Policy Implications", Vision Era-Net project report.

von Hippel, E. (2005) *Democratising Innovation*, MIT Press, Cambridge, MA.

Howells, J. (2004), "Innovation, Consumption and Services: Encapsulation and the Combinatorial Role of Services", *The Service Industries Journal, No.* 24, 19-36.

Murphy, M. (2002), "Organisational Change and Firm Performance", STI Working Paper 2002/14, OECD.

National Endowment for Science, Technology and the Arts (NESTA) (2007), *Hidden Innovation – How Innovation Happens in Six "Low Innovation" Sectors,* June.

Nilsson, R. and I. Pettersson (2008), *Comparison of Research and Development in the Nordic Countries*, Report for the NIND project – Policy Relevant Nordic Innovation Indicators.

Nordic Council of Ministers (2006), *Understanding User-driven Innovation*, TemaNord, 2006:522.

OECD (2005), *Governance of Innovation Systems – Synthesis Report*, Vol. 1, OECD, Paris.

OECD (2007), *OECD Science, Technology and Industry Scoreboard 2007 – Innovation and Performance in the Global Economy*, OECD, Paris.

OECD/Eurostat (2005), *Oslo Manual* – Proposed Guidelines for Collecting and Interpreting Innovation Data, 3rd edition, OECD, Paris.

Tether, B.S. (2001), "Identifying Innovation, Innovators and Innovative Behaviours: A Critical Assessment of the Community Innovation Survey (CIS)", CRIC Discussion Paper No. 48, CRIC, University of Manchester and UMIST, Manchester.

ANNEX 1.A1

Statistical Tables

Section A: Simple indicators (S-tables)

Table S.1. **Firms having introduced a product innovation**

As a % of all firms

	All firms	SMEs	Large	Manufacturing	Services
Australia[1]	24.0	23.7	32.5	26.8	18.6
Austria	37.8	36.5	67.9	43.4	33.1
Belgium	35.0	33.8	65.3	39.1	31.5
Canada (manuf.)[2]	n.a.	44.4	52.4	47.6	n.a.
Denmark	32.8	31.5	59.5	34.6	30.7
Finland	29.7	28.1	58.5	34.7	26.2
France	19.4	17.8	57.3	23.3	15.8
Germany	43.3	41.3	71.9	52.2	35.8
Japan	17.3	16.3	40.6	19.8	14.6
Korea (manuf.)	n.a.	34.7	60.8	35.7	n.a.
Luxembourg	38.6	37.1	66.2	31.3	40.7
Netherlands	24.0	23.0	51.8	29.2	20.2
New Zealand[3]	35.0	34.0	52.0	37.0	33.0
Norway	25.4	24.6	44.2	28.9	22.4
Sweden	37.1	36.1	57.9	37.9	36.5
Switzerland	47.6	47.2	60.7	59.3	40.8
United Kingdom	32.7	32.1	49.0	35.8	30.8

1. Two-year reference period and includes firms with fewer than ten employees for manufacturing/services groupings.
2. Lower threshold is more than 20 employees and more than CAD 250 000 in revenues.
3. Two-year reference period (2004-05).

StatLink http://dx.doi.org/10.1787/547410003558

Table S.2. **Firms having introduced a process innovation**

As a % of all firms

	All firms	SMEs	Large	Manufacturing	Services
Australia[1]	28.7	28.1	46.0	27.3	20.7
Austria	40.4	39.1	70.5	44.5	36.5
Belgium	36.2	35.0	66.9	42.4	30.7
Canada (manuf.)[2]	n.a.	46.3	60.2	50.0	n.a.
Denmark	32.8	31.4	62.6	39.5	26.3
Finland	27.8	26.2	59.5	30.7	25.3
France	25.3	23.8	59.4	27.4	23.2
Germany	36.2	34.3	64.1	40.8	31.9
Japan	11.7	10.9	29.2	12.7	10.5
Korea (manuf.)	n.a.	21.3	50.7	22.5	n.a.
Luxembourg	35.9	34.6	60.3	32.6	36.9
Netherlands	22.4	21.1	55.7	29.0	17.3
New Zealand[3]	28.0	27.0	48.0	29.0	27.0
Norway	19.1	18.2	40.7	22.2	16.5
Sweden	31.9	30.7	60.2	37.1	27.2
Switzerland	36.5	35.8	54.3	46.3	30.6
United Kingdom	20.1	19.4	38.2	23.6	17.7

1. Two-year reference period and includes firms with fewer than ten employees for manufacturing/services groupings.
2. Lower threshold is more than 20 employees and more than CAD 250 000 in revenues.
3. Two-year reference period (2004-05).

StatLink http://dx.doi.org/10.1787/547434140531

Table S.3. **Firms having introduced either a product or a process innovation**

As a % of all firms

	All firms	SMEs	Large	Manufacturing	Services
Australia	n.a.	n.a.	n.a.	n.a.	n.a.
Austria	50.6	49.4	79.5	55.4	46.4
Belgium	48.2	46.9	80.7	54.0	43.2
Canada (manuf.)[1]	n.a.	60.8	71.3	65.0	n.a.
Denmark	46.4	45.1	74.5	51.3	41.2
Finland	38.7	37.0	71.2	44.8	33.5
France	31.6	29.9	71.3	35.0	28.4
Germany	56.2	54.4	83.4	65.9	47.9
Japan	21.6	20.5	46.9	24.4	18.5
Korea (manuf.)	n.a.	39.0	68.7	40.2	n.a.
Luxembourg	50.3	49.2	72.1	47.2	51.2
Netherlands	32.4	31.1	67.6	39.5	27.0
New Zealand[2]	46.0	45.0	67.0	48.0	44.0
Norway	31.7	30.8	54.3	36.3	27.8
Sweden	47.6	46.5	73.8	51.3	44.4
Switzerland	56.4	56.1	66.5	67.2	50.0
United Kingdom	38.7	37.9	57.6	41.9	36.5

1. Lower threshold is more than 20 employees and more than CAD 250 000 in revenues.
2. Two-year reference period (2004-05).

StatLink http://dx.doi.org/10.1787/547460738027

Table S.4. **Firms having developed an in-house technological innovation (product or process)**

As a % of all firms

	All firms	SMEs	Large	Manufacturing	Services
Australia	n.a.	n.a.	n.a.	n.a.	n.a.
Austria	32.9	31.7	59.9	38.4	28.2
Belgium	36.7	35.4	67.4	41.8	32.1
Canada (manuf.)[1]	n.a.	45.5	53.2	48.6	n.a.
Denmark	42.7	41.3	72.3	48.3	36.7
Finland	25.9	24.5	52.0	31.2	21.8
France	30.2	23.8	59.4	27.4	23.2
Germany	36.0	40.1	64.7	46.2	27.3
Japan	18.1	17.0	43.4	20.5	15.5
Korea (manuf.)	n.a.	12.4	32.0	13.1	n.a.
Luxembourg	37.6	36.2	64.7	36.5	37.9
Netherlands	27.5	26.2	61.3	33.4	23.0
New Zealand[2]	38.0	37.0	58.0	41.0	35.0
Norway	29.0	28.1	51.3	33.9	24.8
Sweden	44.2	43.0	71.8	48.0	40.9
Switzerland	30.9	30.5	41.4	39.3	26.1
United Kingdom	34.0	33.2	53.9	37.9	31.3

1. Lower threshold is more than 20 employees and more than CAD 250 000 in revenues.
2. Two-year reference period (2004-05).

StatLink http://dx.doi.org/10.1787/547473780152

Table S.5. **Firms having introduced a new-to-market product innovation**

As a % of all firms

	All firms	SMEs	Large	Manufacturing	Services
Australia[1]	11.8	11.4	21.8	15.0	8.1
Austria	25.4	24.2	53.0	28.6	22.7
Belgium	20.9	19.9	43.9	23.8	18.2
Canada (manuf.)[2]	n.a.	28.8	36.3	31.0	n.a
Denmark	24.8	23.9	45.0	26.8	22.4
Finland	21.5	20.2	44.1	26.1	18.2
France	12.6	11.3	42.0	15.6	9.7
Germany	17.5	16.2	37.3	25.5	10.5
Japan	11.5	10.9	25.9	13.6	9.3
Korea (manuf.)	n.a.	20.4	41.1	21.2	n.a.
Luxembourg	27.0	25.7	51.5	21.2	28.7
Netherlands	16.2	15.4	37.6	20.6	12.8
New Zealand[3]	21.0	20.0	34.0	22.0	19.0
Norway	12.9	12.5	22.7	13.8	12.2
Sweden	26.2	25.4	43.9	25.9	26.5
Switzerland	19.9	19.8	24.0	24.9	17.1
United Kingdom	19.3	18.8	31.3	21.1	18.2

1. Two-year reference period and includes firms with fewer than ten employees for manufacturing/services groupings.
2. Lower threshold is more than 20 employees and more than CAD 250 000 in revenues.
3. Two-year reference period (2004-05).

StatLink http://dx.doi.org/10.1787/547475224860

Table S.6. **Firms having introduced a marketing innovation**

As a % of all firms

	All firms	SMEs	Large	Manufacturing	Services
Australia	n.a.	n.a.	n.a.	n.a.	n.a.
Austria	27.3	26.5	45.1	26.6	27.9
Belgium	24.3	23.3	49.4	24.3	24.2
Canada	n.a.	n.a.	n.a.	n.a.	n.a.
Denmark	20.9	20.5	30.0	18.1	24.1
Finland[1]	24.0	23.1	41.7	27.3	21.9
France	18.3	17.4	40.4	15.2	21.6
Germany	25.2	23.9	43.5	28.1	23.1
Japan	8.3	8.1	13.9	7.7	9.1
Korea (manuf.)	n.a.	21.6	39.2	22.3	n.a.
Luxembourg	30.2	29.8	38.2	22.5	32.5
Netherlands	13.2	12.6	31.7	12.6	13.7
New Zealand[2]	28.0	27.0	38.0	25.0	30.0
Norway	15.8	15.2	28.6	16.6	15.1
Sweden	n.a.	n.a.	n.a.	n.a.	n.a.
Switzerland	n.a.	n.a.	n.a.	n.a.	n.a.
United Kingdom	23.6	23.0	36.4	22.1	24.7

1. Refers to changes in marketing methods or strategy, and aesthetic changes of products.
2. Two-year reference period (2004-05).

StatLink http://dx.doi.org/10.1787/547488470636

Table S.7. **Firms having introduced an organisational innovation**

As a % of all firms

	All firms	SMEs	Large	Manufacturing	Services
Australia[1]	30.7	30.2	43.5	27.8	24.1
Austria	49.4	48.1	77.4	46.1	51.8
Belgium	39.4	38.1	70.3	39.9	38.8
Canada	n.a.	n.a.	n.a.	n.a.	n.a.
Denmark	57.9	57.1	76.2	55.3	61.0
Finland[2]	44.3	42.7	73.1	45.9	43.2
France	37.0	35.9	61.2	35.5	38.4
Germany	54.8	53.2	78.2	56.0	53.8
Japan	55.6	54.8	74.9	57.3	53.7
Korea (manuf.)	n.a	28.6	69.0	30.1	n.a.
Luxembourg	59.1	58.4	72.1	51.8	61.2
Netherlands	27.1	25.9	59.8	28.2	26.2
New Zealand[3]	32.0	31.0	52.0	30.0	34.0
Norway	24.1	23.2	46.3	23.9	24.3
Sweden	n.a.	n.a.	n.a.	n.a.	n.a.
Switzerland	n.a.	n.a.	n.a.	n.a.	n.a.
United Kingdom	31.2	30.2	54.8	30.1	32.0

1. Two-year reference period and includes firms with fewer than ten employees for manufacturing/services groupings.
2. Refers to changes in business strategy, organisational structure and external relations.
3. Two-year reference period (2004-05).

StatLink http://dx.doi.org/10.1787/547523150501

Table S.8. **Firms having introduced a non-technological innovation (marketing or organisational)**

As a % of all firms

	All firms	SMEs	Large	Manufacturing	Services
Australia	n.a.	n.a.	n.a.	n.a.	n.a.
Austria	54.5	53.3	81.1	52.6	55.8
Belgium	46.6	45.3	77.9	47.6	45.6
Canada	n.a.	n.a.	n.a.	n.a.	n.a.
Denmark	63.4	62.6	79.7	60.8	66.5
Finland[1]	49.0	47.5	78.2	52.0	46.8
France	42.5	41.3	70.1	40.8	44.3
Germany	61.1	59.5	83.5	63.7	58.9
Japan	55.8	55.0	75.2	57.8	53.7
Korea (manuf.)	n.a.	34.3	74.1	35.9	n.a.
Luxembourg	63.5	62.8	76.5	56.7	65.5
Netherlands	31.5	30.2	65.4	32.6	30.5
New Zealand[2]	43.0	42.0	61.0	41.0	45.0
Norway	31.2	30.3	54.0	32.1	30.5
Sweden	n.a.	n.a.	n.a.	n.a.	n.a.
Switzerland	n.a.	n.a.	n.a.	n.a.	n.a.
United Kingdom	37.5	36.5	61.3	36.8	38.0

1. See Tables S.6 and S.7 for definitions.
2. Two-year reference period (2004-05).

StatLink http://dx.doi.org/10.1787/547616324440

Table S.9. **Expenditure on innovation**

As a % of total turnover

	All firms	SMEs	Large	Manufacturing	Services
Australia[1]	2.3	1.5	2.8	3.4	1.9
Austria[2]	1.7	1.5	1.8	2.8	0.9
Belgium	2.0	1.2	2.6	4.3	0.7
Canada (manuf.)[3]	n.a.	6.3	5.8	6.6	n.a.
Denmark	2.7	2.1	3.3	4.2	1.6
Finland	n.a.	n.a.	n.a.	n.a.	n.a.
France	2.2	1.2	2.9	3.6	1.2
Germany	2.9	2.0	3.3	5.2	1.2
Japan	n.a.	n.a.	n.a.	n.a.	n.a.
Korea	n.a.	n.a.	n.a.	n.a.	n.a.
Luxembourg	2.6	2.7	2.6	3.3	2.4
Netherlands	1.3	0.8	1.7	2.6	0.4
New Zealand	n.a.	n.a.	n.a.	n.a.	n.a.
Norway	0.7	0.5	1.0	1.2	0.4
Sweden	4.7	4.4	4.9	5.6	3.7
Switzerland	4.8	4.8	5.4	4.9	4.7
United Kingdom	1.4	2.0	1.0	3.8	0.8

1. Includes firms with fewer than ten employees for manufacturing/services groupings.
2. CIS 3 data and quality problems.
3. Lower threshold is more than 20 employees and more than CAD 250 000 in revenues.

StatLink http://dx.doi.org/10.1787/547618487352

Table S.10. **Expenditure on innovation by type**

As a % of total innovation expenditure

	All firms	SMEs	Large	Manufacturing	Services
Australia	n.a.	n.a.	n.a.	n.a.	n.a.
Austria (CIS 3)					
Internal R&D	47.0	35.3	54.4	51.7	38.2
External R&D	6.2	6.6	5.9	5.4	7.6
Machinery	28.5	38.8	22.0	27.9	28.7
External knowledge	6.1	6.0	6.2	2.7	13.6
Other	12.2	13.3	11.5	12.3	11.8
Belgium					
Internal R&D	34.0	39.3	31.5	30.5	48.7
External R&D	12.7	6.2	15.9	13.7	10.0
Machinery, equipment, software	34.3	51.0	26.3	33.8	32.6
Other external knowledge	18.9	3.4	26.3	22.0	8.6
Canada	n.a.	n.a.	n.a.	n.a.	n.a.
Denmark					
Internal R&D	55.2	36.8	66.0	59.1	47.7
External R&D	12.2	9.7	13.7	15.5	5.8
Machinery, equipment, software	16.2	31.9	6.9	14.9	18.7
Other external knowledge	5.8	10.1	3.3	2.8	11.6
Other intramural	10.6	11.4	10.1	7.7	16.2
Finland	n.a.	n.a.	n.a.	n.a.	n.a.
France					
Internal R&D	68.4	62.4	70.0	68.8	67.0
External R&D	16.7	10.2	18.4	19.8	8.5
Machinery, equipment, software	12.5	10.2	9.4	9.7	19.9
Other external knowledge	2.4	3.3	2.2	1.6	4.7
Germany					
Internal R&D	43.9	36.8	45.5	47.7	31.4
External R&D	8.0	4.3	8.9	9.0	4.7
Machinery, equipment, software	26.7	35.4	24.9	23.8	35.6
Other external knowledge	3.0	3.2	3.0	2.7	4.1
Other intramural	18.3	20.4	17.8	16.8	24.2
Japan	n.a.	n.a.	n.a.	n.a.	n.a.
Korea (manuf.)					
Internal R&D	n.a.	43.5	45.6	43.7	n.a.
External R&D	n.a.	8.5	6.2	8.3	n.a.
Machinery	n.a.	22.6	18.3	22.3	n.a.
External knowledge	n.a.	3.8	4.8	3.9	n.a.
Other	n.a.	21.6	25.1	21.8	n.a.
Luxembourg					
Internal R&D	47.2	29.4	62.2	74.2	36.9
External R&D	4.5	4.8	4.2	1.3	5.7
Machinery, equipment, software	34.8	46.8	24.7	21.8	39.8
Other external knowledge	13.5	19.1	8.8	2.7	17.6

Table S.10. **Expenditure on innovation by type** *(cont.)*

As a % of total innovation expenditure

	All firms	SMEs	Large	Manufacturing	Services
Netherlands					
Internal R&D	59.7	41.8	67.1	64.8	43.9
External R&D	15.6	11.5	17.2	13.6	18.0
Machinery, equipment, software	22.6	44.1	13.7	19.9	34.5
Other external knowledge	2.2	2.6	2.0	1.7	3.5
New Zealand	n.a.	n.a.	n.a.	n.a.	n.a.
Norway					
Internal R&D	57.7	57.9	57.4	55.1	62.6
External R&D	18.2	16.5	20.0	18.3	17.9
Machinery, equipment, software	11.1	10.5	11.7	14.0	5.5
Other external knowledge	3.7	5.5	1.9	3.0	5.2
Other	9.3	9.6	8.9	9.6	8.7
Sweden					
Internal R&D	50.7	24.0	66.2	64.3	26.9
External R&D	13.2	4.2	18.4	15.8	8.5
Machinery, equipment, software	31.2	61.6	13.6	17.5	55.1
Other external knowledge	4.9	10.2	1.8	2.3	9.5
Switzerland	n.a.	n.a.	n.a.	n.a.	n.a.
United Kingdom					
Intramural R&D	25.6	19.9	30.8	30.4	19.8
Extramural R&D	6.2	4.1	8.1	6.5	6.0
Machinery, equipment, software	39.0	47.4	31.3	39.7	37.5
Other external knowledge	3.6	3.3	3.9	3.6	3.7
Training	4.6	5.1	4.1	3.8	5.4
Design	4.6	4.0	5.1	6.1	2.9
Marketing	16.5	16.3	16.7	10.0	24.7

StatLink http://dx.doi.org/10.1787/547624025640

Table S.11. **Share of turnover from product innovations**

As a % of total turnover[1]

	All firms	SMEs	Large	Manufacturing	Services
Australia[2]	3.1	3.5	3.1	3.7	2.5
Austria	10.6	8.9	12.2	15.7	7.4
Belgium	12.9	7.2	18.5	17.8	10.4
Canada (manuf.)[3]	n.a.	9.0	10.3	9.1	n.a.
Denmark	11.0	7.7	14.1	17.7	6.0
Finland	14.8	6.2	18.8	21.6	6.2
France	11.8	5.6	15.8	17.1	7.6
Japan	4.8	4.5	9.4	4.8	4.8
Luxembourg	11.6	11.4	14.4	7.3	12.8
Netherlands	7.7	5.7	9.5	12.2	5.2
New Zealand	n.a.	n.a.	n.a.	n.a.	n.a.
Norway	4.7	3.0	8.1	6.9	3.5
Sweden	13.4	8.7	16.5	16.6	9.8
Switzerland	n.a.	n.a.	n.a.	n.a.	n.a.
United Kingdom	13.0	12.0	15.0	12.0	13.0

1. Refers to all firms (not only product innovators).
2. Includes firms with fewer than ten employees for manufacturing/services groupings.
3. Lower threshold is more than 20 employees and more than CAD 250 000 in revenues.

StatLink http://dx.doi.org/10.1787/547626748420

Table S.12. **Share of turnover from new-to-market product innovations**

As a % of total turnover[1]

	All firms	SMEs	Large	Manufacturing	Services
Australia	n.a.	n.a.	n.a.	n.a.	n.a.
Austria	5.2	4.2	6.2	7.8	3.6
Belgium	4.8	3.4	6.1	6.3	3.8
Canada (manuf.)[2]	n.a.	4.7	5.3	5.0	n.a.
Denmark	5.2	3.9	6.5	8.5	2.7
Finland	9.7	2.7	13.0	15.3	2.3
France	6.2	2.8	8.3	8.3	4.4
Germany	7.6	2.6	9.4	11.3	5.1
Japan	2.2	2.1	3.2	2.4	2.0
Luxembourg	5.4	5.4	5.6	3.2	6.1
Netherlands	3.6	2.9	4.3	5.8	2.4
New Zealand	n.a.	n.a.	n.a.	n.a.	n.a.
Norway	1.2	0.8	2.0	1.9	0.8
Sweden	8.3	3.5	11.4	11.9	4.2
Switzerland	12.8	12.8	13.2	11.3	14.1
United Kingdom	4.0	4.0	4.0	3.0	4.0

1. Denominator refers to all firms (not only product innovators).
2. Lower threshold is more than 20 employees and more than CAD 250 000 in revenues.

StatLink http://dx.doi.org/10.1787/547636012370

Table S.13. **Firms that performed R&D**

As a % of all firms

	All firms	SMEs	Large	Manufacturing	Services
Australia	n.a.	n.a.	n.a.	n.a.	n.a.
Austria[1]	24.6	21.7	71.1	32.7	16.6
Belgium	27.3	25.8	65.8	35.2	20.3
Canada (manuf.)[2]	n.a.	49.3	62.6	53.2	n.a.
Denmark	20.8	19.1	58.3	27.7	13.8
Finland	30.0	28.0	67.1	37.9	22.8
France	22.9	21.2	61.2	27.7	18.3
Germany	35.1	33.0	65.8	47.3	24.3
Japan	21.8	20.7	47.9	27.9	15.0
Korea (manuf.)	n.a.	40.9	56.9	42.0	n.a.
Luxembourg	23.5	21.4	63.2	27.4	22.4
Netherlands	22.3	21.1	55.1	29.6	16.8
New Zealand[3]	14.0	13.0	34.0	19.0	9.0
Norway	25.1	24.1	50.4	32.4	18.8
Sweden	33.7	32.4	62.5	40.7	29.5
Switzerland	31.6	31.0	51.4	47.9	22.1
United Kingdom	33.2	32.4	53.5	40.2	28.3

1. CIS 3 data.
2. Lower threshold is more than 20 employees and more than CAD 250 000 in revenues.
3. One-year reference period (2005).

StatLink http://dx.doi.org/10.1787/547640220762

Table S.14. **Firms that performed continuous R&D**

As a % of all firms

	All firms	SMEs	Large	Manufacturing	Services
Australia	n.a.	n.a.	n.a.	n.a.	n.a.
Austria[1]	15.0	12.3	58.4	20.5	9.9
Belgium	18.3	16.9	52.7	22.7	14.2
Canada	n.a.	n.a.	n.a.	n.a.	n.a.
Denmark	10.8	9.3	43.4	14.5	7.0
Finland	17.5	15.2	60.2	22.7	12.9
France	12.0	10.6	46.3	14.6	9.6
Germany	19.1	16.9	52.2	26.7	12.5
Japan	14.2	13.0	42.8	17.9	10.1
Korea	n.a.	n.a.	n.a.	n.a.	n.a.
Luxembourg	16.6	14.7	52.9	21.2	15.3
Netherlands	15.9	14.7	48.6	21.6	11.5
New Zealand	n.a.	n.a.	n.a.	n.a.	n.a.
Norway	12.7	11.7	38.3	16.2	9.7
Sweden	17.7	16.3	49.6	20.8	16.2
Switzerland	16.3	15.3	44.5	28.4	9.2
United Kingdom	n.a.	n.a.	n.a.	n.a.	n.a.

1. CIS 3 data.

StatLink http://dx.doi.org/10.1787/547648025882

Table S.15. **Firms that were active on international markets**

As a % of all firms

	All firms	SMEs	Large	Manufacturing	Services
Australia	n.a.	n.a.	n.a.	n.a.	n.a.
Austria[1]	29.9	28.0	60.9	35.1	25.7
Belgium	67.9	67.5	77.7	77.6	59.6
Canada (manuf.)[2]	n.a.	67.7	84.5	72.9	n.a.
Denmark	58.7	58.2	70.2	69.0	47.9
Finland	n.a.	n.a.	n.a.	n.a.	n.a.
France	40.6	39.2	72.2	49.0	32.8
Germany	47.5	46.3	65.9	56.0	40.6
Japan	9.3	8.3	32.6	12.0	6.5
Korea (manuf.)	n.a.	37.9	73.5	39.3	n.a.
Luxembourg	80.5	79.9	91.2	78.2	81.1
Netherlands	55.4	54.8	70.3	58.7	53.0
New Zealand[3]	38.0	37.0	59.0	49.0	28.0
Norway	33.2	32.6	48.1	39.3	28.1
Sweden	48.2	47.1	74.3	57.3	43.1
Switzerland	28.7	28.1	45.2	48.5	17.1
United Kingdom	40.2	39.3	62.3	48.6	34.4

1. CIS 3 data.
2. Lower threshold is more than 20 employees and more than CAD 250 000 in revenues.
3. Two-year reference period (2004-05).

StatLink http://dx.doi.org/10.1787/547656405850

Table S.16. **Firms that received public financial support for innovation**

As a % of all firms

	All firms	SMEs	Large	Manufacturing	Services
Australia[1]	4.3	4.0	6.9	7.0	1.9
Austria	17.8	16.6	43.0	24.5	12.0
Belgium	11.7	11.0	27.3	16.9	6.9
Canada (manuf.)[2]	n.a.	36.6	59.2	40.4	n.a.
Denmark	7.8	7.3	18.6	12.6	2.9
Finland	15.2	13.6	43.9	23.0	7.6
France	9.0	8.2	27.8	13.1	5.0
Germany	9.2	8.1	25.2	13.2	5.4
Japan	5.9	5.6	12.7	7.8	3.7
Korea (manuf.)	n.a.	30.9	59.6	32.0	n.a.
Luxembourg	13.0	11.5	41.2	22.8	10.2
Netherlands	12.5	11.5	37.9	20.5	6.4
New Zealand	n.a.	n.a.	n.a.	n.a.	n.a.
Norway	16.3	15.8	27.4	22.7	10.8
Sweden	n.a.	n.a.	n.a.	n.a.	n.a.
Switzerland	4.1	3.9	10.1	5.7	3.2
United Kingdom	9.9	9.7	13.7	12.8	7.8

1. Two-year reference period and includes firms with fewer than ten employees for manufacturing/services groupings.
2. Lower threshold is more than 20 employees and more than CAD 250 000 in revenues.

StatLink http://dx.doi.org/10.1787/547673375473

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Table S.17. **Firms that co-operated on innovation activities**

As a % of all firms

	All firms	SMEs	Large	Manufacturing	Services
Australia[1]	10.6	10.4	15.8	11.2	9.0
Austria	9.1	7.7	40.2	10.8	7.6
Belgium	18.3	16.6	60.9	22.0	14.9
Canada (manuf.)[2]	n.a.	12.4	23.3	14.0	n.a.
Denmark	22.2	20.8	53.9	24.6	20.0
Finland	19.2	17.3	56.1	23.4	14.8
France	12.9	11.6	43.6	14.1	11.7
Germany	10.4	8.6	36.3	14.2	7.0
Japan	7.4	6.5	27.9	8.4	6.2
Korea (manuf.)	n.a.	32.9	49.3	34.0	n.a.
Luxembourg	15.9	14.8	38.2	17.9	15.4
Netherlands	13.2	12.0	47.3	18.4	9.2
New Zealand[3]	17.0	16.0	34.0	18.0	15.0
Norway	12.3	11.3	36.9	15.8	9.3
Sweden	21.4	20.0	53.5	26.0	18.6
Switzerland[4]	9.9	9.4	22.2	16.6	5.9
United Kingdom	15.8	15.3	27.7	14.7	16.7

1. Two-year reference period and includes firms with fewer than ten employees for manufacturing/ services groupings.
2. Lower threshold is more than 20 employees and more than CAD 250 000 in revenues.
3. Two-year reference period (2004-05).
4. Refers to collaboration on R&D.

StatLink http://dx.doi.org/10.1787/547736748323

Table S.18. **Firms that co-operated on innovation with higher education or government institutions**

As a % of all firms

	All firms	SMEs	Large	Manufacturing	Services
Australia	n.a.	n.a.	n.a.	n.a.	n.a.
Austria	5.7	4.5	31.9	6.6	4.8
Belgium	8.0	7.0	33.5	10.3	5.9
Canada (manuf.)[1]	n.a.	4.2	11.9	5.0	n.a.
Denmark	8.5	7.4	31.7	9.3	7.7
Finland	14.9	12.8	53.2	19.0	10.5
France	4.0	3.3	21.1	4.9	3.1
Germany	6.0	4.7	23.7	8.9	3.3
Japan	2.4	1.9	15.6	3.3	1.4
Korea (manuf.)	n.a.	16.8	29.8	17.7	n.a.
Luxembourg	6.7	5.6	27.9	10.7	5.6
Netherlands	4.8	4.0	26.1	6.8	3.1
New Zealand[2]	5.0	5.0	20.0	7.0	4.0
Norway	7.4	6.4	31.9	10.3	5.0
Sweden	9.3	8.0	39.4	13.6	5.8
Switzerland[3]	4.4	4.0	16.7	8.7	1.9
United Kingdom	6.3	5.9	14.9	6.8	5.9

1. Lower threshold is more than 20 employees and more than CAD 250 000 in revenues.
2. Refers to firms collaborating with universities, polytechnics, Crown Research institutes and other research institutes/institutions. Two-year reference period (2004-05).
3. Refers to collaboration on R&D.

StatLink http://dx.doi.org/10.1787/547741285320

Table S.19. **Firms that co-operated on innovation with foreign partners**

As a % of all firms

	All firms	SMEs	Large	Manufacturing	Services
Australia	n.a.	n.a.	n.a.	n.a.	n.a.
Austria	5.3	4.2	30.2	6.1	4.7
Belgium	13.5	11.3	51.0	15.7	10.1
Canada (manuf.)[1]	n.a.	8.8	19.5	10.2	n.a.
Denmark	14.8	13.5	44.2	16.5	13.3
Finland	13.3	11.2	51.6	16.9	9.8
France	6.2	5.0	31.9	7.4	5.0
Germany	4.8	2.9	32.4	7.6	2.1
Japan	1.2	0.9	9.9	1.6	0.8
Korea (manuf.)	n.a.	16.1	32.5	17.7	n.a.
Luxembourg	14.6	13.4	38.2	17.9	13.7
Netherlands	7.8	6.7	36.8	11.8	4.9
New Zealand[2]	8.0	8.0	24.0	8.0	8.0
Norway	7.9	7.1	27.4	10.1	6.0
Sweden	11.4	9.9	45.3	14.2	9.5
Switzerland[3]	6.4	6.0	19.1	11.0	3.8
United Kingdom	7.7	7.2	19.7	7.8	7.6

1. Lower threshold is more than 20 employees and more than CAD 250 000 in revenues.
2. Two-year reference period (2004-05).
3. Refers to collaboration on R&D.

StatLink http://dx.doi.org/10.1787/547758568344

Table S.20. **Firms that applied for one or more patents to protect their innovations**

As a % of all firms

	All firms	SMEs	Large	Manufacturing	Services
Australia	n.a.	n.a.	n.a.	n.a.	n.a.
Austria[1]	9.0	6.5	49.3	14.3	3.5
Belgium	5.9	5.2	22.5	7.9	4.3
Canada (manuf.)[2]	n.a.	10.7	21.1	12.2	n.a.
Denmark	11.7	10.7	32.1	16.3	7.1
Finland	8.4	6.7	38.6	12.2	5.0
France	9.4	8.1	38.2	12.0	6.8
Germany	14.5	12.5	43.6	24.1	5.9
Japan	8.6	7.4	35.9	11.3	5.5
Korea (manuf.)	n.a.	45.5	58.6	46.4	n.a.
Luxembourg	5.6	4.2	32.4	14.0	3.2
Netherlands	5.4	4.9	19.3	8.9	2.7
New Zealand	n.a.	n.a.	n.a.	n.a.	n.a.
Norway	7.6	6.9	23.9	9.4	6.0
Sweden	n.a.	n.a.	n.a.	n.a.	n.a.
Switzerland	8.0	7.4	25.8	14.8	4.1
United Kingdom	20.6	19.5	45.8	26.3	16.6

1. CIS 3 data.
2. Lower threshold is more than 20 employees and more than CAD 250 000 in revenues.

StatLink http://dx.doi.org/10.1787/547780822111

Section B: Composite indicators (C-tables)

Table C.1. **Output-based innovation modes, all sectors**

	New-to-market international	New-to-market domestic	International modifiers	Domestic modifiers	Adopters
Austria[1]	10.2	2.8	15.1	9.6	4.9
Belgium	15.5	3.5	18.7	6.2	4.3
Brazil	n.a.	n.a.	n.a.	n.a.	n.a.
Canada	n.a.	n.a.	n.a.	n.a.	n.a.
Denmark	17.6	5.0	13.3	6.8	3.7
Finland	15.5	5.1	9.7	5.9	2.5
France	8.8	3.5	9.5	8.4	1.4
Germany	12.4	4.1	19.5	13.3	6.8
Japan	2.1	5.4	1.8	8.8	3.4
Korea	n.a.	n.a.	n.a.	n.a.	n.a.
Luxembourg	18.1	7.7	15.0	6.5	3.1
Netherlands	11.9	4.3	8.4	4.8	5.0
New Zealand[2]	9.1	7.0	8.6	13.1	8.0
Norway	7.5	4.7	7.7	9.0	2.7
Sweden	16.8	7.2	11.7	8.6	3.4
United Kingdom	14.2	6.4	10.4	8.4	4.7

1. CIS 3 data.
2. Two-year reference period (2004-05).

StatLink http://dx.doi.org/10.1787/547811560768

Table C.2. **Output-based innovation modes, all sectors, employee-weighted**

	New-to-market international	New-to-market domestic	International modifiers	Domestic modifiers	Adopters
Austria[1]	30.6	10.6	19.8	8.3	3.9
Belgium	24.8	9.9	28.6	9.8	2.0
Brazil	n.a.	n.a.	n.a.	n.a.	n.a.
Canada	n.a.	n.a.	n.a.	n.a.	n.a.
Denmark	33.0	6.4	15.2	10.3	2.5
Finland	40.6	8.2	17.3	3.8	1.3
France	35.0	6.0	14.3	7.6	1.1
Germany	38.3	8.2	20.4	10.9	3.2
Japan	19.4	9.6	7.5	11.8	2.3
Korea	n.a.	n.a.	n.a.	n.a.	n.a.
Luxembourg	37.0	5.5	12.7	8.7	1.4
Netherlands	30.9	4.6	16.9	5.2	4.1
New Zealand[2]	16.6	9.3	10.2	16.4	7.1
Norway	15.4	6.8	13.5	12.4	2.6
Sweden	36.0	6.1	13.5	7.8	1.6
United Kingdom	24.4	8.7	15.5	8.1	3.5

1. CIS 3 data.
2. Two-year reference period (2004-05).

StatLink http://dx.doi.org/10.1787/547841228228

Table C.3. **Output-based innovation modes, manufacturing**

	New-to-market international	New-to-market domestic	International modifiers	Domestic modifiers	Adopters
Austria[1]	15.5	2.7	13.7	7.0	5.0
Belgium	20.1	2.5	23.3	4.6	3.4
Brazil[2]	0.2	2.1	0.5	17.6	13.1
Canada	25.3	5.0	24.0	7.3	3.5
Denmark	23.0	3.3	16.2	5.9	3.0
Finland	19.1	4.9	12.8	3.9	2.8
France	11.7	3.3	10.9	6.9	1.9
Germany	20.4	3.4	24.7	9.9	6.3
Japan	2.7	5.9	2.6	9.2	3.9
Korea	12.6	9.5	7.9	7.7	2.6
Luxembourg	16.7	2.8	15.1	6.0	5.7
Netherlands	16.4	3.6	11.2	3.7	6.3
New Zealand[3]	11.8	6.1	10.9	11.7	7.1
Norway	9.4	4.2	10.6	9.8	2.4
Sweden	19.2	5.5	16.0	7.1	3.3
United Kingdom	16.7	5.4	12.2	7.5	4.3

1. CIS 3 data.
2. Also includes mining.
3. Two-year reference period (2004-05).

StatLink http://dx.doi.org/10.1787/547850646477

Table C.4. **Output-based innovation modes, manufacturing, employee-weighted**

	New-to-market international	New-to-market domestic	International modifiers	Domestic modifiers	Adopters
Austria[1]	42.8	3.7	22.8	5.6	4.1
Belgium	39.4	1.9	28.7	3.9	1.7
Brazil[2]	1.3	7.0	3.7	28.0	14.4
Canada	31.6	3.3	32.0	5.4	2.9
Denmark	46.7	2.5	18.0	4.1	1.9
Finland	47.9	6.3	20.6	1.5	1.0
France	44.9	2.6	17.3	3.5	1.2
Germany	49.0	1.8	26.2	5.2	2.7
Japan	28.4	5.4	9.6	7.0	2.3
Korea	24.7	7.7	14.8	6.5	2.7
Luxembourg	54.3	1.1	14.2	2.7	1.8
Netherlands	40.2	3.2	17.1	3.3	4.4
New Zealand[3]	25.7	5.8	15.0	7.0	6.8
Norway	23.0	5.8	16.3	11.0	3.1
Sweden	46.1	3.1	16.9	5.0	1.7
United Kingdom	30.9	4.9	18.5	6.0	3.0

1. CIS 3 data.
2. Also includes mining.
3. Two-year reference period (2004-05).

StatLink http://dx.doi.org/10.1787/547884333165

Table C.5. **Output-based innovation modes, services**

	New-to-market international	New-to-market domestic	International modifiers	Domestic modifiers	Adopters
Austria[1]	4.7	2.9	16.5	12.3	4.9
Belgium	11.2	4.4	14.5	7.7	5.1
Brazil	n.a.	n.a.	n.a.	n.a.	n.a.
Canada	n.a.	n.a.	n.a.	n.a.	n.a.
Denmark	11.9	6.8	10.2	7.8	4.6
Finland	11.6	5.4	6.3	7.9	2.3
France	5.9	3.6	8.0	10.0	1.0
Germany	4.5	4.6	14.4	16.8	7.3
Japan	1.3	4.8	0.7	8.4	2.7
Korea	n.a.	n.a.	n.a.	n.a.	n.a.
Luxembourg	18.6	9.1	15.0	6.6	2.4
Netherlands	8.7	4.7	6.5	5.5	4.2
New Zealand[2]	6.3	7.9	6.2	14.4	8.8
Norway	5.9	5.2	5.3	8.3	3.1
Sweden	14.6	8.7	7.7	9.9	3.5
United Kingdom	11.4	7.5	8.4	9.4	5.0

1. CIS 3 data.
2. Two-year reference period (2004-05).

StatLink http://dx.doi.org/10.1787/548007537321

Table C.6. **Output-based innovation modes, services, employee-weighted**

	New-to-market international	New-to-market domestic	International modifiers	Domestic modifiers	Adopters
Austria[1]	11.4	21.6	15.2	12.5	3.6
Belgium	10.0	18.0	28.5	15.8	2.4
Brazil	n.a.	n.a.	n.a.	n.a.	n.a.
Canada	n.a.	n.a.	n.a.	n.a.	n.a.
Denmark	18.6	10.4	12.2	16.7	3.1
Finland	27.6	11.6	11.6	7.8	1.8
France	23.7	9.8	10.8	12.3	1.0
Germany	19.8	19.3	10.4	20.9	4.1
Japan	3.9	16.9	3.9	20.0	2.3
Korea	n.a.	n.a.	n.a.	n.a.	n.a.
Luxembourg	29.0	7.6	12.1	11.5	1.2
Netherlands	22.8	5.9	16.7	6.9	3.8
New Zealand[2]	7.0	13.0	5.2	26.3	7.4
Norway	6.9	7.9	10.4	13.9	2.1
Sweden	23.1	9.8	9.2	11.4	1.5
United Kingdom	17.2	13.1	12.0	10.5	4.2

1. CIS 3 data.
2. Two-year reference period (2004-05).

StatLink http://dx.doi.org/10.1787/548030086437

Table C.7. **Share of firms with co-operation in innovation by output-based modes, all sectors**

	New-to-market international	New-to-market domestic	International modifiers	Domestic modifiers	Adopters
Austria[1]	26.6	9.4	22.5	17.2	16.6
Belgium	46.4	45.2	33.1	31.7	17.9
Brazil	n.a.	n.a.	n.a.	n.a.	n.a.
Canada	n.a.	n.a.	n.a.	n.a.	n.a.
Denmark	53.2	54.4	42.8	35.0	23.8
Finland	56.4	43.6	40.1	41.0	17.6
France	51.6	54.3	36.5	26.8	30.6
Germany	29.6	15.8	17.7	10.7	4.9
Japan	41.8	33.9	36.3	24.6	16.6
Korea	n.a.	n.a.	n.a.	n.a.	n.a.
Luxembourg	41.5	24.8	28.5	15.2	11.2
Netherlands	50.7	40.3	37.5	31.8	25.3
New Zealand[2]	37.9	28.6	29.8	26.2	20.4
Norway	53.9	44.3	38.5	23.4	24.4
Sweden	54.6	41.1	41.4	29.9	28.7
United Kingdom	43.4	33.7	28.1	21.2	21.2

1. CIS 3 data.
2. Two-year reference period (2004-05).

StatLink http://dx.doi.org/10.1787/548125280836

Table C.8. **Share of firms with co-operation in innovation by output-based modes, manufacturing**

	New-to-market international	New-to-market domestic	International modifiers	Domestic modifiers	Adopters
Austria[1]	23.3	13.3	25.5	0.5	18.8
Belgium	54.9	38.7	33.5	12.1	24.9
Brazil[2]	22.2	16.3	12.2	4.0	0.9
Canada	29.5	24.1	16.2	13.0	13.0
Denmark	53.2	54.8	45.6	22.6	12.3
Finland	58.7	40.3	41.8	53.9	19.6
France	48.7	57.8	37.9	20.0	28.2
Germany	31.3	15.3	18.0	11.0	3.4
Japan	42.3	30.9	40.1	24.1	13.9
Korea	40.4	40.3	27.7	36.2	44.3
Luxembourg	57.8	37.6	26.9	27.3	100.0
Netherlands	57.0	44.1	43.1	34.1	27.9
New Zealand[3]	40.1	23.4	31.5	27.3	16.8
Norway	57.5	51.4	40.3	26.2	17.9
Sweden	60.8	43.5	44.8	32.8	35.0
United Kingdom	42.5	27.2	28.6	16.7	13.0

1. CIS 3 data.
2. Also includes mining.
3. Two-year reference period (2004-05).

StatLink http://dx.doi.org/10.1787/548126225275

Table C.9. **Share of firms with co-operation on innovation by output-based modes, services**

	New-to-market international	New-to-market domestic	International modifiers	Domestic modifiers	Adopters
Austria[1]	38.1	5.4	19.9	27.2	14.3
Belgium	32.2	48.8	32.5	42.5	13.8
Brazil	n.a.	n.a.	n.a.	n.a.	n.a.
Canada	n.a.	n.a.	n.a.	n.a.	n.a.
Denmark	53.3	54.2	38.1	44.8	31.6
Finland	52.5	46.8	36.5	34.1	15.1
France	57.4	51.1	34.7	31.5	35.3
Germany	21.9	16.1	17.0	10.6	6.2
Japan	40.6	38.9	21.0	25.2	22.2
Korea	n.a.	n.a.	n.a.	n.a.	n.a.
Luxembourg	37.1	23.6	28.9	11.9	19.4
Netherlands	42.4	38.2	30.9	30.7	22.6
New Zealand[2]	33.9	32.6	26.8	25.2	23.3
Norway	48.9	39.6	35.4	20.6	29.1
Sweden	47.1	39.6	35.0	28.0	23.0
United Kingdom	45.0	38.8	27.4	25.2	29.0

1. CIS 3 data.
2. Two-year reference period (2004-05).

StatLink http://dx.doi.org/10.1787/548182244383

Table C.10. **Innovation-active firms by type of innovation status,[1] all sectors**

	Informal non-collaborative	Inventive (formal) non-collaborative	Informal collaborative	Inventive (formal) collaborative	No innovation activity
Australia	10.7	10.3	11.6	11.1	56.4
Austria[2]	11.1	13.2	12.3	12.0	51.5
Belgium	12.2	11.1	11.0	17.0	48.8
Brazil	n.a.	n.a.	n.a.	n.a.	n.a.
Canada	n.a.	n.a.	n.a.	n.a.	n.a.
Denmark	12.5	7.0	17.5	15.0	48.0
Finland	5.8	9.2	7.0	21.2	56.8
France	4.6	11.5	4.2	12.3	67.4
Germany	12.9	18.3	15.2	18.9	34.7
Japan	7.3	7.8	4.2	9.1	71.6
Korea	n.a.	n.a.	n.a.	n.a.	n.a.
Luxembourg	15.3	9.3	13.1	14.6	47.8
Netherlands	3.3	8.1	7.9	16.5	64.2
New Zealand[3]	19.9	7.6	18.6	10.3	43.7
Norway	5.8	11.6	5.2	14.5	63.0
Sweden	6.6	12.0	9.7	21.7	50.0
United Kingdom	5.7	16.5	6.7	17.8	53.3

1. Collaborative = engaged in innovation co-operation or product/process innovations developed together with or mainly by others. Formal = engaged in intramural R&D or having applied for a patent.
2. CIS 3 data.
3. Two-year reference period (2004-05).

StatLink http://dx.doi.org/10.1787/548214230731

Table C.11. **Innovation-active firms by type of innovation status,[1] all sectors, employment-weighted**

	Informal non-collaborative	Inventive (formal) non-collaborative	Informal collaborative	Inventive (formal) collaborative	No innovation activity
Australia	10.2	15.8	11.7	29.4	32.9
Austria[2]	10.8	18.1	10.2	37.5	23.5
Belgium	7.4	8.0	8.9	53.2	22.6
Brazil	n.a.	n.a.	n.a.	n.a.	n.a.
Canada	n.a.	n.a.	n.a.	n.a.	n.a.
Denmark	8.9	10.7	11.5	40.3	28.6
Finland	2.8	9.5	4.3	58.1	25.3
France	4.5	15.7	4.2	40.7	34.9
Germany	6.6	16.7	8.5	53.9	14.3
Japan	4.2	11.6	2.6	36.0	45.6
Korea	n.a.	n.a.	n.a.	n.a.	n.a.
Luxembourg	12.5	15.3	7.8	31.6	32.9
Netherlands	2.8	7.2	11.6	42.3	36.2
New Zealand[3]	14.0	9.9	22.3	21.9	32.0
Norway	5.9	14.0	5.3	31.7	43.1
Sweden	6.0	8.1	7.9	46.3	31.7
United Kingdom	5.2	19.6	6.5	31.9	36.7

1. Collaborative = engaged in innovation co-operation or product/process innovations developed together with or mainly by others. Formal = engaged in intramural R&D or having applied for a patent.
2. CIS 3 data.
3. Two-year reference period (2004-05).

StatLink http://dx.doi.org/10.1787/548226180126

Table C.12. **Innovation-active firms by type of innovation status,[1] manufacturing**

	Informal non-collaborative	Inventive (formal) non-collaborative	Informal collaborative	Inventive (formal) collaborative	No innovation activity
Australia	10.2	13.0	10.7	12.8	53.2
Austria[2]	10.3	18.5	8.8	15.1	47.4
Belgium	12.3	13.9	9.8	22.2	41.9
Brazil[3]	6.7	3.1	22.7	3.8	63.7
Canada[4]	4.4	29.0	5.1	26.5	35.0
Denmark	12.9	9.8	15.8	19.3	42.3
Finland	6.0	10.7	6.2	26.3	50.7
France	4.0	14.0	4.0	14.2	63.9
Germany	11.7	23.7	12.0	25.5	27.0
Japan	7.7	10.6	3.7	10.9	67.0
Korea	3.4	21.2	1.7	16.9	56.9
Luxembourg	10.2	11.4	10.9	16.4	51.1
Netherlands	3.1	9.6	8.8	21.8	56.7
New Zealand[5]	21.1	9.8	17.0	13.2	38.9
Norway	5.7	14.1	4.4	19.1	56.7
Sweden	5.1	13.2	8.6	27.4	45.7
United Kingdom	5.0	18.4	6.0	19.6	51.0

1. Collaborative = engaged in innovation co-operation or product/process innovations developed together with or mainly by others. Formal = engaged in intramural R&D or having applied for a patent.
2. CIS 3 data.
3. Includes mining.
4. Based on product/process innovative firms only.
5. Two-year reference period (2004-05).

StatLink http://dx.doi.org/10.1787/548228450822

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Table C.13. **Innovation-active firms by type of innovation status,[1] services**

	Informal non-collaborative	Inventive non-collaborative	Informal collaborative	Inventive collaborative	No innovation activity
Australia	11.2	7.0	12.5	9.1	60.3
Austria[2]	12.0	7.5	15.9	8.7	55.8
Belgium	12.0	8.5	12.2	12.2	55.2
Brazil	n.a.	n.a.	n.a.	n.a.	n.a.
Canada	n.a.	n.a.	n.a.	n.a.	n.a.
Denmark	12.0	4.2	19.4	10.5	54.0
Finland	5.6	7.5	7.9	15.7	63.3
France	5.1	9.1	4.4	10.3	71.0
Germany	14.1	12.9	18.3	12.3	42.4
Japan	6.8	4.4	4.9	6.8	77.1
Korea	n.a.	n.a.	n.a.	n.a.	n.a.
Luxembourg	16.9	8.7	13.7	14.0	46.8
Netherlands	3.5	7.1	7.2	12.8	69.5
New Zealand[3]	18.7	5.4	20.1	7.4	48.5
Norway	5.9	9.5	5.8	10.5	68.3
Sweden	7.9	10.9	10.8	16.4	54.1
United Kingdom	6.4	14.5	7.5	15.9	55.7

1. Collaborative = engaged in innovation co-operation or product/process innovations developed together with or mainly by others. Formal = engaged in intramural R&D or having applied for a patent.
2. CIS 3 data.
3. Two-year reference period (2004-05).

StatLink http://dx.doi.org/10.1787/548251422720

Table C.14. **Firms with technological and non-technological innovations,[1] all sectors**

	Enterprise weights			Employee weights		
	Technological innovation only	Technological and non-technological innovation	Non-technological innovation only	Technological innovation only	Technological and Non-technological innovation	Non-technological innovation only
Australia	13.4	27.0	6.3	13.2	49.7	6.5
Austria	11.6	39.0	15.4	7.5	68.0	10.3
Belgium	14.2	34.0	12.5	11.1	64.0	9.4
Brazil	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Canada	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Denmark	8.7	37.7	25.7	9.4	57.9	17.4
Finland	10.9	27.8	18.0	7.0	64.1	16.5
France	9.0	22.6	19.9	9.2	54.8	12.0
Germany	15.6	40.5	19.2	11.9	69.2	9.8
Japan	3.7	17.8	39.0	3.7	46.9	32.3
Korea	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Luxembourg	9.2	41.3	22.2	11.5	53.8	15.7
Netherlands	14.6	19.7	12.7	13.2	48.5	11.2
New Zealand[2]	15.9	29.7	13.0	17.0	42.6	12.0
Norway	12.4	19.3	11.9	16.5	34.1	12.6
Sweden	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
United Kingdom	21.2	22.9	10.7	23.1	37.2	10.8

1. Technological innovation = product/process; non-technological innovation = marketing/organisational innovation.
2. Two-year reference period (2004-05).

StatLink http://dx.doi.org/10.1787/548280740443

Table C.15. **Firms with technological and non-technological innovations,[1] manufacturing**

	Enterprise weights			Employee weights		
	Technological innovation only	Technological and non-technological innovation	Non-technological innovation only	Technological innovation only	Technological and non-technological innovation	Non-technological innovation only
Australia	16.8	27.0	5.4	19.3	38.0	6.7
Austria	15.0	40.2	12.8	11.2	65.1	9.5
Belgium	16.9	37.0	10.8	12.9	62.7	9.8
Brazil[2]	14.4	7.6	22.4	7.0	47.4	27.2
Canada	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Denmark	12.3	39.1	21.4	10.7	62.6	12.8
Finland	13.2	30.4	17.4	69.6	7.6	11.8
France	12.2	22.5	18.3	12.3	57.2	9.3
Germany	18.5	46.3	15.2	12.6	72.2	8.0
Japan	3.6	20.8	38.6	3.3	49.4	33.6
Korea	10.9	29.4	6.4	8.4	48.1	9.3
Luxembourg	11.5	34.8	21.8	23.4	50.5	13.7
Netherlands	17.9	23.2	10.7	16.3	51.9	9.3
New Zealand[3]	19.6	28.0	12.8	22.8	37.5	10.6
Norway	15.1	21.2	10.9	18.2	41.0	9.6
Sweden	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
United Kingdom	23.9	22.2	8.8	23.0	40.2	9.9

1. Technological innovation = product/process; non-technological innovation = marketing/organisational innovation.
2. Includes mining.
3. Two-year reference period (2004-05).

StatLink http://dx.doi.org/10.1787/548311543072

Table C.16. **Firms with technological and non-technological innovations,[1] services**

	Enterprise weights			Employee weights		
	Technological innovation only	Technological and non-technological innovation	Non-technological innovation only	Technological innovation only	Technological and non-technological innovation	Non-technological innovation only
Australia	9.3	27.1	7.3	7.8	60.0	6.3
Austria	8.5	37.9	17.8	4.0	70.7	11.2
Belgium	11.7	31.2	14.1	9.3	65.4	8.9
Brazil	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Canada	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Denmark	5.0	36.3	30.2	8.0	53.0	22.2
Finland	25.0	8.5	47.8	54.5	5.9	24.9
France	5.7	22.8	21.5	5.7	52.0	15.1
Germany	12.8	34.8	23.2	10.6	63.9	13.0
Japan	3.7	14.3	39.4	4.5	42.5	29.9
Korea	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Luxembourg	8.5	43.2	22.3	5.9	55.4	16.6
Netherlands	12.3	17.3	14.1	10.5	45.7	12.8
New Zealand[2]	12.2	31.4	13.2	10.8	48.0	13.6
Norway	10.1	17.7	12.8	14.7	26.5	16.0
Sweden	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
United Kingdom	18.2	23.7	12.8	23.1	33.8	11.9

1. Technological innovation = product/process; non-technological innovation = marketing/organisational innovation.
2. Two-year reference period (2004-05).

StatLink http://dx.doi.org/10.1787/548315881434

Table C.17. **Firms with product-process innovations by type of innovation,[1] all sectors**

	Dual innovators[2]	Goods innovation	Service innovation	Process innovation only
Austria	12.8	15.6	9.5	12.8
Belgium	12.6	15.1	7.2	13.3
Canada	n.a.	n.a.	n.a.	n.a.
Denmark	9.8	17.7	5.3	13.6
Finland	9.2	13.4	7.1	9.1
Germany	5.4	24.3	13.6	12.9
Korea	n.a.	n.a.	n.a.	n.a.
Luxembourg	17.5	9.2	11.9	11.9
Netherlands	5.4	14.4	5.6	8.9
Norway	0.7	17.9	6.8	6.3
Sweden	9.4	20.2	10.6	7.4
United Kingdom	11.3	16.9	9.5	6.4

1. Data not available for other countries.
2. Dual innovators = having both goods and service innovations.

StatLink http://dx.doi.org/10.1787/548345886455

Table C.18. **Firms with product-process innovations by type of innovation,[1] manufacturing**

	Dual innovators[2]	Goods innovation	Service innovation	Process innovation only
Austria	15.4	24.0	3.6	12.3
Belgium	14.1	22.3	2.6	14.9
Canada	17.0	27.7	2.9	17.4
Denmark	6.7	24.6	3.5	16.6
Finland	9.2	20.4	3.3	10.7
Germany	5.1	39.8	6.2	13.7
Korea	9.3	25.3	1.1	4.5
Luxembourg	10.1	17.4	2.6	16.2
Netherlands	6.2	21.6	2.3	11.0
Norway	0.6	24.3	4.0	7.4
Sweden	8.2	25.5	13.4	4.0
United Kingdom	10.6	23.6	5.1	6.8

1. Data not available for other countries.
2. Dual innovators = having both goods and service innovations.

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Table C.19. **Firms with product/process innovations by type of innovation,[1] services**

	Dual innovators[2]	Goods innovation	Service innovation	Process innovation only
Austria	10.4	7.9	14.8	13.3
Belgium	11.2	8.4	11.5	11.9
Canada	n.a.	n.a.	n.a.	n.a.
Denmark	13.0	10.5	7.2	10.6
Finland	9.2	6.0	11.1	7.3
Germany	5.7	8.8	21.0	12.1
Korea	n.a.	n.a.	n.a.	n.a.
Luxembourg	19.7	6.8	14.7	10.5
Netherlands	4.8	9.3	8.0	7.5
Norway	0.8	12.5	9.2	5.4
Sweden	10.6	15.2	7.9	10.7
United Kingdom	12.1	9.5	14.3	6.0

1. Data not available for other countries.
2. Dual innovators = having both goods and service innovations.

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Innovation in Firms: A Microeconomic Perspective

Chapter 2

Exploring Non-technological and Mixed Modes of Innovation Across Countries[1]

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2.1. Introduction

There is considerable evidence that innovation plays an important role in shaping the growth and competitiveness of firms, industries and nations (as well as regions). It is linked to increased welfare, the creation of new types of jobs and the destruction of old ones. At the firm level, innovation is linked to performance and competitiveness.

Analysis and modelling of the economics of innovation has traditionally concentrated on the definition and role of technological change, usually measured by R&D or patents. But the importance of other dimensions of innovation, such as managerial or organisational change, investment in design or skills, and the management of the innovation process itself, is increasingly acknowledged. While the latest edition of the *Oslo Manual* does not distinguish between technological and non-technological innovation, it recognises the importance of organisational and marketing changes along with innovations in products and processes. Given the number and scale of innovation survey datasets across OECD member countries, it seems an oversimplification to capture organisational and marketing innovations on the one hand and product and process innovation on the other and the data currently available make it possible to explore a much richer set of possibilities and activities carried out by firms in tandem. This chapter uses innovation survey data from various countries to capture dimensions of innovation practices that include technological and non-technological activities and estimates their role in innovation outcomes.

The chapter is structured as follows. Section 2.2 introduces the theoretical context of the study. Section 2.3 explains the data and methodology. Section 2.4 discusses the results of the individual countries and Section 2.5 concludes.

2.2. Theoretical context

This section sets the theoretical backdrop for the study and begins by highlighting the emphasis on technological activities in early innovation-related research. This is followed by a discussion of current definitions of non-technological activities.

Traditionally, empirical and theoretical work on the determinants and effects of innovation were confined to technological activities (*e.g.* Cohen, 1995; Smith, 2005). This is because a large proportion of innovations, specifically in high-technology manufacturing sectors, are based on technological activities, including those carried out in R&D departments (*e.g.* Fagerberg, 2005). Studies of innovation have focused on two Schumpeterian definitions of innovation: the introduction of a new product and the introduction of a new production process (Schumpeter, 1934). A similar approach to capturing innovation is suggested in the 2nd edition of the *Oslo Manual* with an emphasis on the technological component of such innovations.

A technological product innovation is the implementation/commercialisation of a product with improved performance characteristics such as to deliver objectively new or improved services to the consumer. A technological process innovation is the implementation/adoption of new or significantly improved production or delivery methods (OECD, 1996, p. 8).

With the introduction of the 3rd edition of the *Oslo Manual* in 2005, the above definition – now referred to as the narrow definition of innovation – was extended to encompass organisational and marketing changes, and to include non-technological characteristics of product and process innovations.

An innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations (OECD/Eurostat, 2005, p. 46).

The need to cover appropriately innovation in services, which now dominate OECD economies, has been a major force behind these changes. Along with, if not somewhat ahead of, the shift in emphasis in the *Oslo Manual*, have been changes in the Community Innovation Survey (CIS) questionnaires and in innovation surveys in other countries. The CIS2 adopted the definition of technological product and process innovations from the 2nd edition of the *Oslo Manual*; since CIS 3 the word "technological" has been dropped from the questionnaire items measuring product and process innovation.

These recent changes are reflected in theoretical and empirical studies on broader measures and/or modes of innovation. For example, a number of recent papers focus on the determinants and effects of marketing and organisational innovations (*e.g.* Acha and Salter, 2004) and innovation in services (*e.g.* Djellal and Gallouj, 2001; Tether and Miles, 2001). In conjunction with such research, a loose distinction is made between technological and non-technological types of innovation. By and large, product and process innovations in manufacturing firms are considered technological, whereas organisational and marketing innovations and/or innovations in services are considered as non-technology-based (*e.g.* Battisti and Stoneman, 2007).

However, product and process innovations are likely to have non-technological components, and technological knowledge often enters organisational and marketing innovation. Confining non-technological innovation to organisational and marketing innovation may be a convenient simplification, given the variations in coverage and variables in countries' innovation surveys; however, it is likely to give an inaccurate, or at best incomplete, picture of the complementarity of these dimensions of innovation inputs and outputs.

In particular, innovation practices in the services sector are very heterogeneous. Some are technological, such as the introduction of advanced communication technologies, while a larger proportion is likely to be non-technological. Innovations in the hotel and catering industries, for example, are mostly considered to be non-technological (Djellal and Gallouj, 2001).

Accumulated analytical results suggest that both technological and non-technological innovation activities are relevant to firm performance. Firms that engage in both product and process innovations and, at the same time, introduce organisational changes outperform firms that do either one or the other (Geroski *et al.*, 1993).

A number of studies have considered different innovation practices as they relate to non-technological and technological innovations. Hollenstein (2003) used the Swiss Innovation Survey to examine different modes of innovation in the services sector. He used factor and cluster analysis to group firms into five categories with specific ratings in terms of their technological and non-technological activities. He found that firms that engage in both are more likely to engage in co-operation and have a higher innovation output. Jensen *et al.* (2007) use the 2001 Danish DISKO Survey to cluster firms into different modes of knowledge: the "science, technology and innovation" mode – which may be seen as closer to technological types of activities – and the "doing, using and interacting" mode – which may be closer to non-technological types of innovation. They, too, find evidence that firms that engage in both types of knowledge generation and acquisition outperform in terms of product innovation. In a similar vein, see the use of Innobarometer data by Howells and Tether (2007).

In the United Kingdom, Battisti and Stoneman (2007) use the UK CIS 4 to identify different modes of innovation. They, too, use both factor and cluster techniques to explore the data. The modes of innovation they identify are: "wide innovative activities", including marketing, organisational, management and strategic innovations; and "traditional activities", including product, process and technological innovations. They link the two modes to firm performance and find that "wide innovative activities" and "traditional activities" are complements rather than substitutes and that enterprises that engage in both have stronger performance.

Although these studies make a distinction between technological and non-technological activities, there is considerable overlap between the modes or classification of these activities. This project uses methods similar to those of Hollenstein (2003), Jensen *et al.* (2007), Battisti and Stoneman (2007) and Peeters *et al.* (2004) to explore innovation practices in the nine participating countries. It also links the innovation modes to indicators of productivity to gain insight into the relative importance of different modes of innovation. Indicators to measure the relationships between productivity and human capital, competition conditions, industry sector and enterprise structure and characteristics are included in the regression models.

This project may be the most comprehensive to date in terms of the number of countries involved, the number of variables feeding into the analysis, and the number of observations for each country. It covers a diverse range of economies in terms of geographical location and economic development and cultural context in North and South America, Southeast Asia and Europe.

The aim of the project is to further our knowledge of how different countries' innovation systems function and to see their common features and differences. On the one hand, innovation practices are likely to depend on national and regional innovation systems and country-specific socio-economic environments; on the other, the growing interdependency of economies and the activities of transnational corporations, which play a significant role in the generation and diffusion of innovations across national borders, may have led to increased convergence of innovation practices. The study may shed further light on the extent to which differences across nations or regions matter, and on the extent to which it is possible to establish a link between different innovation practices and productivity.

2.3. Data and methodology

The data analysis is based on the items in the fourth harmonised CIS questionnaire for which information was collected for all (or most) participating countries. This has meant a choice to work with a smaller set of variables than may have been possible in specific countries in order to achieve the highest level of comparability, but it limits the ability of the models to "fit" the salient characteristics of individual countries. This section first describes the questionnaire items included in the study and then presents the statistical techniques.

Data

Initially, the variables feeding into this study were selected from the CIS 4 harmonised survey questionnaire. The variables are introduced and defined, along with an indication of whether or not an activity is likely to lean towards non-technological innovation. The analysis of modes of innovation incorporates measures of innovation outputs, such as a new product together with innovation inputs, *e.g.* R&D activities or a patent application. These measures are summarised to represent modes of innovation. A possible mode of innovation in this case would be a new-to-market product innovation together with in-house R&D and protection *via* intellectual property rights which may be classified as an innovation practice with a high technological component. Alternatively, the innovation practices may centre on design issues and new marketing strategies and lean towards non-technological efforts. The approach is therefore more systems-based than a simple input-output approach to framing the innovation process.

The questionnaire items that feed into the factor analysis are grouped under the following broad headings: product innovation, process innovation, marketing and organisational innovation, own technology, diffused and embedded technology, design and other inputs. Table 2.1 summarises the set of variables used to identify modes of innovation practices.

Table 2.1. **Variables included in the explorative analysis of non-technological and technological activities**

Description of the variable	Name of the variable
Product innovation	
Introduction of a new-to-firm product (not new to the market)	New-to-firm product innovation
Introduction of a new-to-market product	New-to-market product innovation
Process innovation	
Process innovation (methods of manufacturing; delivery or distribution methods)	Process innovation
Organisational and marketing innovation	
New knowledge management system	New knowledge management
Change to the organisation of work, incl. management structure	New organisational structure
Changes in relationships to other firms, incl. partnerships	New relations with other organisations
Changes in design or packaging	New design or packaging
Changes in sales or distribution methods	New distribution methods
Own technology	
Intramural R&D	In-house R&D
Enterprise applied for a patent	Patent
Diffused and embedded technology	
Extramural R&D	Extramural R&D
Expenditure on acquisition of machinery, equipment and software	Machinery
Expenditure on external knowledge acquisition	External knowledge
Design	
Registered industrial design	Design registration
Claim copyright	Copyright
Other inputs	
Expenditure on training	Training
Expenditure on market introduction of innovations	Marketing expenditures

The left column of Table 2.1 describes the questionnaire items and the right column gives the names used to identify the variable in this study. With respect to *innovation outputs*, the surveys include information on product and process innovations, which may be based on technological and non-technological activities. Under the title "wider innovation outputs" the surveys include changes to management techniques and organisational structures, marketing strategies and the appearance of products. The latter are likely to incorporate a high share of non-technological activities and are considered as such here.

Among *innovation inputs* are activities relating to in-house R&D such as technology-relevant inputs or own generation of technology, on the one hand, and purchased and diffused technology (the acquisition of machinery, equipment and software, and other external knowledge) on the other. The latter are considered technological activities even though they are generated outside the firm and transferred to the enterprise. Innovation inputs captured in the surveys may also be linked to design functions and marketing activities. Registration of a design or copyright is used as a proxy for design-related activities, which are partly non-technological but also an important component of new and applied technologies. With respect to marketing activities, a survey question covers expenditure on marketing new innovations. This is considered a largely non-technological input. Finally, training of employees in relation to innovations is included in the set of variables.

The following restriction with respect to *sample selection* was made. Observations feeding into the analysis come from "innovation-active" enterprises according to the Eurostat definition for two reasons. First, because the project focuses on exploring practices in innovation-active firms, and second, because not all information included in Table 2.1 is available for enterprises that are not innovation-active. An enterprise is considered to be "innovation-active" if it had a product innovation or a process innovation or any innovation activities to develop a product or process that were abandoned or still ongoing during the survey reference period. The observations cover all manufacturing and most private services, with the exception of the Brazilian dataset which only covers manufacturing. The reference period for the innovation surveys is 2002-04 with the following exceptions: for Austria the reference period is 1998-2000; for Brazil 2001-03; and New Zealand 2004-05.

Methodology

The aims of this chapter are to identify innovation practices, to compare these across national systems of innovation, and to examine their relative effects on productivity. The methodological point of departure, rather than operationalising and testing hypotheses, is to start from observations and explore these to arrive at a new, conceptual understanding of innovation practices. Factor analysis is used to identify different innovation modes or practices. Combinations of innovation practices used by groups of innovation-active firms are found based on clustering techniques, and, regression models are used to determine the relevance of innovation practices for firm-level performance by examining their association with productivity.

Exploratory (as opposed to confirmatory) factor analysis is used to reduce a set of variables into different concepts (factors) which summarise combinations of inputs and outputs to innovation. In other words, the aim is to discover which of the variables listed in Table 2.1 form coherent subsets. The variables of a subset are correlated with one another and the strength of their correlation is summarised in factor loadings. Variables that score high in one factor are largely independent from other factors, except when loadings on a variable are similar across more than one factor.

All variables feeding into the factor analyses and included in Table 2.1 are measured on a binary scale. If an enterprise engaged in a specific innovation-related activity, such as a new-to-market product, during the survey reference period, the variable *new-to-market product innovation* is coded one, otherwise it is coded zero. Although innovation surveys contain continuous data for some variables included in Table 2.1, such as the amount spent on R&D, this information is not used, for technical reasons.

Since all participating countries used a centrally written STATA do file to simultaneously run the same estimations on their respective datasets, the analysis is restricted to the confines of STATA commands available for factor analysis. Analysing a mixture of binary and continuous data requires factor analysing a polychoric correlation matrix. The necessary command is available for STATA; however, it is user-driven and needs to be imported into STATA first. This is not possible for countries in which the data were analysed in statistical offices.[2]

Therefore, binary data factor analysis is used (*e.g.,* Battisti and Stoneman, 2007). This involves the computation of a tetrachoric correlation matrix and factor analysing this matrix, under the assumption that the observed binary variables correspond to latent continuous variables.[3] Four factor solutions are computed for all countries in order to maximise the comparability of results. In most cases this corresponds to the number of factors with eigenvalues greater than one. Any deviation from this rule, *i.e.* the inclusion of factors with eigenvalues smaller than one, is discussed in the relevant results section. The results are based on unweighted data, principal component analysis and varimax rotation method, unless otherwise specified. For Austria, Brazil and the United Kingdom results were also computed based on weighted data and oblique rotations. The respective patterns are very similar to the structures presented here.[4] Finally, it is worth mentioning that an advantage of factor analysis is that it provides indicators in the form of factor scores – regression methods were used to compute the factor scores – which show low correlation (Fidell and Tabachnick, 2006).

Factors linked to different modes of innovation are identified and then interpreted on the basis of inductive reasoning, *i.e.* moving from the specific observation to the general concept. The interpretation of underlying modes of innovation activity brings out which innovation strategies are prevalent in the different countries.

Based on the factor analyses, and more precisely on the four factors derived from the factor analyses, cluster analyses are conducted. Enterprises are grouped according to their factor scores. This makes it possible to identify groups of firms with similar values across the four factors, and the extent and intensity of their innovation practices. This also makes it possible to see if one or two of the innovation practices are relevant for all innovation-active enterprises, while others may form single strategies of firms. A k-means clustering technique, with a random allocation of the first observation, and four cluster solutions are used. In selected countries five cluster solutions are presented where this improves on the distribution of group sizes. Six cluster solutions were not stable enough to be considered, because, depending on the randomly chosen starting point in the cluster analysis, repeated solutions differed.

Finally, the factor scores computed for each firm in the survey are used directly as variables in regressions predicting firm-level labour productivity. Labour productivity is computed as turnover in 2004 over number of employees in 2004. This shows a broadly contemporaneous relationship – productivity is "explained" by innovation characteristics over a three-year period. In addition to exploring the impact of different types of innovation modes via the factor scores, the effects of the following variables are controlled for:

- A measure designed to capture the effects of human capital. This measure is based on the number of employees holding a tertiary degree irrespective of the subject.
- The effect on performance of belonging to a wider company group.
- A variable measuring the openness of the firm to international markets.
- Enterprise size measured by the number of employees and two digit sector dummies.

Computed are elasticities, the percentage change in the dependent variable induced by a 1 percentage point change in the independent variables, at the means of the regressors or for discrete changes from zero to one in the case of binary variables.

2.4. Results

Austria

Austria, with a population of around 8 million, is a medium-sized social market economy in the European Union. It is characterised by high income levels and a high standard of living. The bulk of GDP derives from services, specifically consultancy, financial firms and tourism. Firms in Austria tend to be less internationalised than firms in the United Kingdom and the Nordic countries, except for the steel sector chemicals and oil companies (which include many multinationals). Over the last ten years, emphasis has been placed on innovation policies aimed at raising the level of business R&D (OECD, 2007).

Table 2.2 gives the factor loadings for four distinct modes of innovation based on Austrian data. The Austrian dataset differs from the other datasets in two ways. First, as mentioned previously, the reference period is 1998-2000 (CIS 3). Second, the dataset contains unique items relating to organisational and marketing innovations. The variables used relate to: *i)* the introduction of advanced management techniques; *ii)* improved organisational structures; *iii)* improved aesthetic appearance, design or other subjective change; and *iv)* new or improved marketing concept or strategy. Information on organisational relations is not available. Table 2.2 presents the rotated pattern matrix.

The first column gives the factor loadings with respect to the first factor, "new-to-market innovators". Factor loadings represent the correlation between each variable entered into the factor analysis and the factor computed by the analysis. For example, the variable "new-to-market product innovation" has a correlation of $r = 0.76$ with Factor 1. Within a factor, high values indicate that the respective variables load up together and represent one underlying concept and one mode of innovation. The meaning of these underlying concepts is then interpreted and discussed. It is based, to some extent, on the authors' judgement.

The final row in Table 2.2 gives the amount of variation in the data explained by each factor. For example, Factor 1 explains 24% of variation in the data. The first factor explains the highest common variation and the last factor the least amount of variation, at 9%.

The factor loadings of Factor 1 are interpreted as *new-to-market innovating* based on own and diffused technology with design. This mode/practice is interpreted as new-to-market innovation because of its high loading on new-to-market product innovations. Together with technological activities, design-related activities appear specifically relevant for such strategies in Austrian firms, as indicated by the high loadings of the variables design registration ($r = 0.79$) and copyright ($r = 0.52$). Factor 1 resembles a mode of innovation

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Table 2.2. **Factor analysis based on survey data from Austria**

Variables	Factor 1: *New-to-market innovating*	Factor 2: *Wider innovating*	Factor 3: *Process modernising*	Factor 4: *Marketing-based imitating*
New-to-firm product innovation	0.01	0.03	–0.02	**0.78**
New-to-market product innovation	**0.76**	0.15	0.01	0.16
Process innovation	0.06	0.34	**0.56**	–0.39
Advanced management techniques	0.19	**0.70**	0.26	–0.09
New organisational structure	0.07	**0.69**	0.25	–0.10
Improved appearance or design	0.11	**0.71**	–0.12	0.06
New marketing concepts/strategies	–0.01	**0.81**	0.12	0.20
In-house R&D	**0.89**	0.00	0.11	0.07
Patent	**0.88**	0.03	0.12	–0.04
Extramural R&D	**0.72**	0.13	0.26	0.00
Machinery	0.27	–0.07	**0.67**	–0.07
External knowledge	–0.01	0.16	**0.68**	–0.02
Design registration	**0.79**	0.05	0.03	0.06
Copyright	**0.52**	0.31	0.11	0.36
Training	0.19	0.21	**0.74**	0.34
Marketing expenditures	0.32	0.14	**0.45**	**0.59**
Proportion of variance explained by each factor	0.24	0.16	0.14	0.09

N = 540; data is CIS 3; number of eigenvalues greater than 1 = 4. Tetrachoric correlations, unweighted data, rotation method varimax. *Note:* definition of new-to-firm innovators: enterprises whose turnover from new-to-firm innovations is greater than turnover of new-to-market innovations.
Source: OECD Innovation Microdata Project, 2008.

StatLink http://dx.doi.org/10.1787/546344115331

based on both technological and non-technological activities, as it links own, diffused technologies with design activities.

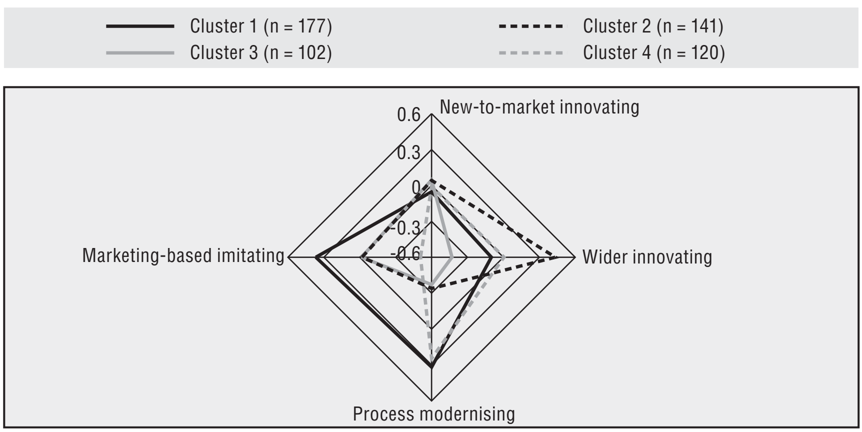
Factor 2, called *wider innovating*, attaches high values to organisational/ marketing innovations. Variables with high loadings are linked to the use of advanced management techniques and improved organisational structures, as well as improved product appearances, design and marketing strategies. Thus, the practice "organisational/marketing innovations" leans towards non-technological activities.

Factor 3 is interpreted as representing a mode of innovation based on diffused and embedded technology and other inputs including training. This mode of innovation may be seen as *process modernising* and exhibits high loadings in relation to process innovations, acquisition of machinery and equipment, other external knowledge and training, and thus contains a combination of (embedded) technological as well as non-technological components.

Finally, Factor 4 is summarised under the heading *marketing-based imitating*. This innovation practice adopted by firms in the Austrian dataset is largely based on the introduction of new-to-firm only innovations brought to the market with a high propensity for marketing-related expenditures. Variables associated with own and diffused technologies load up negatively on this factor. This mode of innovation appears to emphasise non-traditional activities, particularly marketing concepts, and excludes technology- based activities.

Enterprises are then grouped according to their scores across the four factors. Figure 2.1 represents the results of the cluster analysis in a spider diagram.[5] Positive values suggest that enterprises in a specific cluster perform above average in relation to the relevant factors, negative values suggest that they perform below average.

Figure 2.1. **Cluster analysis based on survey data from Austria**



Source: OECD Innovation Microdata Project, 2008.

StatLink http://dx.doi.org/10.1787/545760374482

Firms grouped in Cluster 1 apply strategies linked to process modernising jointly with marketing-based following, and Cluster 2 contains firms whose strategies are linked to wider innovating. Cluster 3 contains firms which perform below average on all four innovation practices; and firms in Cluster 4 focus on process modernising alone. Worth noting is that performance, in terms of new-to-market innovating, is approximately equal across all four clusters.

The next step links different types of innovation practices to levels of productivity. Table 2.3 summarises the regression results.

Table 2.3 suggests that two modes have a statistically significant association with productivity levels. First, marketing-based imitating has a negative impact on enterprise productivity (beta = –0.07; $p < 0.05$). This finding is counterintuitive, as one would expect to find higher sales per employees if enterprises strongly emphasise marketing-based activities. Because the

Table 2.3. **Regression results based on survey data from Austria**

	Dependent variable: log turnover per employee		
	Beta	S.E.	
Independent variables			
Factor 1: New-to-market innovating	–0.03	0.11	
Factor 2: Wider innovating	–0.02	0.06	
Factor 3: Process modernising	0.06	0.06	◆
Factor 4: Marketing-based imitating	–0.07	0.06	*
Control variables			
Group belonging	0.24	0.07	***
Foreign market orientation	0.28	0.08	***
Human capital	0.36	0.04	***
Co-operation with science and technology base	–0.05	0.09	
Information from science and technology base	0.04	0.08	
Enterprise size	–0.15	0.04	◆
Industry dummies	Yes		
Number of observations	540		
F(38, 498)	. .		
R-squared	0.50		

◆ => $p < 0.10$; * => $p < 0.05$; ** => $p < 0.01$; *** => $p < 0.001$. Regression computed with constant. Beta coefficients/ marginal effects and robust standard errors are reported.

Source: OECD Innovation Microdata Project, 2008.

StatLink http://dx.doi.org/10.1787/546344551066

analysis is based on single regression methods and cross-sectional data, causality cannot be inferred; indeed, a possible explanation of this finding may be that comparatively low sales per employee cause enterprises to allocate greater resources to marketing activities. Alternatively, marketing-based innovations might be associated with strategies of growth, which, in turn, might be inconsistent with productivity.

Second, the process modernising mode has a significant positive impact (beta = 0.06; $p < 0.10$). This may be linked to an ongoing modernisation of Austrian firms reflected in productivity growth rates above the EU15 average in previous decades. According to Eurostat value added per employee in Austria grew by 3.7% a year between 1985 and 2000 compared with 2.9% for the EU15.

Finally, labour productivity is strongly positively and significantly associated with human capital, foreign market orientation and group affiliation. Enterprise size, as measured by the number of employees, has a significant negative association with labour productivity. Enterprise size is only negative for the model including human capital. If human capital is excluded enterprise size shows a significantly positive relation with productivity. Consequently, in the full model, the impact of size is negative, other things being equal; that is, if human capital is constant a larger enterprise is associated with lower labour productivity. Interestingly, neither new-to-market innovating, nor wider innovating, has a significant relationship with productivity.

The following problems emerged from the regression analysis. There are high correlations, especially between Factor 1 and foreign market orientation, human capital, co-operation with the science and technology base and enterprise size as well as between size and group belonging, foreign market orientation, human capital, co-operation with the science and technology base and information from the science and technology base. The number of independent variables is too large given the sample size.

Testing for inequality among coefficients suggests that differences between wider innovating and process modernising ($p < 0.10$) as well as between process modernising and market-based imitations ($p < 0.01$) are statistically significant.

Brazil

Measured by geographical region and population size, Brazil is the world's fifth largest economy. It has a diverse industry structure, which includes production of automobiles, steel and chemicals through to computers and aircraft. In recent years the services sector has been growing, with the banking sector now accounting for around 15% of GDP. In relation to spending on innovation, almost three-quarters of R&D is publicly funded, and research is carried out in universities and research institutes. Overall R&D spending is low, compared to the other countries studied, at around 1% of GDP (OECD, 2006a).

The data analysed here derive from the *Technological Innovation Survey 2003* (PINTEC2003), which covers the mining and quarrying and manufacturing sector. For the purpose of this chapter, the manufacturing sector is analysed. As mentioned previously, the reference period of the survey is 2001-03.

Brazil's sampling frame is divided into three strata associated with high, medium and low probabilities of being innovative. To account for this difference in sampling techniques – other surveys use stratification based on enterprise size, sector and region – weighted and unweighted results were compared. Both factor analyses gave very similar results. Here, the factor analysis based on unweighted data is presented.

The Brazilian innovation survey does not include a question on new relations with other organisations. Table 2.4 gives the results of the factor loadings.

The first factor in Table 2.4 is *new-to-market innovating* and reflects a mode of innovation linked to own technology (in-house R&D and patents) and design activities. It is similar to the Austrian innovation practice new-to-

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Table 2.4. **Factor analysis based on survey data from Brazil**

Variables	Factor 1: *New-to-market innovating*	Factor 2: *Marketing-based imitating*	Factor 3: *Process modernising*	Factor 4: *Wider innovating*
New-to-firm product innovation	–0.16	**0.86**	–0.20	0.13
New-to-market product innovation	**0.87**	–0.03	0.13	0.00
Process innovation	–0.19	–0.28	**0.78**	0.07
New knowledge management	**0.43**	0.19	**0.41**	**0.32**
New organisational structure	0.23	0.07	0.09	**0.63**
New design or packaging	–0.02	0.13	–0.03	**0.68**
New distribution method	0.09	0.09	0.08	**0.77**
In-house R&D	**0.70**	**0.53**	0.06	–0.02
Patent	**0.85**	0.01	–0.01	0.07
Extramural R&D	**0.53**	**0.46**	0.29	–0.07
Machinery	0.09	0.03	**0.88**	0.04
External knowledge	**0.42**	**0.44**	**0.33**	0.06
Design registration	**0.68**	0.14	–0.10	0.24
Copyright	**0.69**	–0.01	–0.08	0.22
Training	**0.43**	**0.43**	**0.56**	–0.11
Marketing expenditures	**0.47**	**0.65**	0.09	0.18
Proportion of variance explained by each factor	0.26	0.14	0.14	0.11

N = 4 476; data is PINTEC2003; number of eigenvalues greater than 1 = 5. Tetrachoric correlations, unweighted data, rotation method varimax.
Source: OECD Innovation Microdata Project, 2008.

StatLink http://dx.doi.org/10.1787/546358642628

market innovating, but adds design activities. An alternative interpretation could be a link to in-house/intellectual property rights (IPRs) activities as, for example, in the UK data.

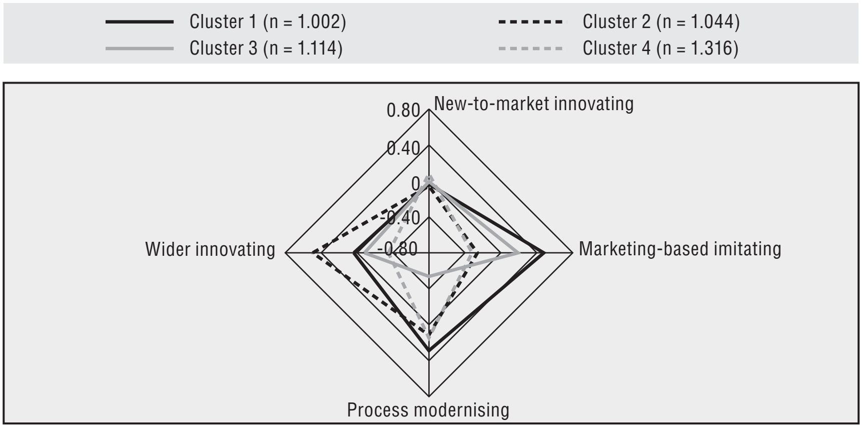
The second factor is *marketing-based imitating*. This factor exhibits a high loading in relation to new-to-firm product innovation combined with marketing expenditures; however, R&D activities have some relevance.

The third factor is *process modernising*. This innovation mode is based on technology embedded in machinery, equipment and software connected with training of staff to encourage innovation and a high propensity of new-to-firm product innovation.

Finally, the fourth factor, *wider innovating*, links changes in the organisational structure, new design and packaging and improved distribution methods. Thus, this factor groups non-technological activities involved in organisational and marketing innovations.

Next, the Brazilian manufacturing enterprises are grouped according to their scores in relation to Factors 1 to 4 (see Figure 2.2).

Figure 2.2. **Cluster analysis based on survey data from Brazil**



Source: OECD Innovation Microdata Project, 2008.

StatLink http://dx.doi.org/10.1787/545776686170

The picture presented is similar to the cluster analysis for Austria with respect to the innovation practice new-to-market innovating. This practice appears to be adopted equally by all enterprises included in the study because all clusters exhibit average scores of zero. In contrast to the Austrian results no cluster of enterprises scores high in relation to all other practices.

Cluster 1 contains a group of firms with high scores for marketing-based imitating and process modernising and approximately average scores for wider innovating and new-to-market innovating. Cluster 2 links process modernising with wider innovation activities. This group can be described as business process modernisers since enterprises in this cluster stress improvements in both production processes and organisational processes. Cluster 3 contains manufacturing enterprises that predominantly adopt marketing-based imitation strategies. Finally, Cluster 4 has process modernisers with a low propensity to engage in wider innovating and marketing-based imitating.

Table 2.5 considers the association between different innovation practices and productivity.

Of the four innovation strategies, process modernising is the only practice with a positive and significant association with labour productivity (beta = 0.02; $p < 0.10$). This suggests that an emphasis on improved production processes for goods increases productivity levels over and above innovation-related activities in conjunction with new goods, own or purchased technology and managerial changes. However, the Wald tests of equality did not show any statistically significant differences among the coefficients.

Table 2.5. **Regression results based on survey data from Brazil**

	Dependent variable: log turnover per employee		
	Beta	S.E.	
Independent variables			
Factor 1: New-to-market innovating	0.01	0.05	
Factor 2: Marketing-based imitating	0.00	0.03	
Factor 3: Process modernising	0.02	0.03	◆
Factor 4: Wider innovating	0.01	0.03	
Control variables			
Group belonging	0.11	0.03	***
Foreign market	0.04	0.05	**
Human capital	0.73	0.02	***
Co-operation with science and technology base	–0.03	0.06	*
Information from science and technology base	0.02	0.03	
Enterprise size	–0.27	0.02	***
Industry dummies	Yes		
Number of observations	4 468		
F(32, 4 435)	176.33		
R-squared	0.54		

◆ => p < 0.10; * => p < 0.05; ** => p < 0.01; *** => p < 0.001. Regression computed with constant. Beta coefficients/marginal effects and robust standard errors are reported.
Source: OECD Innovation Microdata Project, 2008.

StatLink http://dx.doi.org/10.1787/546380003443

Of relevance are the control variables. Productivity is positively associated with group belonging, foreign market projections and the indicator measuring human capital. There are negative associations with enterprise size and co-operation with the science and technology base.

Although the interpretation of factors based on weighted and unweighted data is the same, the regression results based on unweighted or weighted factor scores differ. Compared to Table 2.5 factors resulting from a weighted correlation matrix lead to the factor new-to-market innovating also being positively associated with productivity ($p < 0.10$).

Canada

Canada's innovation system is very advanced. The industrial environment is influenced, among other things, by a large services sector – three-quarters of the population are employed in services and generate two-thirds of GDP. Unlike other advanced economies, and owing to its geography and size, Canada has strong forestry and oil sectors. According to the OECD's *Economic Survey of Canada 2006* (OECD, 2006b), Canada exhibits high levels of product innovation outputs compared with other innovation outputs.

This section presents results derived from the *Canadian Innovation Survey 2005*. As in the case of the CIS 4, the reference period is the three-year period 2002-04. The differences in the dataset, as compared to the other datasets analysed, are as follows. First, the Canadian sample is based on responses from manufacturing enterprises only; services are not included. This may be more problematic than for Brazil, since it omits a larger proportion of Canada's economy. Second, the Canadian innovation survey does not include information on organisational innovations: knowledge management systems, organisational structures and relations. Third, no information is available on marketing innovations: changes in design, packaging, sales or distribution methods. Data on marketing expenditures and registration of design are available. Because these variables are not included, a three-factor solution is presented to increase the comparability of results across countries, even though the factor analysis suggests a possible four-factor solution with the first four factors exhibiting eigenvalues greater than 1.

Table 2.6. **Factor analysis based on survey data from Canada**

Variables	Factor 1: *In-house/market-driven innovating*	Factor 2: *Process modernising*	Factor 3: *IPR/external innovating*
New-to-firm product innovation	**0.73**	0.02	–0.04
New-to-market product innovation	**0.73**	–0.11	**0.30**
Process innovation	–0.20	**0.76**	–0.18
In-house R&D	**0.71**	0.11	0.06
Patent	0.15	–0.05	**0.80**
Extramural R&D	0.15	0.28	**0.44**
Machinery	0.09	**0.79**	0.00
External knowledge	0.07	**0.49**	**0.46**
Design registration	**0.35**	0.04	**0.47**
Copyright	0.11	–0.07	**0.80**
Training	0.24	**0.75**	0.07
Marketing expenditures	**0.70**	0.18	0.27

N = 540; number of eigenvalues greater than 1 = 4. Tetrachoric correlations, unweighted data, rotation method varimax.

Definition of new-to-firm innovators – enterprises whose turnover from new-to-firm innovations is greater than turnover for new–to-market innovations.

Source: OECD Innovation Microdata Project, 2008.

StatLink http://dx.doi.org/10.1787/546421224177

The results of the three-factor solution are interpreted as follows. Factor 1 is interpreted as combining *in-house/market-driven innovating*. Such activities are based on own technology and marketing activities, with some relevance of design functions. Process innovating has a negative loading in relation to this factor and suggests a strong demarcation between innovating

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in products and innovating in processes. The second factor relates to *process modernising*. This is based on embedded technology and training.

Factor 3 summarises different ways of protecting innovations from imitations, specifically copyright and patents and, to a lesser degree, design registrations. The latter is the only IPR-related variable that also hangs together with Factor 1, in-house/market-driven innovating. In addition to IPR-related variables, Factor 3 has comparatively high loadings for external R&D and external knowledge. Factor 3 is here called *IPR and external innovating*. The association between purchased R&D and other knowledge and strategies of appropriation suggests that, in Canadian firms, external search may be more likely to take place when IPRs protect innovation efforts. A similar observation was made by Laursen and Salter (2005) based on a UK study and the related phenomenon referred to as open innovation paradox. Acha (2007) found that design registration and complexity is positively associated with open innovation. In the UK factor analysis reported here, however, a factor called in-house/IPR innovating is identified, where IPRs loads up with in-house R&D and not with external R&D or knowledge.

Results of the cluster analysis are not available. The link between the three factors of innovation modes and labour productivity is summarised in Table 2.7.

Table 2.7. **Regression results based on survey data from Canada**

	Dependent variable: log turnover per employee		
	Beta	S.E.	
Independent variables			
Factor 1: In-house/market driven innovating	–0.01	0.04	
Factor 2: Process modernising	0.05	0.04	*
Factor 3: IPR and external innovating	0.004	0.06	
Control variables			
Group belonging	0.19	0.04	**
Foreign market	–0.01	0.04	
Human capital	0.08	0.01	**
Co-operation with science and technology base	–0.02	0.09	
Information from science and technology base	0.004	0.04	
Enterprise size	0.04	0.02	
Industry dummies	Yes		
Number of observations	9 621		
R-squared	0.32		

♦ => $p < 0.10$; * => $p < 0.05$; ** => $p < 0.01$; *** => $p < 0.001$. Regression computed with constant. Beta coefficients/marginal effects and robust standard errors are reported.

Source: OECD Innovation Microdata Project, 2008.

StatLink http://dx.doi.org/10.1787/546504406880

Table 2.7 shows only one mode of innovation to be associated with levels of productivity. Factor 2 *process modernising* is positively and significantly correlated with productivity (beta = 0.05; $p < 0.05$). The other factors, in-house/market-driven innovating and IPR/external innovating, do not appear to be associated with the dependent variable. This finding contrasts the results in Chapter 3, where direct measures of process innovation do not appear to be correlated with productivity. Enterprises that are part of company groups appear to have higher productivity and levels of human capital are positively associated with productivity.

Denmark

Denmark is a small, advanced and comparatively open economy. The services sector, high-technology manufacturing and agriculture are important segments of the economy. This section explores data derived from the Danish CIS 4, which covers manufacturing and service enterprises. Table 2.8 gives the factor loadings of the four-factor solution.

Table 2.8. **Factor analysis based on survey data from Denmark**

Variables	Factor 1: *Technology producing and using*	Factor 2: *New-to-market/design innovating*	Factor 3: *Wider innovating*	Factor 4: *Process modernising*
New-to-firm product innovation	0.33	**0.54**	0.25	–0.18
New-to-market product innovation	**0.39**	**0.62**	0.14	–0.15
Process innovation	0.17	0.09	0.20	**0.70**
New knowledge management	0.05	0.21	**0.60**	0.27
New organisational structure	0.09	0.09	**0.70**	0.06
New relations other organisations	0.06	–0.04	**0.68**	–0.04
New design or packaging	–0.07	**0.67**	**0.45**	0.15
New distribution method	–0.19	**0.42**	**0.57**	0.09
In-house R&D	**0.93**	0.14	0.07	0.00
Patent	**0.83**	0.20	–0.17	0.05
Extramural R&D	**0.86**	0.07	0.10	0.10
Machinery	–0.08	0.06	–0.01	**0.72**
External knowledge	0.16	0.31	0.11	**0.40**
Design registration	0.24	**0.73**	–0.07	0.27
Copyright	0.28	**0.61**	–0.21	0.25
Training	0.25	–0.05	**0.39**	**0.38**
Marketing expenditures	**0.40**	**0.62**	0.24	–0.17
Proportion of variance explained by each factor	0.18	0.17	0.13	0.10

N = 1 033; CIS 4; five factors with eigenvalues greater than one. Tetrachoric correlations, unweighted data, rotation method varimax.

Source: OECD Innovation Microdata Project, 2008.

StatLink http://dx.doi.org/10.1787/546515437802

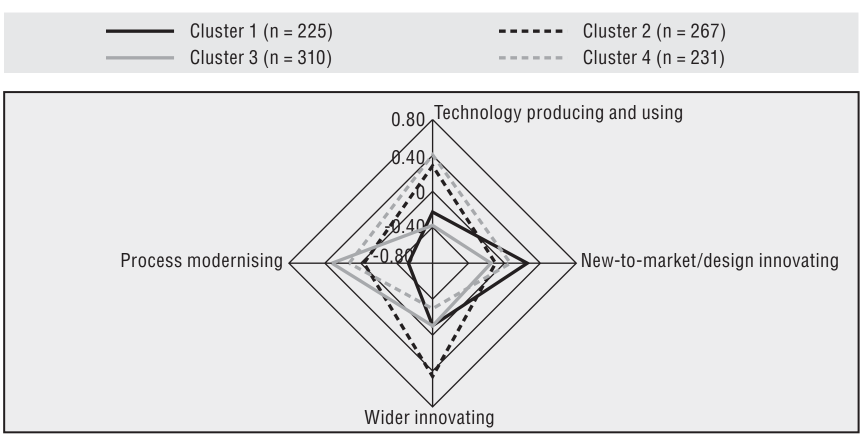
For Denmark, Factor 1 summarises a mode of innovating associated with own and diffused technologies. It is interpreted as *technology producing and using*. Particularly, high loadings are given to in-house R&D, purchased R&D and patenting. Other variables to do with IPRs – copyright and design registration – have low loadings. Factor 1 is also correlated with product innovation outputs and marketing expenditures. This indicates that technological efforts are complemented by research into new markets.

The second factor summarises a mode of innovation that links new-to-market innovations with design-related activities, including the development of new designs and packaging, design registration, copyright, marketing expenditures as well as new sales methods. Factor 2 is referred to as *new-to-market/ design innovating.* Factors 1 and 2 are both related to new-to-market innovations which involve design on the one hand and technology on the other.

Factor 3 exhibits high loadings of organisational changes, marketing innovations and training and, as elsewhere, it is called *wider innovating.* Finally, Factor 4 is *process modernising* based on high loadings of process innovation, acquisition of machinery, equipment or software, external knowledge and training. It emphasises diffused or embedded technologies and training. Factors 3 and 4 represent modes of innovation practices similar to those found for the four countries discussed so far; the key differences have to do with the loadings of product innovation outputs.

Figure 2.3 gives the results of the clusters based on the saved factor scores.

Figure 2.3. **Cluster analysis based on survey data from Denmark**



Source: OECD Innovation Microdata Project, 2008.

StatLink http://dx.doi.org/10.1787/545784207561

Cluster 1 includes enterprises that have above average score on Factor 2 (new-to-market/design innovating). These firms perform just below average with respect to wider innovating, process modernising and technology generating and adopting. Cluster 2 contains enterprises that focus on practices related to wider innovating and technology generating. Cluster 3 includes process modernisers, which perform below average with respect to other innovation modes. Finally, Cluster 4 groups enterprises that score high with respect to new-to-market/design innovating, technology producing and using, and process modernising.

Table 2.9. **Regression results based on survey data from Denmark**

	Dependent variable: log turnover per employee		
	Beta	S.E.	
Independent variables			
Factor 1: Technology producing and using	0.02	0.07	
Factor 2: New-to-market/design innovating	0.04	0.07	
Factor 3: Wider innovating	–0.02	0.06	
Factor 4: Process modernising	0.02	0.05	
Control variables			
Group belonging	0.13	0.06	***
Foreign market	0.04	0.06	
Cooperation with science and technology base	0.00	0.06	
Information from science and technology base	0.01	0.05	
Enterprise size	0.03	0.02	
Industry dummies	Yes		
Number of obs.	1 033		
F(23, 1 008)	. .		
R-squared	0.29		

◆ => $p < 0.10$; * => $p < 0.05$; ** => $p < 0.01$; *** => $p < 0.001$. Regression computed with constant. Beta coefficients/ marginal effects and robust standard errors are reported.
Source: OECD Innovation Microdata Project, 2008.

StatLink http://dx.doi.org/10.1787/546524282304

In terms of the relationship between modes of innovation and productivity, no significant associations are found between the factor scores and productivity in the Danish sample; however, the coefficients are positive for Factors 1, 2 and 4 and negative for Factor 3 (wider innovating). Indeed, the only variables that indicate some relationship are group belonging and strong industry effects.

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France

Along with the United Kingdom, France is the largest European economy included in the study. This section summarises the findings of the factor analysis based on the CIS 4 for France. The analysis is based on Pearson correlations, rather than tetrachoric correlations, and findings for the cluster and regression analysis are not available. Table 2.10 gives the factor loadings for the four-factor solution.

Table 2.10. **Factor analysis based on survey data from France**

Variables	Factor 1: *Technology innovating and process modernising*	Factor 2: *Organisational innovating*	Factor 3: *IPR innovating*	Factor 4: *Marketing-based innovating*
New-to-firm product innovation	**0.64**	0.00	0.15	–0.20
New-to-market product innovation	**0.64**	–0.02	**0.29**	–0.19
Process innovation	**0.74**	**0.31**	0.02	–0.11
New knowledge management	0.19	**0.74**	0.04	–0.16
New organisational structure	0.22	**0.72**	0.08	–0.17
New relations with other organisations	0.16	**0.60**	0.15	–0.16
New design or packaging	0.22	0.13	0.09	**–0.80**
New distribution method	0.10	0.16	0.03	**–0.83**
In-house R&D	**0.77**	0.10	0.20	–0.13
Patent	0.36	0.01	**0.67**	0.06
Extramural R&D	**0.61**	0.04	0.28	0.01
Machinery	**0.76**	0.23	0.01	–0.07
External knowledge	0.54	0.17	0.07	–0.12
Design registration	0.12	0.08	**0.75**	–0.11
Copyright	–0.02	0.15	**0.65**	–0.18
Training	**0.76**	0.27	0.03	–0.13
Marketing expenditures	**0.63**	0.04	0.20	–0.37

N = 19 304 (sample is not restricted to innovation-active firms); CIS 4; four factors with eigenvalues greater than one. Pearson correlations, unweighted data, rotation method varimax.
Source: OECD Innovation Microdata Project, 2008.

StatLink http://dx.doi.org/10.1787/546574302601

The French results produce one factor which combines previously found concepts of new-to-market innovating, technology generating and adopting, and process modernising into one factor. This single mode of innovating is interpreted as doing-it-all or *technology innovating and process modernising*.

Factor 2 gives high loadings to organisational and management changes and Factor 4 groups new design, packaging and sales methods. Previous country results linked these two factors into a single factor called wider innovating. Here Factor 2 is called *organisational innovating* and Factor 4 *marketing-based innovating*.

Finally, Factor 3 relates to *IPR innovating* and emphasises formal and informal techniques for protecting inventions and innovations from imitation through activities which lean towards the technological – patents – and activities that are perhaps more likely to be non-technological – design and copyright.

Korea

In the Korean survey used here, no information regarding copyrights is collected. Information on all other indicators is available. Table 2.11 gives an overview of the results.

Table 2.11. **Factor analysis based on survey data from Korea**

Variables	Factor 1: *IPR/in-house innovating*	Factor 2: *Organisational innovating*	Factor 3: *Marketing innovating*	Factor 4: *Technology producing and using*
New-to-firm product innovation	**0.74**	0.26	0.31	0.35
New-to-market product innovation	**0.73**	0.19	0.32	0.29
Process innovation	0.43	**0.51**	0.24	**0.43**
New management systems	0.27	**0.78**	0.25	0.31
New organisational structure	0.31	**0.77**	0.37	0.28
New relations with organisations	0.22	**0.83**	0.25	0.23
New design or packaging	0.37	0.24	**0.80**	0.18
New distribution method	0.22	0.30	**0.85**	0.15
In-house R&D	**0.66**	0.41	0.43	**0.45**
Patent	**0.79**	0.31	0.18	0.28
Extramural R&D	0.42	0.34	0.21	**0.66**
Machinery	0.44	0.42	0.37	**0.59**
External knowledge	0.33	0.40	0.28	**0.70**
Design registration	**0.77**	0.24	0.34	0.14
Training	0.33	0.48	0.40	**0.61**
Marketing expenditures	0.28	0.27	**0.76**	0.42
Proportion of variance explained by each factor	0.25	0.22	0.2	0.17

N = 2 595; three factors with eigenvalues greater than one. Tetrachoric correlations, unweighted data, rotation method varimax. Two factors with eigenvalues greater 1.
Source: OECD Innovation Microdata Project, 2008.

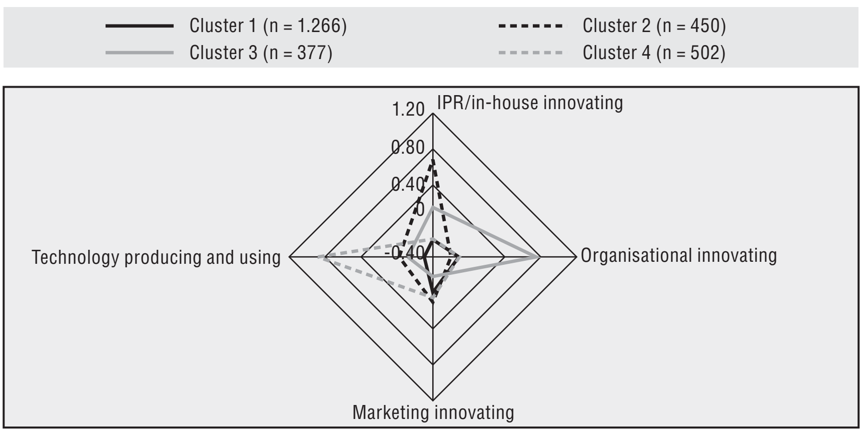
StatLink http://dx.doi.org/10.1787/546585513725

Factor 1 is interpreted as *IPR/in-house innovating* based on high loadings of in-house R&D, patent and design registration. Innovation in products, both new-to-firm and new-to-market, is also highly correlated with Factor 1.

Factor 2 exhibits high loadings for *organisational innovating*, and Factor 3 for *marketing innovating*. Like the results for France, and contrary to findings in other economies, innovation practices relating to organisational and managerial changes do not necessarily go hand-in-hand with marketing innovations in Korean firms.

Finally, Factor 4 summarises activities associated with internal and external R&D and knowledge, including technology embedded in machinery and training. This factor is called *technology producing and using* and is similar to factors found in Denmark, New Zealand and Norway.

Figure 2.4. **Cluster analysis based on survey data from Korea**



Source: OECD Innovation Microdata Project, 2008.

StatLink http://dx.doi.org/10.1787/545785435503

Cluster 1 is the largest group of enterprises (1 266) and they base their innovation activities on marketing, design and packaging activities. Cluster 2 contains 450 enterprises whose strategy or mode of innovation is linked to IPRs and in-house innovating; it thus tends to be technology-based and closed; however, there are some design and marketing innovations included in the mix of innovation activities. Cluster 3 is the smallest cluster and enterprises exhibit high scores for organisational innovating. Finally, Cluster 4 contains 502 enterprises that emphasise technology, both in-house and externally acquired. Table 2.12 links the factors to levels of productivity.

Table 2.12 suggests that Factor 3, marketing innovating, is positively associated with the dependent variable log of turnover per employee. None of the remaining factors shows a significant relationship with levels of productivity.

Table 2.12. **Regression analysis based on survey data from Korea**

	Dependent variable: log turnover per employee		
	Beta	S.E.	
Independent variables			
Factor 1: IPR/in-house innovating	0.05	0.09	
Factor 2: Organisational innovating	0.08	0.09	
Factor 3: Marketing innovating	0.09	0.08	◆
Factor 4: Technology producing and using	0.08	0.07	
Control variables			
Group belonging	0.15	0.09	***
Foreign market	Dropped		
Human capital	–0.02	0.07	
Co-operation with science and technology base	–0.04	0.07	
Information from science and technology base	–0.01	0.07	
Enterprise size	0.19	0.04	***
Industry dummies	Yes		
Number of observations	585		
F(24, 1 591)	. .		
R-squared	0.21		

◆ => p < 0.10; * => p < 0.05; ** => p < 0.01; *** => p < 0.001. Regression computed with constant. Standardised coefficients and robust standard errors are reported.
Source: OECD Innovation Microdata Project, 2008.

StatLink http://dx.doi.org/10.1787/546635616313

New Zealand

The analysis for New Zealand is based on the 2005 Business Operations Survey. The relevant questions relate to a two-year reference period rather than the three -year period used in most other innovation surveys. The second reference year is the latest financial year for which information is available, either 2004 or 2005.

The following country-specific variables are used in the analysis:

- New-to-firm product innovation: the firm introduced a new (or significantly improved) product (goods or services) and this was obtained from others and no significant improvements were made by the business itself.
- New management techniques: the firm made changes to organisational and managerial processes or implemented new business strategies or management techniques.
- Organisational structure: the firm made changes to organisational or managerial processes and engaged in organisational restructuring.
- New design: the firm is a marketing innovator and engaged in design activities.

- Improved marketing strategy: the firm is a marketing innovator and made significant changes to the marketing strategy.

The variables patent, copyright and design registration relate to stock, *i.e.* the enterprise holds patents, copyrights or design registrations, rather than flows as is the case for the CISs, *i.e.* the firm applied for a patent, claimed a copyright or registered a design during the survey reference period.

As throughout this study, the factor analysis is based on innovation-active firms. The definition of innovation-active is narrower than that used in previous country data. It includes firms which engage in any of the following: product innovation, process innovation, organisational innovation or marketing innovation. Studies based on the CISs also consider enterprises with ongoing or abandoned innovation projects as innovation-active.

Table 2.13. **Factor analysis based on survey data from New Zealand**

Variables	Factor 1: *Business process modernising*	Factor 2: *Technology producing and using*	Factor 3: *IPR innovating*	Factor 4: *Marketing-based imitating*
New-to-firm product innovation	0.01	0.00	–0.10	**0.84**
New-to-market product innovation	–0.08	**0.48**	**0.51**	–0.28
Process innovation	**0.52**	0.14	–0.13	**–0.40**
New management technique	**0.93**	0.06	0.06	0.01
New organisational structure	**0.88**	0.00	0.10	0.01
New design	**0.43**	**0.58**	0.20	**0.30**
Improved marketing strategy	**0.60**	**0.43**	0.15	**0.28**
In-house R&D	0.11	**0.65**	0.18	–0.12
Patent	0.02	0.09	**0.87**	–0.04
Extramural R&D	0.00	**0.75**	0.09	–0.13
Machinery	**0.41**	**0.41**	–0.25	–0.35
External knowledge	0.23	**0.53**	0.11	–0.04
Design registration	0.07	0.12	**0.79**	0.07
Copyright	0.13	0.09	**0.79**	0.01
Training	**0.61**	0.39	–0.09	–0.11
Marketing expenditures	0.20	**0.65**	0.27	**0.45**
Proportion of variance explained by each factor	0.20	0.18	0.16	0.09

N = 1 887; BOS2005; five factors with eigenvalues greater than one. Tetrachoric correlations, unweighted data, rotation method varimax.
Source: OECD Innovation Microdata Project, 2008.

StatLink http://dx.doi.org/10.1787/546641223265

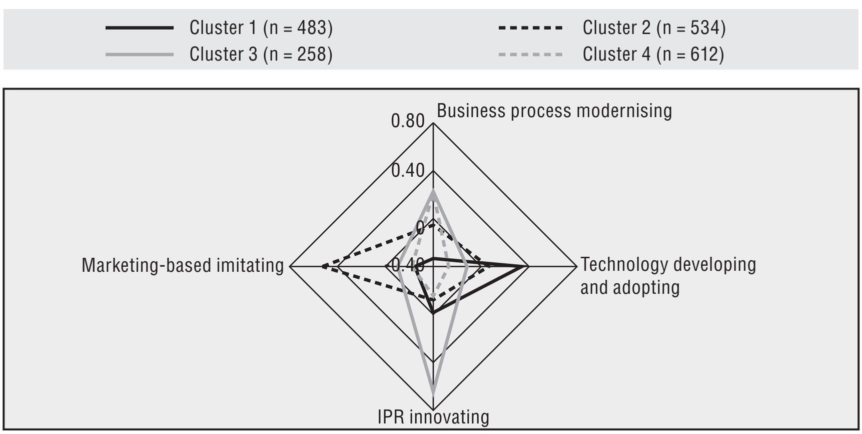
The first factor identified in the New Zealand dataset exhibits high correlations with process innovation, management and organisational innovations, and machinery and training. It thus includes elements of process modernising and wider innovating. This factor is therefore called *business* *process modernising*. Businesses scoring high on this factor tend to innovate in processes, introduce new management techniques and make changes to their organisational structure as well as marketing strategies.

The second factor is interpreted as *technology producing and using*. Firms engage in internal R&D, external R&D and the acquisition of external knowledge. Design activities load up with these variables. Moreover, there is a positive association with new-to-market innovations. This mode of innovation relates strongly to technological (diffused and generated), design activities and novel products.

Factor 3 has high values on measures of appropriability. The factor is also linked to new-to-market innovations. As for Denmark and France, this factor is referred to as *IPR innovating*.

Finally, the fourth factor is *marketing-based imitating*. A similar factor was discussed in reference to the Austrian and Brazilian datasets. It takes high loadings for new-to-firm innovations teamed up with engagement in marketing activities.

Figure 2.5. **Cluster analysis based on survey data from New Zealand**



Source: OECD Innovation Microdata Project, 2008.

StatLink http://dx.doi.org/10.1787/545824548334

Clusters 1 and 2 group enterprises that engage in marketing-based imitating and technology developing and adopting, respectively, and have low scores on business modernising and IPR innovating. Cluster 3 contains firms that perform above average with reference to both IPR innovating and business process modernising, while Cluster 4, with the largest number of observations, contains business process modernisers with below average scores on the three remaining innovation practices. Table 2.14 presents the results of the regression analysis.

Table 2.14. **Regression results based on survey data from New Zealand**

	Dependent variable: log turnover per employee		
	Beta	S.E.	
Independent variables			
Factor 1: Business process modernising	–0.01	0.05	
Factor 2: Technology producing and using	0.05	0.07	*
Factor 3: IPR innovating	0.07	0.07	**
Factor 4: Marketing-based imitating	0.03	0.05	
Control variables			
Group belonging	0.22	0.05	***
Foreign market	0.08	0.05	***
Co-operation with science and technology base	0.01	0.07	
Information from science and technology base	–0.01	0.04	
Enterprise size	–0.04	0.02	◆
Industry dummies	Yes		
Number of observations	1 887		
F(24, 1 862)	52.79		
R-squared	0.31		

◆ => $p < 0.10$; * => $p < 0.05$; ** => $p < 0.01$; *** => $p < 0.001$. Regression computed with constant. Beta coefficients/marginal effects and robust standard errors are reported.

Source: OECD Innovation Microdata Project, 2008.

StatLink http://dx.doi.org/10.1787/546652871784

The results of the regression indicate a positive and significant association between Factor 2 technology producing and using (beta = 0.05; $p < 0.05$) as well as Factor 3 IPR innovating (beta = 0.07; $p < 0.01$) and labour productivity. This suggests that for New Zealand technological innovation modes are associated with higher productivity levels, while marketing-based activities and changes in business processes are not.

Norway

The factor analysis for Norway is summarised in Table 2.15. For Norway the data suggested a six-factor rather than four-factor solution, with six factors generating eigenvalues greater than 1. As a result, the four-factor solution presented here leaves high uniqueness to the variable new-to-firm product innovation.

Factor 1 can be seen as representing *technology adopting* owing to high loadings of diffused technology embedded in machinery and external knowledge which is linked to training and marketing activities. This factor also has a positive loading of new-to-market innovations, although this is weaker than for machinery, external knowledge, training and marketing expenditures. Thus, this mode of innovation leads to some new-to-market innovations based on embedded technologies, training and marketing

Table 2.15. **Factor analysis based on survey data from Norway**

Variables	Factor 1: *Technology adopting*	Factor 2: *Business process modernising*	Factor 3: *IPR/design innovating*	Factor 4: *Technology producing and using*
New-to-firm product innovation	0.21	–0.02	0.25	0.27
New-to-market product innovation	**0.41**	0.11	**0.38**	0.23
Process innovation	**0.33**	**0.50**	–0.03	–0.13
New management systems	0.16	**0.78**	0.04	–0.02
New organisational structure	0.10	**0.79**	0.04	0.14
New relations with other organisations	–0.02	**0.72**	0.10	0.16
New design or packaging	0.19	**0.37**	**0.39**	–0.02
New distribution method	0.08	**0.66**	0.13	–0.19
In-house R&D	0.24	–0.09	0.11	**0.84**
Patent	0.00	–0.01	**0.73**	**0.41**
Extramural R&D	0.02	0.15	0.08	**0.84**
Machinery	**0.74**	0.04	–0.01	0.02
External knowledge	**0.67**	0.20	0.06	0.04
Design registration	0.04	0.05	**0.88**	0.09
Copyright	0.06	0.13	**0.77**	–0.10
Training	**0.83**	0.08	–0.06	0.12
Marketing expenditures	**0.79**	0.11	0.20	0.18
Proportion of variance explained by each factor	0.18	0.17	0.15	0.15

N = 1 033; CIS 4; Six factors with eigenvalues greater than one. Tetrachoric correlations, unweighted data, rotation method varimax.
Source: OECD Innovation Microdata Project, 2008.

StatLink *http://dx.doi.org/10.1787/546683610371*

expenditures with relatively less importance of own generation and diffusion of technologies in terms of R&D and patents. The latter might be seen as lower reliance on technologies.

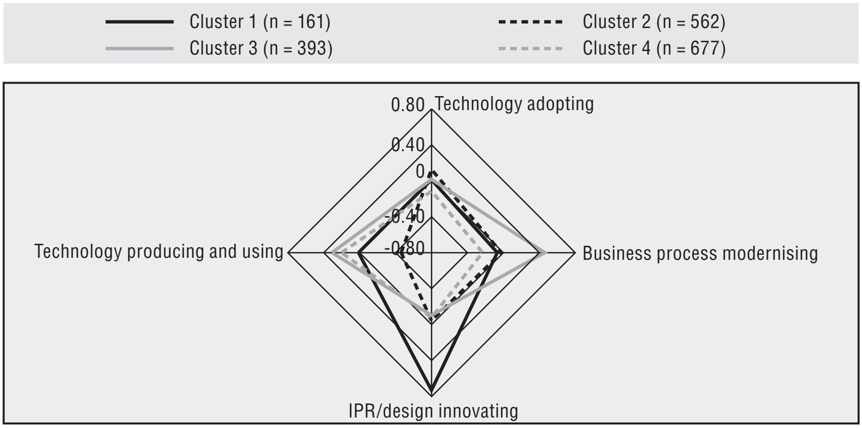
Factor 2 is interpreted as *business process modernising*. New Zealand also displayed a factor which loads process modernising with wider innovating, but in contrast to New Zealand, embedded technology (machinery) and training do not load up with the factor business process modernising.

Factor 3 exhibits high loadings in relation to *IPR/design innovating*. Interestingly, new design and packaging loads up on Factor 3. Elsewhere, other IPR modes tend to be linked to in-house technology and external technology.

Finally, Factor 4 is associated with *technology producing and using*. This factor gives high loadings to internal and external R&D and to patenting.

Cluster 1 contains 161 enterprises which are IPR/design innovators as indicated by the high value for IPR/design innovating and the average (approximately zero) scores for all other innovation modes. Cluster 2 exhibits above-average values for technology adopting but below average values for

Figure 2.6. **Cluster analysis based on survey data from Norway**



Source: OECD Innovation Microdata Project, 2008.

StatLink http://dx.doi.org/10.1787/545827350627

technology producing and using. Technology adopting refers to technology not directly associated with R&D, including purchased technology embedded in machinery and other knowledge, whereas technology producing and using refers to in-house and purchased R&D.

Cluster 3 groups enterprises which are technology producers and users as well as business process modernisers, while Cluster 4, with 677 enterprises the largest cluster, contains technology producers/users that are not business process modernisers.

Table 2.16 indicates the impact the factors may have on firm-level productivity.

Two out of the four factors are positively associated with levels of productivity. First, business process modernising is positively associated with levels of labour productivity (beta = 0.05; $p < 0.05$). Second, enterprises that score high on modes related to technology producing and using exhibit higher levels of productivity (beta = 0.12; $p < 0.001$). The Wald test of equal coefficients between Factor 2 and 4 is insignificant and it is not possible to suggest a stronger association between the technology-driven factor, Factor 4, and the non-technological factor, Factor 2.

United Kingdom

Much of the patenting and R&D data available tends to indicate that the United Kingdom is not among the top-performing countries in terms of innovation; yet, economic trends, including productivity growth, suggest that the United Kingdom performs well above average. The discrepancy between

Table 2.16. **Regression results based on survey data from Norway**

	Dependent variable: log turnover per employee		
	Beta	S.E.	
Independent variables			
Factor 1: Technology adopting	0.00	0.06	
Factor 2: Business process modernising	0.05	0.08	*
Factor 3: IPR/design innovating	–0.02	0.10	
Factor 4: Technology producing and using	0.12	0.07	***
Control variables			
Group belonging	0.20	0.06	***
Foreign market	0.07	0.08	**
Human capital	0.10	0.14	**
Co-operation with science and technology base	–0.04	0.07	◆
Information from science and technology base	0.01	0.08	
Enterprise size	–0.11	0.04	*
Industry dummies	Yes		
Number of observations	1 616		
F(24, 1 591)	11.61		
R-squared	0.15		

◆ => p < 0.10; * => p < 0.05; ** => p < 0.01; *** => p < 0.001. Regression computed with constant. Beta coefficients/ marginal effects and robust standard errors are reported.

Source: OECD Innovation Microdata Project, 2008.

StatLink http://dx.doi.org/10.1787/546700417440

traditional and technology-oriented indicators of innovation and performance in the United Kingdom implies the need for a broader understanding of the innovation practices that lead to improved performance.

While the United Kingdom does not collect information on wider innovation in terms of new or significantly changed relations with other firms or public institutions, as suggested by the harmonised CIS questionnaire, UK innovation surveys collect information on the following over and above the harmonised CIS questionnaire: implementation of advanced management techniques; changes in organisational structure; and changes in marketing concepts or strategies. These are used in this section.

The factor analysis presented in Table 2.17 is based on a tetrachoric correlation matrix based on unweighted data. Four factors with eigenvalues greater than 1 are extracted and their correlations with the variables feeding into the analysis are summarised.

The first factor is interpreted as *IPR/in-house innovating*. It is based on high loadings of protection of inventions and innovations from imitation, including patenting, design registration and copyright. In order to register IPRs, the enterprise has to be the originator of the protected idea, and the in-house

Table 2.17. **Factor analysis based on survey data from the United Kingdom**

Variables	Factor 1: *IPR/in-house innovating*	Factor 2: *Process modernising*	Factor 3: *Wider innovating*	Factor 4: *Market-driven innovating*
New-to-firm product innovation	–0.03	0.04	0.10	**0.72**
New-to-market product innovation	**0.36**	0.14	0.17	**0.50**
Process innovation	0.00	**0.40**	0.27	**–0.62**
Advanced management techniques	0.08	0.17	**0.80**	–0.11
New organisational structure	0.16	0.05	**0.83**	0.03
Marketing change	0.10	0.14	**0.79**	0.15
In-house R&D	**0.40**	**0.47**	0.14	**0.37**
Patent	**0.95**	0.09	0.05	0.03
Extramural R&D	0.27	**0.63**	0.14	0.27
Machinery	0.01	**0.81**	0.05	–0.19
External knowledge	0.18	**0.73**	0.09	0.09
Design registration	**0.95**	0.07	0.07	0.03
Copyright	**0.91**	0.08	0.14	0.04
Training	0.05	**0.71**	0.24	–0.07
Marketing expenditures	0.25	**0.48**	0.29	**0.40**
Proportion of variance explained by each factor	0.21	0.19	0.15	0.11

N = 5 203; CIS 4; four factors with eigenvalues greater than one. Tetrachoric correlations, unweighted data, rotation method varimax.

Source: OECD Innovation Microdata Project, 2008.

StatLink http://dx.doi.org/10.1787/546704166541

component is also linked to a relatively high loading of own technology. IPR/in-house innovating is correlated with new-to-market product innovations. Innovation practices based on strong IPRs are also apparent in other countries with advanced innovation systems, such as France, Canada and New Zealand. Strategies of appropriation appear less relevant in smaller, perhaps more open, economies such as Austria and Denmark; or countries with perhaps less advanced innovation systems such as Brazil and Korea.

Factor 2 relates to *process modernising*. It is based on process innovation, in-house R&D, external R&D and knowledge, as well as other inputs: training and marketing expenditures. It summarises own generation of technology and diffused technology together with other activities (training and marketing). Throughout the study it was found that the acquisition of machinery and training tends to hang together with process innovation, but own generation or diffused R&D tended not to be of high importance in relation to process modernising. In Norway and New Zealand, process modernising is linked to managerial and marketing changes.

Factor 3 represents *wider innovating*. It links managerial, organisational and marketing changes. Thus, enterprises which innovate in terms of improved managerial techniques tend to modify the structure of their organisations and their marketing strategies at the same time. Wider innovation practices are relevant in most countries. In Austria design-related activities load up with this factor. In France and Korea two distinct factors are identified, one relating to management and organisational changes, and the other relating to marketing strategies, but these activities are not necessarily carried out together.

Finally, Factor 4 combines innovation outputs in products, both new-to-market and new-to-firm, with marketing expenditures, and excludes innovations in processes. This factor is called *market-driven innovating*. Enterprises that engage in this mode of innovation recognise the need to take a specific approach to realise their innovations effectively. Market intelligence and spending on marketing also load up with own and diffused technology. The negative loading of process innovation may be explained by and linked to the innovation's product life cycle.[6] For example, at the start of the product cycle firms are likely to be concerned with and compete *via* the introduction of new and improved products, whereas in the later stages of a product cycle the emphasis shifts towards process innovation and, then, competition is based on improved efficiencies in the production of existing products.

Across factors in-house R&D loads up positively, and is relevant to three modes of innovation practices: IPR/in-house innovating, process modernising and market-driven innovating. Marketing expenditures are relevant to two factors: process modernising and market-driven innovating.

While the factor analysis provides a definition of innovation practices, the cluster analysis groups firms according to these practices. The cluster analysis groups enterprises by similarity across the factor scores and innovation modes. The results are presented in Figure 2.7.

All four clusters are similar in size and contain between 1 000 and 1 745 enterprises. Enterprises in Cluster 1 engage in in-house/IPR innovating, and perform below average in terms of wider innovating. Cluster 2 contains enterprises that perform above average in terms of process modernising and score low on in-house/IPR innovating and wider innovating.

Cluster 3 is made up of enterprises that carry out process modernising and wider innovating, involving managerial, organisational and marketing innovations. Finally, Cluster 4 contains enterprises that engage in market-driven innovating. Thus, with the exception of Cluster 3, enterprises are grouped predominantly by a single, shared innovation practice.

Table 2.18 gives an overview of the regression estimations. The dependent variable is the level of turnover per employee and the key independent variables are the factor scores of the four factors representing the four modes of innovation practices: in-house/IPR innovating; process modernising; wider innovating; and market-driven innovating.

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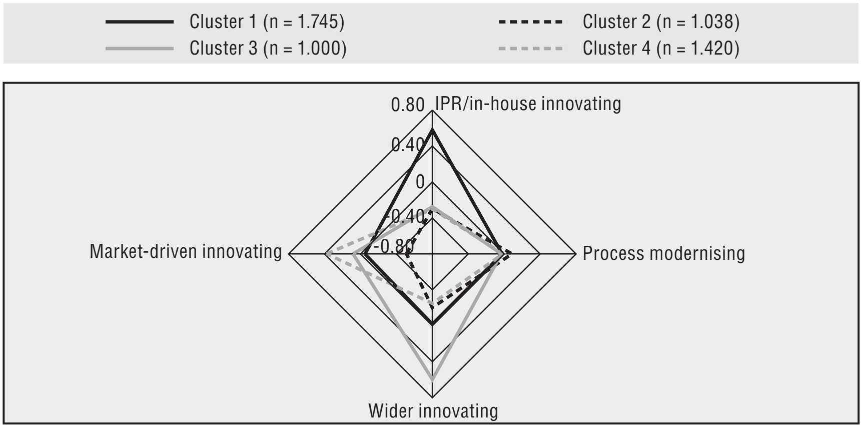
Figure 2.7. **Cluster analysis based on survey data from the United Kingdom**



Source: OECD Innovation Microdata Project, 2008.

StatLink http://dx.doi.org/10.1787/545851428535

Table 2.18. **Regression results based on survey data from the United Kingdom**

	Dependent variable: log of turnover per employee		
	Beta	S.E.	
Independent variables			
Factor 1: IPR/in-house innovating	0.06	0.02	***
Factor 2: process modernising	0.01	0.01	
Factor 3: wider innovating	0.02	0.01	◆
Factor 4: market-driven innovating	0.00	0.01	
Control variables			
Part of a company group	0.16	0.03	***
International competition	0.14	0.03	***
Human capital	0.05	0.00	***
Co-operation with the science and tech base	–0.01	0.04	
Information science and tech base	0.01	0.04	
Enterprise size	–0.02	0.01	
Number of observations	5 152		
F(48, 5 104)	59.19		***
R-squared	0.19		

◆ => $p < 0.10$; * => $p < 0.05$; ** => $p < 0.01$; *** => $p < 0.001$. Regression computed with constant. We report standardised coefficients and robust standard errors.
Source: OECD Innovation Microdata Project, 2008.

StatLink http://dx.doi.org/10.1787/546716312177

Table 2.18 suggests that Factor 1, IPR/in-house innovating, is positively and significantly related to productivity (beta = 0.06; $p < 0.001$). Further, there is some indication that wider innovating, *i.e.* managerial, organisational and marketing innovations, is associated with higher productivity levels (beta = 0.02; $p < 0.10$). Testing the linear hypothesis of equality among coefficients finds that the strength of the association between Factor 1 and productivity is statistically higher than for the other innovation practices. In New Zealand this study also finds a positive association between appropriation practices and productivity. Wider innovating is linked to increased productivity in Korea and Norway.

Perhaps somewhat surprising is the lack of association between process modernising and high levels of productivity (beta = 0.01; p not significant). However, similar innovation modes identified in Austria, Brazil and Canada show a significant association.

Overall, the association between innovation modes and productivity is less strong than anticipated. Structural characteristics, including group affiliation, foreign market orientation and human capital are strongly positively associated with labour productivity ($p < 0.001$).

2.5. Summary of findings

This section brings together the country results with a view to identifying common modes of innovation across the nine countries. Table 2.19 works towards identifying modes of innovation based on the results presented above.

Common patterns

This section draws out the common patterns derived from the factor analyses which are summarised the first column of Table 2.19 as the following common modes of innovation practices: *i)* new-to-market innovating; *ii)* marketing-based imitating; *iii)* process modernising; and *iv)* wider innovating. In general, the innovation modes *process modernising* and *wider innovating* show relatively high consistency across the nine countries studied; while the highest degree of country specificity is found in conjunction with the mode *new-to-market innovating*. The discussion starts with the latter, and, thus, relates to the second row in Table 2.19.

First, all countries exhibit some form of *new-to-market innovating modes*. The most general pattern suggests that new-to-market innovating is linked to own generation of technology, as indicated by the high loadings associated with in-house R&D and patenting.

In Austria, Denmark and New Zealand diffused technology (externally acquired R&D) is commonly found in conjunction with own technology; this may be an indication of a more open innovation pattern in these countries. In Austria, Brazil, Denmark, Korea and Norway, design-related activities are also associated with new-to-market innovating; in such cases, innovation may be relatively design-led.

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Table 2.19. **Summary of findings from the factor analyses**

Modes of innovation	Austria	Brazil	Canada	Denmark	France	Korea	New Zealand	Norway	United Kingdom
New-to-market innovating	Factor 1 based on own and *diffused technology*, and based on *design*.	Factor 1 based on own technology, and based on *design*.	Factor 3 based on *IPR/external innovating*. Factor 1 *in-house/market driven innovating* product innovations with own technology and marketing expenditures.	Factor 1 based on own technology and *diffused technology*. Factor 2 new-to-market and new-to-firm innovations with marketing and *design*.	Factor 3 based on IPR *innovating*. Factor 1 *Technology innovating and process modernising*. New-to-market, new-to-firm, process innovators, own and diffused technology, machinery and training.	Factor 1 based on *IPR/in-house innovating* with own technology and *design*.	Factor 2 based on own and *diffused technology and marketing*. Factor 3 based on IPR *innovating*.	Factor 1 based on *diffused technology, excl. own technology*. Factor 3 based on *IPR/design innovating*.	Factor 1 based on *IPR/in-house innovating*. Factor 4 based new-to-firm innovation, marketing expenditures, *plus new-to-market, own technology*.
Marketing-based imitating	Factor 4 based on new-to-firm innovation with marketing expenditures.	Factor 2 based on new-to-firm innovation with marketing expenditures, *own, diffused technology*.				No directly associated factor.	Factor 4 based on new-to-firm innovators with marketing expenditures.	No directly associated factor.	
Process modernising	Factor 3 based on process innovation, machinery and training.	Factor 3 based on process innovation, machinery and training.	Factor 2 based on process innovation, machinery and training.	Factor 4 based on process innovation, machinery and training.		Factor 4 process innovation, with *technology producing and using*.	Factor 1 *Business process modernising* based on process innovation, organisational innovation, marketing innovation, machinery and training.	Factor 2 *Business process modernising* based on process innovation linked with organisational innovations and not based on machinery and training.	Factor 2 based on process innovation, machinery and training.
Wider innovating	Factor 2 joining organisational and marketing activities, *plus design*.	Factor 4 based on organisational and marketing innovation.	n.a.	Factor 3 based on organisational and marketing activities.	Factor 2 organisational innovations. Factor 3 with marketing activities.	Factor 2 marketing innovating. Factor 3 organisational innovating.			Factor 3 based on organisational and marketing activities.

Note: Country-specific loadings of variables and country-specific factors are italicised. In the case of Norway, Factor 4: "technology producing and using" loads up with in-house R&D, patents and extramural R&D.
Source: OECD Innovation Microdata Project, 2008.

Another pattern linked to new-to-market innovation is appropriation strategies, with both formal and informal methods of protection. Results for Canada, France, New Zealand and the United Kingdom suggest that firms use such strategies. It seems likely that such firms rely to a greater extent on closed innovation practices; except in New Zealand, they are less likely to adopt external technologies, and more likely to protect their innovation efforts from imitation.

The second distinct factor is here called *process modernising*. Activities considered as process modernising include acquisition of machinery, equipment and software, and, thus, the use of embedded technologies, along with training of staff to apply the new equipment to innovation-related activities. Firms in Austria, Brazil, Canada, Denmark and the United Kingdom exhibit such innovation practices. Technological activities in the form of in-house or acquired R&D generally play a lesser role; however, in Korea one factor/innovation mode links process innovation with internal and external R&D.

Organisational and marketing innovations are linked to process modernising in New Zealand and Norway and are here referred to as *business process modernising* to acknowledge a strategy which involves changes to production processes in tandem with changes to the organisational structure and managerial techniques and competencies.

All countries, for which the relevant information is available, exhibit a mode or practice which is referred to as *wider innovating*. Here, organisational and marketing-related innovation strategies load up in one factor for firms in Austria, Brazil, Denmark, and the United Kingdom. In France and Korea, two separate factors are linked to *organisational innovating* on the one hand and *marketing innovating* on the other hand.

Country-specific findings

Perhaps the most noticeable country-specific deviation emerges from the factor analysis based on the French dataset, where one factor, called *technology innovating and process modernising*, emerges. This factor joins all forms of product and process innovation outputs, with technology – own, diffused and embedded – as well as training expenditures. Also noticeable are the cross categories and innovation practices summarised here as *business process modernising* in New Zealand and Norway.

In the case of Norway, there is a fourth factor which does not appear in Table 2.19 but is referred to in the note to the table. It is called *technology producing and using* and loads up on internal and external R&D. It has a positive association with new-to-firm and new-to-market product innovation, yet the loadings on the latter are not very pronounced (0.27 and 0.23 respectively), and, therefore, it is not included in Table 2.19. The factor has a negative

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loading with process innovation outputs (–0.13). Moreover, the Norwegian results on new-to-market innovating give little indication of reliance on formal R&D, whether internal or external, and instead a higher reliance on diffused knowledge and training.

A further example of country-specific findings, beyond those highlighted in the relevant sections, relates to the innovation practice summarised as *marketing-based imitating* (new-to-firm product innovation) in Brazil, which is also linked to own and diffused technologies. In Korea the factor *process modernising* exhibits high loadings on own and diffused technologies, next to machinery and training expenditures. Findings from Austria suggests that design activities are connected with new-to-market innovating and with wider innovating (organisational and marketing innovating).

Findings on innovation modes and productivity

Table 2.20 summarises the findings on innovation practices and productivity.

In terms of productivity, enterprises with high scores on factors related to *process modernising* exhibit higher values in Austria, Brazil and Canada. In Norway the factor *business process modernising*, *i.e.* process innovating plus organisational and marketing innovating, is associated with higher productivity levels.

A different pattern emerges in New Zealand and the United Kingdom with positive associations between *new-to-market (product) innovating* and productivity. Similarly, in Norway, *technology producing and using* is positively linked to productivity.

Surprisingly, the Austrian sample shows a negative association between *marketing-based imitating* and productivity.

Overall, no consistent pattern emerges in terms of the effects of specific modes of innovation and productivity across countries. Different innovation modes are significantly related to the level of productivity, measured at the end of the three-year period covered by the surveys. This suggests that, even with datasets constrained to be as comparable as possible across participating countries, there are major national differences in patterns of competitive and comparative advantage. This would imply, for example, potentially different responses to similar policy instruments.

Also notable is the limited number of modes of innovation that are statistically significant in the productivity equations. This points to the need for more extensive analyses of alternative measures of performance. Businesses use innovation to achieve a range of objectives such as growth, survival, profitability, gains in market share, etc., that will not always correlate with levels of labour productivity. Analyses using data matching to other sources, such as value added or financial performance, is a line of research to be pursued.

Table 2.20. **Summary of findings on the link between different modes of innovation and labour productivity**

<table>
<tr><th>Modes of innovation</th><th>Austria</th><th>Brazil</th><th>Canada</th><th>Denmark</th><th>France</th><th>Korea</th><th>New Zealand</th><th>Norway</th><th>United Kingdom</th></tr>
<tr><td>New-to-market innovating</td><td>No association.</td><td>No association.</td><td rowspan="2">No association.</td><td rowspan="2">No association.</td><td rowspan="3">Not tested.</td><td>No association.</td><td>Positive association Factor 2 (p < 0.05) and Factor 3 (p < 0.01).</td><td>No association.</td><td>Positive association (p < 0.05).</td></tr>
<tr><td>Marketing-based imitating</td><td>Negative association (p < 0.05).</td><td>No association.</td><td>No association.</td><td>No association.</td><td>No association.</td><td>No association.</td></tr>
<tr><td>Process modernising</td><td>Positive association (p < 0.10).</td><td>Positive association (p < 0.10).</td><td>Positive association (p < 0.05).</td><td>No association.</td><td>No association.</td><td>No association.</td><td rowspan="2">Positive association (p < 0.05).</td><td>No association</td></tr>
<tr><td>Wider innovating</td><td>No association.</td><td>No association.</td><td>No association.</td><td>No association.</td><td>Not tested.</td><td>Positive association (p < 0.10).</td><td>No association.</td><td>No association.</td></tr>
</table>

Note: Additionally the factor technology generators – Norway-specific – showed a positive association with productivity ($p < 0.001$).
Source: OECD Innovation Microdata Project, 2008.

Dynamic processes – all modes of innovation – can be expected to have an impact over time, even on the productivity measure. Further runs of the survey will soon provide, for several countries, the possibility of modelling changes in innovation and productivity levels over time, and matching to other data sources may enable the measurement of the relationship between innovation modes and changes in various indicators of productivity.

Notes

1. Country results were prepared by Martin Berger for Austria; Bruno Araújo and João De Negri for Brazil; Pierre Therrien for Canada; Carter Bloch for Denmark; Fabrice Galia for France; Richard Fabling and Julia Gretton for New Zealand; Svein Olav Nås for Norway; Seok-Hyeon Kim for Korea; Marion Frenz and Ray Lambert for the United Kingdom. Stephanie Robson and Gregory Haigh provided useful comments on an earlier draft. Support throughout the project was provided by Alessandra Colecchia, Dominique Guellec and Vladimir López-Bassols (OECD).
2. For the United Kingdom, results were computed on the basis of polychoric correlations and the patterns found were similar to those presented here.
3. Results derived through principal component analysis based on Pearson correlation coefficients should lead to similar results.
4. Results available on request.
5. While the centrally written STATA commands envisaged that countries would run a k-means cluster analysis that randomly selects a starting seed in the data, Austria provided the solutions of a hierarchical clustering technique using Ward's linkage cluster analysis. This was done because the results of the k-means analysis were unstable: depending on the randomly selected starting point the outcomes of the clustering differed substantially.
6. We owe this point to Andy Cosh.

References

Acha, V. (2007), "Open by Design: The Role of Design in Open Innovation", report to the Department for Innovation, Universities and Skills.

Acha, V. and A. Salter (2004), "Oslo Manual Revision 3 Workshop for a Chapter on the 'Economics of Innovation'", workshop report for the Department of Trade and Industry, November.

Battisti, G. and P. Stoneman (2007), "How Innovative are UK Firms? Evidence from the CIS 4 on the Synergistic Effects of Innovations", report for the Department of Trade and Industry.

Cohen, W. (1995), "Empirical Studies of Innovation Activity" in P. Stoneman (ed.), *Handbook of the Economics of innovation and Technological Change,* Oxford, Blackwell, pp. 182-264.

Djellal, F. and F. Gallouj (2001), "Innovation Surveys for Service Industries: A Review", in B. Thuriaux, E. Arnold and C. Couchot (eds.), *Innovation and Enterprise Creation: Statistics and Indicators*, European Commission, Luxembourg.

Fagerberg, J. (2005), "Innovation: A Guide to the Literature", in J. Fagerberg, D. Mowery and R.R. Nelson (eds.) *The Oxford Handbook of Innovation,* Oxford: Oxford University Press, pp. 1-26.

Fidell, L.S. and B.G. Tabachnick (2006), *Using Multivariate Statistics,* 5th edition, Allyn & Bacon.

Geroski, P.A., S. Machin and J. van Reenen (1993), "The Profitability of Innovating Firms", *Rand Journal of Economics,* 24, pp. 198-211.

Hollenstein, H. (2003), "Innovation Modes in the Swiss Service Sector: A Cluster Analysis Based on Firm-level Data", *Research Policy,* 32, pp. 845-863.

Howells, J. and B. Tether (2007), "Changing Understanding of Innovation in Services", draft report for the Department of Trade and Industry.

Jensen, M.B. *et al.* (2007), "Forms of Knowledge and Modes of Innovation", *Research Policy,* Vol. 36, No. 5.

Laursen, K. and A. Salter (2005), "The Paradox of Openness: Appropriability and the Use of External Sources of Knowledge for Innovation", paper presented at the Academy of Management Conference, Hawaii, August.

OECD (1996), *Oslo Manual: The Measurement of Scientific and Technological Activities. Proposed Guidelines for Collecting and Interpreting Technological Innovation Data*, 2nd edition, OECD, Paris.

OECD (2006a), *OECD Economic Survey of Brazil 2006*, OECD, Paris.

OECD (2006b), *OECD Economic Survey of Canada 2006*, OECD, Paris.

OECD (2007), *OECD Economic Survey of Austria 2007: Improving Innovation*, OECD, Paris.

OECD and Eurostat (2005), *Oslo Manual: The Measurement of Scientific and Technological Activities. Guidelines for Collecting and Interpreting Innovation Data*, 3rd edition, OECD/Eurostat, Paris.

Peeters, L, G. Swinnen, and M. Tiri (2004), "Patterns of Innovation in the Flemish Business Sector: A Multivariate Analysis of CIS 3 Firm-level Data", report for the IWT Studies: Brussels.

Smith, K. (2005), "Measuring Innovation", *in* J. Fagerberg, D. Mowery and R.R. Nelson (eds.), *The Oxford Handbook of Innovation*, Oxford: Oxford University Press, pp. 148-177.

Schumpeter, J.A. (1934), *The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest and the Business Cycle*, Transaction Books, New Brunswick, NJ and London.

Tether, B. and I. Miles (2001), "Surveying Innovation in Services: Measurement and Policy Interpretation Issues", *in* B. Thuriaux, E. Arnold and C. Couchot (eds.), *Innovation and Enterprise Creation: Statistics and Indicators*, European Commission, Luxembourg.

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Innovation in Firms: A Microeconomic Perspective

Chapter 3

Innovation and Productivity: Estimating the Core Model Across 18 Countries[1]

by

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3.1. Background

Innovation is considered one of the main drivers of productivity growth and economists have investigated both its determinants and its contribution to firm performance, measured as productivity; growth and/or market value. There are several reasons for analysing the link between innovation and productivity at the firm level. First, it is firms that innovate, not countries or industries. Second, aggregate analysis hides a lot of heterogeneity. Firms' performance and characteristics differ both across countries and within industries; countries' innovation systems are characterised by mixed patterns of innovation strategies which have an impact on firms' behaviour; and firms may adopt multiple paths to innovation, including non-technological ones.[2] The advantage of micro-level analysis is that it attempts to model the channels through which specific firms' knowledge assets or specific knowledge channels can have an impact on these firms' productivity and therefore shed light on the role that innovation inputs, outputs and policies play in economic performance.

This analysis uses the same modelling and estimation strategy on comparable firm-level data from innovation surveys of 18 countries – European, non-European and one major developing economy, Brazil – for the early 2000s. The use of the same framework on similar variables makes the results as comparable as possible across countries. The results show surprisingly similar and consistent patterns with some notable exceptions, especially the relationship between innovation policy and investments in innovation.

3.2. The innovation and productivity link in a simplified framework

How is innovation measured in empirical studies? A first approach is to use patent data to measure "inventive output". However, not all innovations are patented and there is great heterogeneity in firms' propensity to patent. The relative importance of patenting as a barrier to imitation differs both among sectors and among types of innovation. A second approach is to use R&D expenditure. R&D, while it is typically well codified, is a measure of input to the innovation process rather than output. Moreover, firms, in particular small firms and those in the services sector, may generate technological advances outside formal R&D laboratories which R&D expenditure may not capture.[3]

This analysis builds on a third approach which uses direct information from innovation surveys on firms' product and process innovations, innovation expenditure, R&D and other knowledge investments, co-operation,

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obstacles to innovation and the relative importance of various knowledge flows. The novelty is to look at the relative role played by firms' intangible assets – not only R&D but all innovation-related investments – as well as the use of the share of sales generated by new products and the presence of process innovations as measures of innovation outputs, rather than patents.[4]

A widespread approach is to frame the relationship between innovation and its determinants in a knowledge production function and the contribution of innovation to productivity in an output production function (see Griliches, 1979; Griliches and Pakes, 1980). The knowledge production function approach assumes that the production of new knowledge depends on current and past investment in new knowledge (*e.g.* current and past R&D expenditures) and on other factors such as knowledge flows from outside the firm. The underlying crucial assumption is that innovation inputs determine innovation outputs, which in turn affects productivity. Following the seminal paper of Griliches and Pakes (1980), a new strand of the literature has developed full structural models of the innovation process and the relationship between innovation output and productivity using direct measures of innovative output from innovation surveys. The first to develop such a model were Crépon, Duguet and Mairesse (1998) (henceforth CDM), who used the French Community Innovation Survey. Box 3.1 provides a non-technical explanation of how this analysis compares to the CDM model and to other variants of this model in the literature.

Box 3.1. **The model in a nutshell**

CDM[1] structurally model the innovation investment decision, the innovation process and the role of innovation in the production of output. They correct for two main problems that affect this type of analysis. The first is selectivity; *i.e.* the fact that only a subset of firms engages actively in innovation activity (*e.g.* invests in R&D) and the French innovation survey only asks questions to this subset of innovative firms. If the analysis is restricted to this non-random subset of "R&D spenders" the approach must correct for selection biases that might arise. The second problem is endogeneity due to the fact that some of the explanatory variables in the model might be simultaneously determined as the dependent variables.[2] CDM take both these problems into account in their three-step model. In the first step firms decide whether and how much to invest in R&D. Only if the net returns to this investment (which the analyst cannot observe but firms know) are positive will they actually have positive R&D expenditure. In the second step the model relates the given investment in R&D to innovation outputs, defined either as innovative sales or as number of patents, using a knowledge production function. Finally in the third step CDM estimate an augmented Cobb-Douglas production function that describes the relationship between innovation output and productivity.

Box 3.1. **The model in a nutshell** *(cont.)*

Like CDM, the model used here has three stages and consists of four equations. The first stage explains firms' decision to engage or not in innovation activities and the decision on the amount of innovation expenditure. In the first equation the probability that a firm will innovate depends on the size of the firm, measured as log employment; whether the firm is part of a group; whether the firm serves a foreign market; whether it experienced obstacles to innovation of various kinds; and the industrial sector to which it belongs. The choice of these covariates is mainly dictated by the limited availability of information for non-innovative firms in innovation surveys across all countries.

For a given probability to innovate, the second equation of the first stage models an innovation expenditure intensity equation, where the dependent variable is log innovation expenditure per employee. In addition to the regressors in the first equation, the intensity to innovate is modelled also to depend on whether the firm has co-operation activities and whether the firm is receiving public financial support.

The second stage models the knowledge production function where the dependent variable, log of innovative sales per employee, depends on the intensity of investment in innovation; firm's size; the firm being part of a group; process innovation and different types of co-operation the firm engages in (with clients; suppliers; other private and public agents); and industry dummies. Since the model is estimated only on innovative firms, the estimation technique controls for selectivity. In addition, it controls for potential endogeneity, which might arise because of unobserved heterogeneity or omitted variables; *i.e.* factors that are not controlled for and influence both firms' innovation output and innovation inputs (*e.g.* positive temporary shocks; unobserved managerial ability, etc.); or because of reverse causality (*e.g.* innovation surveys ask for innovation inputs and output in the same year).

The third stage estimates the innovation output productivity link using an augmented Cobb-Douglas production function. The dependent variable is log sales per employee. The right-hand side variables included are size; a dummy for group; process innovation; and log innovative sales per employee. Again, selectivity and potential endogeneity are dealt with by appropriate econometric techniques.

1. CDM = Crépon, Duguet and Mairesse (1998).
2. For example, in the knowledge production function,the positive coefficient on innovation inputs might be driven by the fact that higher expenditure leads to higher innovation output, but it might also be due to the fact that firms that are more likely to have successful innovation output for reasons other than current innovation expenditure (*e.g.* being more successful in the past, or having better management) might also be more likely to spend more on innovation. In the output production function, innovation outputs might be endogenous either because of unobserved shocks or because of unobserved firm characteristics such as management quality which are correlated with both the firm's total sales and with its innovative sales.

As in CDM, this analysis uses a structural model that formalises: *i)* the decision of firms to invest in innovation; *ii)* the knowledge production function, in which this investment, together with other inputs, produces innovation; and finally *iii)* the output production function in which innovation, together with other inputs, is related to labour productivity. Most previous studies that have estimated such a structural model using innovation survey data focus on a single country.[5] While they represent an invaluable contribution for explaining within-country and within-industry firm heterogeneity in performance, they are rather limited when it comes to investigating the role of innovation in explaining differences in performance across countries. In fact, while cross-country variations in firm performance and in the determinants and role of innovation are likely to depend on institutional factors, different results may also be driven by different modelling frameworks, estimation methods and time periods used in the analysis.[6]

Here, the choice of the variables to be included in the model was dictated first by the need to find a minimum common denominator for all countries. For the same reason, the basic model only uses variables available in innovation surveys. This implies that the measure of productivity used, log sales per employee, is a very simple one. In some cases and for some countries, it was possible to extend the analysis to control for other factors such as human capital and physical capital in the production function. Second, the model is estimated only on innovative firms, where a firm is defined as innovative if it has positive innovation expenditure and positive innovative sales.[7] Third, the model aims at correcting for both selectivity and endogeneity following the general framework of the CDM approach. Box 3.2 briefly highlights the main measurement hurdles encountered in the analysis.

Box 3.2. **Some measurement hurdles**

The core of innovation questionnaires is the same across countries and reflects a common framework. However, differences persist not only when comparing the harmonised European Community Innovation Surveys with innovation surveys in Asia, Australia, New Zealand, Canada, Latin America and South Africa but also within EU countries: difference in sampling frames and sectors covered; differences in the nature of the survey, *i.e.* voluntary *versus* mandatory; differences in the formulation of questions; inclusion/exclusion of particular questions; sequencing; amount of information available on non-innovators. Some of these issues can be accounted for in the analysis; but some cannot (*e.g.* differences in the order and formulation of questions). In order to address some of these hurdles, the approach was based as much as possible on a set of "minimum common denominator" variables. Although this improves comparability it also limits the breadth of

Box 3.2. **Some measurement hurdles** *(cont.)*

the analysis. This choice took its toll on the richness of the final specification of the model, leading to a very limited choice of regressors and controls. Moreover, the equality of the model coefficients across participating countries could not be tested since data from each country could not be pooled owing to confidentiality constraints.

The amount of information available for non-innovators is of particular relevance for econometric analysis based on innovation surveys. In fact most innovation surveys now collect information on both innovating and non-innovating firms. A firm is generally defined as innovative if it has introduced (successfully, tried to or in the process of) a new or substantially improved product or process. However, most surveys also report very little information on non-innovators. In general it is largely limited to employment, main industry, most important market (domestic *vs*. foreign) and obstacles to innovation.

Finally, the survey is retrospective and asks information on innovative activity carried out by the firm in the preceding three years. Only some of the information collected is quantitative, some is based on a subjective evaluation of the interviewee and is categorical data from questions based on the Likert scale.

3.3. Preliminary findings and messages

Factors influencing firms' decisions to be innovative

Which firms are more likely to be innovative (*i.e.* to invest in innovation or to introduce a product innovation in the reference year)? Table 3.1 reports the marginal effects from the first (probit) equation of the model, whose dependent variable is the probability of a firm being innovative, and which is estimated on the whole sample of innovative and non-innovative firms. Results are strikingly similar across countries. In particular a firm that is large and operates in foreign markets is more likely to have reported innovation activity. The only exception is Brazil, where international exposure seems not to matter. The effect of size varies between 5 and 32%. It seems to matter less in Switzerland and the United Kingdom – where an increase of 1% in employment is associated with a 5% higher probability of being innovative – and in New Zealand with 8%, and to matter most in the smaller European countries, *e.g.* Norway (32%). Being part of a group is positively correlated with the probability of being innovative except in Canada, Finland and Norway. It is particularly important in Australia and Brazil where firms that are part of a group are 35 and 42%, respectively, more likely to be innovative.[8] The relationship is very similar across EU countries, ranging between 14% in Germany and 22% in France.

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Table 3.1. **Which firms are more likely to be innovative?**

	Belonging to a group	Operating in a foreign market	Being large (size)	Barriers related to knowledge[1]	Barriers related to markets[2]	Barriers related to costs[3]	Rho[4]	No. obs.	P-value[5]
Australia	0.352***		0.153***	0.232***	0.207***	0.348***		3 697	0.522
Austria	0.213*	0.454***	0.253***	–0.0765	–0.182	–0.00122	0.223	1 001	0.226
Belgium	0.198***	0.617***	0.267***	0.0427	–0.0500	0.455***	0.41	2 695	0.0012
Brazil	0.424***	–0.264***	0.123***	0.152***	0.131***	0.0320	2.019***	9 384	0.000
Canada	–0.105*	0.290***	0.140***				1.005***	5 355	0.000
Denmark	0.186**	0.637***	0.253***	0.243**	0.0288	0.391***	0.324**	1 729	0.0202
Finland	0.0649	0.532***	0.254***	0.190**	0.259***	–0.0266	0.477***	2 155	0.00178
France	0.227***	0.778***	0.204***	0.201***	0.0678***	0.227***	0.643***	18 056	0.000
Germany	0.144***	0.529***	0.0884***	0.0144	–0.107	0.173***	0.256**	3 242	0.0656
Italy	0.203***	0.478***	0.185***	0.110***	–0.0680**	0.0908***	0.753***	15 915	0.000
Korea	–0.064		0.202***	0.201***	0.006	0.136*	0.662	1 335	0.007
Luxembourg	0.267*	0.314**	0.248***	0.191	–0.101	0.359*	0.192	545	0.701
Netherlands	0.164***	0.546***	0.213***	0.175***	–0.111**	0.0123	0.727***	6 858	0.000
New Zealand	0.113**	0.349***	0.0785***	0.0892*	0.0270	0.138***	1.337***	3 426	0.000
Norway	–0.0724	0.643***	0.320***	0.301***	0.0478	0.301***	0.739***	1 852	0.000
Sweden	0.173***	0.576***	0.09***	0.556***	0.16***	0.119**		2 954	0.563
Switzerland		0.312***	0.045*	0.075	0.201*	–0.065	0.927***	1 964	0.000
United Kingdom	0.174***	0.464***	0.0468***	0.287***	0.0883**	0.0883**	(0.040)	11 162	0.261

Notes: Coefficients reported are marginal effects, *i.e.* they predict the likelihood of being innovative. For example, an Austrian firm operating on a foreign market is 45% more likely to be innovative than an Austrian firm only active in the local market. For Canada and Brazil the regressions are weighted to the population. Results are based on 2004 innovation surveys (CIS 4 for European countries), except for Austria which used CIS 3 data; Australia where the innovation survey has 2005 as the reference year and New Zealand that has a two-year reference period, 2004-05. For Australia, the group variable is imputed. Switzerland does not have information on whether firms belong to groups; Australia does not have information on whether firms serve a foreign market and in Canada the survey does not ask about obstacles to innovation. Industry dummies included but not reported. Note also that standard errors are not reported for reasons of readability but are available from the author upon request.

1. Knowledge factors are defined *e.g.* as lack of qualified personnel, lack of technological and/or market information or lack of co operation partners.
2. Market factors refer *e.g.* to market dominated by established enterprises or uncertain demand for innovative goods or services.
3. Cost factors refer *e.g.* to lack of internal funds, lack of external finance and costs of innovation too high. All three variables are defined as a 0/1 dummy that equals one if any of the factors included was a very important obstacle.
4. "Rho" is the correlation coefficient between the error terms of the selection and outcome equation.
5. The p-value is used to test whether correction for selection bias is necessary or not. The null hypothesis, Rho = 0, assumes that there is no link between the selection and outcome equations. The null hypothesis is rejected at the 10% level in most countries, hence correcting for selection improves the model, except for Australia, Austria, Luxembourg and the United Kingdom.

* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.

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Results are more puzzling for the variables "obstacles to innovation" due to cost factors; knowledge factors and/or market factors (see notes to Table 3.1). The results are mostly counterintuitive; in fact firms that rate obstacles as very important are also more likely to have innovated.[9] In reality this result is likely to be driven by the nature of the questions about barriers. Respondents' answers to these questions may indicate either a perception (what they perceive as being a barrier to innovation) or reflect their experience. Very often a barrier is encountered only if an activity is undertaken. Firms that have engaged intensively in innovative activity have found obstacles along the way and particularly when they seek additional funding or additional qualified personnel. It is likely, however, that uncertain market outcomes or the existence of a dominant firm in the market deters firms from trying to innovate. These results seem to suggest the need for rephrasing these questions in the survey. One possibility is to split the questions in two parts. The first question could ask all firms about the factors that influenced the decision on whether to innovate. The second question should ask innovation active firms only about factors that influence the extent of innovation. This split could help identifying the different effects.

Co-operation and public financial support affect firms investment in innovation

Which firms invest more in innovation, *i.e.* which firms spend more on the intangible assets, such as R&D, ICT, training, etc., which are inputs in the innovation process? Table 3.2 reports the results of the innovation expenditure equation. Except in Austria and Belgium, co-operation is very strongly correlated with innovation expenditure: the magnitude of the correlation is greatest in Finland where firms that co-operate spend almost 50% more than firms that do not; in Austria, Brazil, France, Germany, Italy, the Netherlands, Norway and the United Kingdom they spend 30 to 40% more and in Canada 17.3% more. In Denmark and Luxembourg, there is no significant association but the sign is still positive.

Public financial support is also associated with higher innovation expenditure and consistently so in many European countries. In Finland, Germany, Italy and the Netherlands, firms that receive financial support have innovation expenditure that is 40 to 50% higher than average; it is even higher in Austria, Belgium, Denmark, France and Norway (70%). The only countries in which financial support does not appear to have an effect are Australia, Luxembourg and Switzerland.[10] In Luxembourg and Switzerland, this may be due to the negligible size of public support to innovation at the firm level.[11]

Does spending in innovation inputs translate into sales from product innovation?

Investing in innovation is associated with an increase in sales from product innovation in all countries except Switzerland.[12] The correlation with sales is greater than 40% in Australia, New Zealand and Norway and ranges

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Table 3.2. **Which firms spend more on innovation?**

	Belonging to a group	Operating in a foreign market	Being engaged in co-operation	Receiving financial public support	No. of observations
Australia	0.443**		–0.161	–0.0334	3 697
Austria	0.161	0.737***	0.408***	0.746***	1 001
Belgium	0.233*	0.524***	–0.0205	0.714***	2 695
Brazil	0.875***	–0.204*	0.384***	0.332***	9 384
Canada	0.145*	0.448***	0.173**	0.183*	5 355
Denmark	0.477***	0.762***	0.182	0.735***	1 729
Finland	0.260**	0.361*	0.495***	0.460***	2 155
France	0.231***	1.158***	0.427***	0.683***	18 056
Germany	0.0538	0.610***	0.402***	0.469***	3 242
Italy	0.268***	0.511***	0.310***	0.412***	15 915
Korea	–0.167		0.079	0.407***	1 335
Luxembourg	0.212	0.434	0.102	0.352	545
Netherlands	0.247***	0.675***	0.389***	0.569***	6 858
New Zealand	0.664***	0.740***	0.225***	0.143	3 426
Norway	–0.0436	0.706***	0.354***	0.657***	1 852
Sweden	0.173***		0.576***		2 954
Switzerland		–0.717**	0.370**	–0.128	1 964
United Kingdom	0.0508	0.513***	0.377***	0.537***	11 162

Notes: Coefficients reported are marginal effects for the co-operation and financial support variables but not for the group and foreign markets variables, because the latter enter both the selection (probability to innovate) and the outcome (innovation intensity) equation. When variables enter both the selection and outcome equations, their marginal effect can be broken down into two parts: the first is the direct effect on the mean of the dependent variable (which is reported in this table), and the second comes from its effect through its presence in the selection equation.

For Canada and Brazil, the regressions are weighted to the population. Results are based on 2004 innovation surveys (CIS 4 for European countries), except for Austria which used CIS 3 data; Australia where the innovation survey has 2005 as the reference year and New Zealand, that has a two-year reference period, 2004-05.

Belonging to a group; operating in a foreign market; being engaged in co-operation and receiving financial support are 0/1 dummies.

For Australia, the group variable is imputed from responses to the question about whether the enterprise collaborated with other members of their group, and is underreported as it omits enterprises that are part of an enterprise group, but did not collaborate with other enterprises within the group on innovation projects.

For New Zealand, information on innovation expenditure is codified as a categorical variable; to transform it to a continuous variable, midpoints of each range are used and multiplied by total reported expenditure.

Industry dummies included but not reported. Note also that standard errors are not reported for reasons of readability, but are available from the author upon request.

* Significant at the 10% level.

** Significant at the 5% level.

*** Significant at the 1% level.

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from 14 to 35% for the other countries. Does size matter for getting innovations to the market? On the one hand, given a certain level of innovation inputs, larger firms might have higher innovative sale intensity because they can appropriate innovation benefits more easily than SMEs and/or because of economies of scale. However, SMEs might use innovation inputs more efficiently because of entrepreneurial abilities or greater flexibility in production processes. Previous evidence has indicated that although larger firms are more likely to sell innovative products this probability increases less than proportionately with size and that among innovative firms, the share of innovative products in total sales tends to be higher in smaller firms (*e.g.* Brouwer and Kleinknecht, 1996). The preliminary analysis provides mixed results: size is positively correlated, negatively correlated or not correlated with sales from product innovation depending on the country. Economies of scope and scale and knowledge flows within the firm (the group variable) seem to play a role in commercialisation in most countries, but not in all. Finally, there is little evidence that firms that engage in collaboration with different partners have significantly more innovative sales.

The innovation-productivity link

Table 3.3 reports estimates of the labour productivity equation. Product innovation is strongly associated with labour productivity. In all countries except Switzerland sales from product innovation per employee show a positive and significant coefficient. The magnitude of the coefficients of sales from innovations in the productivity equation ranges from 0.3 to 0.7%. The largest estimated effects are in Korea, where a 1% increase in innovation sales per employee is associated with an estimated 0.69% increase in labour productivity and in New Zealand (0.68%) and Brazil (0.64%). On average, across this universe of heterogeneous innovating firms in different institutional contexts, a 1% increase in firms' innovation sales per employee is associated with a productivity increase of 0.5%.

The coefficient for process innovation, except in Austria, is either not significant or negative. This might come as a surprise, since process innovation is generally associated with greater productivity because of lower costs, greater efficiency of production, etc. There are two possible explanations: first, the introduction of process innovation entails changes and therefore adjustment costs and additional learning which may temporarily lower productivity. Second, firms are likely to introduce process innovations in times of difficulty or lower production cycles. This is because the expected net gains are higher (lower opportunity cost of introducing the innovation and greater gains from the changes) and possible opposition to change is less strong. Since the analysis is on a cross-section, not panel data, and the productivity variable is contemporaneous with the innovation variable, the data do not allow testing for this hypothesis. However, existing evidence suggests that both of these mechanisms are at work.

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Table 3.3. **What is the impact of product innovation on labour productivity?**

	Belonging to a group	Being large (size)	Having implemented a process innovation	Log innovation sales per worker (product innovation)	No. of observations
Australia	0.120	0.144***	–0.0890	0.557***	509
Austria	0.182**	0.0111	0.0443	0.312***	359
Belgium	0.328***	–0.003	–0.116**	0.447***	718
Brazil	0.183**	0.140***	–0.211***	0.647***	1 954
Canada	0.250***	0.0772**	–0.122**	0.436***	2 273
Denmark	0.186**	0.0732***	–0.0405	0.345***	584
Finland	0.244***	0.0859**	–0.0677	0.314***	698
France	0.232***	0.0536***	–0.129***	0.474***	2 511
Germany	0.0838**	0.0625***	–0.116***	0.500***	1 390
Italy	0.093	0.00391	–0.192**	0.485***	747
Korea	0.171***	0.084	–0.083	0.689***	626
Luxembourg	0.434***	0.0349	–0.142	0.226*	207
Netherlands	0.0219	0.0902***	–0.0440	0.409***	1 374
New Zealand	0.128**	0.0662***	–0.135***	0.682***	993
Norway	0.256***	0.0407	–0.0716	0.344***	672
Switzerland		0.113***	–0.091	0.295	394
United Kingdom	0.150***	0.058***	–0.121***	0.550***	2 989

For Canada and Brazil the regressions are weighted to the population. Results are based on 2004 innovation surveys (CIS 4 for European countries), except for Austria which used CIS 3 data; Australia where the innovation survey has 2005 as the reference year New Zealand that has a two-year reference period, 2004-05.

Belonging to a group; and having implemented process innovation are 0/1 dummies. Size is measured as log employment.

Industry dummies and inverse Mills ratio are included but not reported.

For Australia, the group variable is imputed from responses to the question about whether the enterprise collaborated with other members of their group and is underreported as it omits enterprises that are part of an enterprise group but did not collaborate with other enterprises within the group on innovation projects.

For New Zealand, information on innovation sales is codified as a categorical variable; to transform it to a continuous variable midpoints of each range are used and multiplied by total reported expenditure.

For all countries, except Belgium and Korea, significance levels are reported based on bootstrapped standard errors.

* Significant at the 10% level.

** Significant at the 5% level.

*** Significant at the 1% level.

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3.4. Conclusions and sensitivity analysis

These results represent a first exercise in which the modelling has been constrained by the use of a common set of variables available in the vast majority of countries analysed. Several attempts to solve endogeneity and selectivity issues, implicit in this kind of exercise, have been carried out by trying different estimation methods and different specifications of the model. Are the results robust? Sensitivity analysis was undertaken to see how the results changed when looking at particular sectors of the economy, in particular manufacturing *versus* services, and at different size classes. Finally, richer models in which the role played by human and physical capital could be taken into account in the productivity equation have been tested. This test could only be carried out by a sub-group of countries.[13] Table 3.4 shows some of this sensitivity analysis. When controlling for human capital the correlation between product innovation and productivity is lower but still positive, except in Finland. In Europe the correlation between sales from product innovation and productivity is higher for larger enterprises, and for Brazil, Canada and New Zealand the correlation is higher among SMEs. As expected, in most countries the productivity effect of product innovation is larger in the manufacturing sector than in the services sector. In Australia, Denmark and Finland, the coefficient of innovation sales is not significant for services firms. Exceptions are Germany and New Zealand where the innovation-productivity link seems to be stronger in the services sector sample. Four countries – Canada; Germany; the Netherlands and the United Kingdom – have also estimated extensions of the core model and the results of these efforts are reported in Chapter 4.

Table 3.4. **Product innovation and labour productivity: robustness checks**

	Manufacturing	Services	SMEs	Large firms	Controlling for human capital
Australia	0.399***	0.0155			
Austria	0.436***	0.316**	0.253**		0.241*
Belgium					0.06
Brazil			0.758***	0.589***	0.117***
Canada			0.507***	0.368***	0.380***
Denmark	0.439***	0.229	0.308***		
Finland	0.376***	0.213	0.289***		–0.0929
France	0.495***	0.443***	0.361***	0.605***	
Germany	0.405***	0.613***	0.421***		0.329***
Luxembourg		0.450***			
Netherlands	0.459***	0.390***	0.386***	0.429***	
New Zealand	0.589***	0.707***	0.685***	0.639***	0.245***
Norway	0.353***	0.252***	0.253***		
United Kingdom	0.567***	0.534***	0.479***	0.669***	0.569***

This table shows the impact of product innovation (log of innovation sales per worker) on labour productivity (see Table 3.3 and its notes) when this is estimated on different sub-samples (manufacturing *vs.* services, or SMEs *vs.* large firms) or when the equation includes human capital as an additional control.

stimates for Belgium and New Zealand control for both human and physical capital.

* Significant at the 10% level.

** Significant at the 5% level.

*** Significant at the 1% level.

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Notes

1. Teams of researchers and statisticians from 18 countries contributed to the micro-level analysis of this topic. Particular thanks go to David Brett (Australia), Martin Berger (Austria), Jeoffrey Malek (Belgium), Bruno Araújo and João De Negri (Brazil), Petr Hanel and Pierre Therrien (Canada), Carter Bloch and Ebbe Graversen (Denmark), Mariagrazia Squicciarini, Olavi Lehtoranta and Mervi Niemi (Finland), Stéphane Robin and Jacques Mairesse (France), Bettina Peters (Germany), Francesco Crespi, Mario Denni, Rinaldo Evangelista and Mario Pianta (Italy), Seok-Hyeon Kim (Korea), Anna-Leena Asikainen (Luxembourg), George van Leeuwen, Pierre Mohnen, Michael Polder, Wladimir Raymond (Netherlands), Richard Fabling (New Zealand), Svein Olav Nås and Mark Knell (Norway), Hans Lööf (Sweden), Spyros Arvanitis (Switzerland). Chiara Criscuolo, from the London School of Economics, co-ordinated the modelling effort, provided advice to the team throughout the project and conducted the analysis for the United Kingdom. This chapter was prepared by Chiara Criscuolo and benefited from comments and suggestions by Alessandra Colecchia (OECD), Mariagrazia Squicciarini (VTT, Finland) and Pierre Therrien (Industry Canada). Results from the Czech Republic (prepared by Martin Srholec) could not be included in the final analysis due to differences in the model specification.
2. Another topic analysed in this project deals with non-technological forms of innovation, see Chapter 2.
3. The distribution of both patenting and R&D activity is highly skewed. Firms with positive R&D spending or with some patenting activity are likely to represent a very small percentage of the whole population, thus making estimation of their relationship highly dependent on only a few observations. Also, studies that match performance data with R&D or patent data have two drawbacks. First, they cannot estimate all the stages of the process: for R&D, and productivity studies cannot estimate the knowledge production function; for patents, productivity studies can only estimate the last stage of the model, *i.e.* the innovation output-productivity growth relationship. Second, studies that use both R&D and patent data are only able to measure part of innovation expenditure in the case of R&D and part of changes in the knowledge stock in the case of patents, since there are other expenditures on innovation besides R&D and not all innovations are patented.
4. Of course, the approach also has limitations, related to accuracy of measurement, use of self-reported data and of qualitative rather than quantitative information.
5. Alternatives to the CDM model have been applied to data from other countries: Nordic countries (Lööf and Heshmati, 2002), Chile (Benavente, 2006); China (Jefferson *et al.,* 2006); Germany (Janz and Peters, 2002); the Netherlands (Klomp and van Leeuwen, 2001); the United Kingdom (Criscuolo and Haskel, 2003; and Criscuolo, 2004) and Australia (Wong *et al.*, 2007) to cite a few. For a more exhaustive review of the literature, see Hall and Mairesse (2006) and Mairesse and Mohnen (2002). In some of these studies the researchers have matched the innovation surveys to production panel data in order to estimate the relationship between innovation and total factor productivity (TFP) growth.
6. Two notable exceptions are Griffith *et al.* (2006), who carry out a cross-country comparison for France, Germany, Spain the United Kingdom; Lööf *et al.* (2003), for Scandinavian countries; and Janz *et al.* (2004), for Germany and Sweden. These studies look only at the manufacturing sector in a few European countries.
7. In unreported results a broader definition of innovative firms based on innovation efforts rather than outputs was tested. Firms were defined as being innovative if

they had positive innovation expenditure independently of whether they had positive innovative sales.

8. The former figure might be affected by an omitted variable bias since for Australia the export status of the firm is not controlled for (and serving a foreign market is generally positively correlated both with being innovative and being part of a group).
9. The only country for which this is systematically not the case is Austria, where all of the obstacle variables are insignificant but with a negative sign.
10. In New Zealand information on financial support comes from administrative data supplied by NZ Trade & Enterprise, and the Foundation for Research, Science & Technology – the two main agencies that provide innovation assistance to firms. Because the derived indicators are probabilistically matched, and also capture assistance not targeted at innovation, the variable for New Zealand should be considered a partial measure of the EU CIS-equivalent questions.
11. Note that although the coefficients reported for the group and foreign markets variables are not marginal effects, because the variables group and foreign markets enter both the selection (probability to innovate) and the outcome (innovation intensity) equation of the Heckman model (see Greene, 2007); they reflect the direct effect on the mean of the dependent variable (but not the effect that comes from the presence of the variables in the selection equation). Note that with the exception of Brazil and Switzerland the "direct effect" of operating on a foreign market is never negative; and the "direct effect" of being part of a group is never statistically significantly negative.
12. Concerning the data from Austria a quick caveat concerning the information on total innovation expenditure: Statistik Austria, the national statistics office, refused to publish figures on innovation expenditure from CIS 3, because they consider these as unreliable. The reason is that many firms found it difficult to report these figures and that consequently the response rate is very low, which causes methodological problems for imputation and grossing up (according to the official report on CIS 3 by Statistik Austria). Nevertheless the Austrian results match very well with the other international findings, which suggest that this might not be a major problem
13. For example, in Korea, the data only cover the manufacturing sector, while in Luxembourg, the number of observations available for the manufacturing sector and for large firms did not allow for a separate analysis of these groups. Similarly, only a few countries had information on human and physical capital from either the innovation surveys or from other data in which this information is available.

References

Acs, Z.J. and D.B. Audretsch (1988), "Innovation in Large and Small Firms: an Empirical Analysis", *American Economic Review*, Vol. 78(4), pp. 678-690, September.

Ahn, S. (1999), "Technology Upgrading with Learning Cost: A Solution of Two Productivity Puzzles", *OECD Economics Department Working Papers*, No. 220, July.

Basu, S., J. Fernald and M. Kimball (1998), "Are Technology Improvements Contractionary?", *International Finance Discussion Papers*, No. 625, Board of Governors of the Federal Reserve System (US).

Benavente, J.M. (2006), "The Role of Research and Innovation in Promoting Productivity in Chile", *Economics of Innovation and New Technology*, 15(?), pp. 301-315.

Bessen, J. (2002), "Technology Adoption Costs and Productivity Growth: the Transition to Information Technology", *Review of Economic Dynamics*, Vol. 5(2), pp. 443-469, April.

Brouwer, E. and A. Kleinknecht (1996), "Firm Size, Small Business Presence and Sales of Innovative Products: A Micro-econometric Analysis", *Small Business Economics* 8, pp. 189-201.

Cohen, W.M. and S. Klepper (1996), "Firm Size and the Nature of Innovation within Industries: the Case of Process and Product R&D", *The Review of Economics and Statistics*, MIT Press, Vol. 78(2), pp. 232-43.

Crépon, B., E. Duguet and J. Mairesse (1998), "Research, Innovation, and Productivity: An Econometric Analysis at the Firm Level", *Economics of Innovation and New Technology*, 7(3), pp. 115–156.

Criscuolo, C. and J. Haskel (2003), "Innovation and productivity growth in the UK: Evidence from CIS2 and CIS 3", Working Paper, Centre for Research into Business Activity.

Criscuolo, C. (2004), "Explaining Firms' Heterogeneity in Productivity and Wages: Ownership, Innovation and Size", PhD thesis submitted to the University of London.

Greene, W.H. (2007), *Economic Analysis*, 6th edition, Prentice Hall.

Griffith, R., E. Huergo, J. Mairesse and B. Peters (2006), "Innovation and Productivity across Four European Countries", Oxford Review of Economic Policy, Vol. 22(4), pp. 483-498, Winter.

Griliches, Z. (1979), "Issues in Assessing the Contribution of R&D to Productivity Growth", *Bell Journal of Economics*, 10, pp. 92-116.

Griliches, Z. and A. Pakes (1980), "Patents and R and D at the Firm Level: A First Look", NBER Working Paper *No. 0561*, National Bureau of Economic Research.

Hall, B. and J. Mairesse (2006) "Empirical Studies of Innovation in the Knowledge-driven Economy: An Introduction", *Economics of Innovation and New Technology*, Vol. 15, Issues 4/5.

Heckman, J. (1999), "Sample Selection Bias as a Specification Error", *Econometrica*, Vol. 47, pp. 153-161.

Janz, N., H. Lööf and B. Peters (2004), "Firm Level Innovation and Productivity – Is There a Common Story Across Countries?", *Problems and Perspectives in Management*, 2, pp. 184-204.

Janz, N. and B. Peters (2002), "Innovation and Innovation Success in the German Manufacturing Sector: Econometric Evidence at Firm Level", Paper presented at EARIE.

Jefferson, G., B. Huamao, G. Xiaojing and Y. Xiaoyun (2006), "R&D Performance in Chinese Industry", *Economics of Innovation and New Technology*, 15(?), pp. 345-366.

Jovanovic, B. and Y. Nyarko (1996), "Learning by Doing and the Choice of Technology", *Econometrica*, Vol. 64(6), pp. 1299-1310, November.

Klette, T.J. and S. Kortum (2004), "Innovating Firms: Evidence and Theory", UCLA Department of Economics.

Klomp,L. and G. van Leeuwen (2001), "Linking Innovation and Firm Performance: A New Approach", *International Journal of the Economics of Business*, 8:343-364.

Lewbel, A. (2007), "Endogenous Selection or Treatment Model Estimation", *Journal of Econometrics*, 141(2), December, pp. 777-806.

Lööf, H. and A. Heshmati (2002), "Knowledge Capital and Performance Heterogeneity: A Firm Level Innovation Study", *International Journal of Production Economics*, 76(1), pp. 61-85.

Lööf, H., A. Heshmati, R. Asplund and S-O. Nås (2003), "Innovation and Performance in Manufacturing Industries: A Comparison of the Nordic Countries", *The Icfaian Journal of Management Research*, 2, pp. 5-35.

Mairesse, J. and P. Mohnen (2002), "Accounting for Innovation and Measuring Innovativeness: An Illustrative Framework and an Application", *American Economic Review*, 92(2), pp. 226-230.

Nickell, S. and J. Van Reenen (2001), "Technological Innovation and Performance in the United Kingdom", *CEP Discussion Papers*, No. 0488, Centre for Economic Performance, LSE.

Scherer, F.M. (1980), *Industrial Market Structure and Economic Performance*, Rand McNally, Chicago.

Schumpeter, J.A. (1942), *Capitalism, Socialism and Democracy*, George Allen & Unwin, London.

Wong, M., D. Page, R. Abello and K. Pang (2007), "Explorations of Innovation and Business Performance using linked firm-level data", Research Paper, Australian Bureau of Statistics, September.

ANNEX 3.A1

The Model Specification: Advantages and Limitations

The model presented below was agreed among the participating countries and has the following features. First, the variables included in the core model represent a minimum common set that was chosen in order to maximise the ability of countries to estimate the same equations. A variant of the core model was estimated by a group of countries with the information necessary to control for human and physical capital in the output production function. Second, the model aims at correcting for both selectivity and endogeneity and does so within the framework of the CDM model. Third, the model is estimated only on innovative firms. A firm is defined as innovative if it has both positive innovation expenditure and positive innovative sales.[1] Finally, to maximise international comparability, the model only uses variables available in innovation surveys. This implies that the measure of productivity used, *i.e.* log of sales per employee, is a very simple one and only makes it possible to look at correlations between innovation and labour productivity levels. In the project, all countries estimated the same model using the same or close to the same definitions of the variables. Participants applied the same econometric software package (STATA) to a common estimation routine, which was compiled by the project technical co-ordinator.[2]

Similarly to the CDM model, the model used in the project is developed according to three stages and consists of four equations.

The first stage explains firms' decision to engage in innovation activities, and the amount of innovation expenditure chosen. It is composed of two equations and it is estimated using a generalised Tobit model (Heckman, 1979).

The first equation accounts for firms' innovative effort (*innov**) and can be formally written as follows:

$$Innov_i^* = X'_{1i}b + u_i$$

where the subscript *i* indicates firms; *X* is a vector of regressors described below and *u* is the error term that is assumed to be normally distributed. As firms will only innovate if the expected net gains from this activity (known to the firm but unobserved by the econometrician) are positive, the observation is a discrete event (innovative or not) rather than a latent variable $Innov^*$. Therefore, the first equation models the probability that the firm is innovating using a probit model:

$$Prob(Innov_i = 1) = Pr(Innov_i^* > 0) = Pr(u_i > -X'_{1i}b)$$

where X'_1 is a vector of variables affecting the innovation investment decision and includes: size of the firm, measured as log employment; a dummy for whether the firm is part of a group or not; a dummy for whether the firm serves foreign markets or not; a set of dummy variables that captures the importance of obstacles to innovation due to knowledge, costs and market; and industry dummies. The choice of these covariates is mainly dictated by the limited availability of information for non-innovative firms in innovation surveys across all countries.

Conditional on the firm being innovative, one can observe the amount of investment and thus the intensity of investing in innovation. The second equation of the first stage is an innovation expenditure intensity equation, where the dependent variable is innovation expenditure per employee. It estimates the role of exogenous covariates on the amount of innovation expenditure:

$$InnExp = X'_2d + e_i \text{ if } Innov = 1$$

and

$$InnExp = 0 \text{ if } Innov = 0$$

It is assumed that the error terms *u* and *e* are jointly normally distributed with mean zero and covariance *rho* and the two equations are estimated as a generalised Tobit equation, by maximum likelihood.

Additional regressors are used with respect to the first equation. In particular two dummy variables are added. The first shows whether a firm has had co-operation activities when innovating, the second whether the firm has received public financial support. To sum up, the vector of covariates *X'* includes a dummy for belonging to a group; a dummy for serving foreign markets; a dummy for co-operation activities; and a dummy for public financial support.

For the parameters of interest to be correctly identified, a crucial assumption is whether there are variables that affect the decision to invest in innovation but not the intensity of the innovation effort, *i.e.* whether exclusion restrictions exist. In this model the variables included in the first equation, but excluded from the second, are firm size and obstacles to

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innovation. The idea is that while it is well known in the literature that larger firms are more likely to invest in innovation (Schumpeter, 1942; Cohen and Klepper, 1996; and Klette and Kortum, 2004), the intensity of investing in innovation – measured as the ratio of total innovation expenditure per employee – is already scaled and therefore less likely to be correlated to size.[3]

Finally from this first step the inverse Mills ratio is estimated and used as an additional regressor in the second and third step of the model to control for selectivity. In addition the predicted value of innovation expenditure is calculated.

The second step consists of the estimation of the knowledge production function, where the dependent variable, log innovative sales per employee, depends on: intensity of investment in innovation; firm size; whether the firm is part of a group or not; process innovation; different types of co-operation (with clients, suppliers, and other private and public agents); and industry dummies. Given that the model is estimated only on innovative firms, the Mills ratio, estimated in the first stage, is added to correct for selectivity. Estimates that also control for the potential endogeneity of innovation expenditure in the knowledge production function have also been performed but have not reported for the sake of brevity (they are available from the authors upon request). Endogeneity might arise for different reasons, such as unobserved heterogeneity; omitted variables, *i.e.* factors that cannot be controlled for but that can influence firms' innovation output and are likely to affect innovation inputs (*e.g.* positive temporary shocks; unobserved managerial ability, etc.); or reverse causality, since innovation surveys ask questions on innovation inputs and outputs related to the very same year. Predicted, rather than actual innovation expenditure values, are used in the knowledge production function. The identification restriction here is that public financial support only affects innovation outcomes through increased investment in innovation and, similarly, that – once one conditions for the co-operation activity of the firm – serving foreign markets only affects innovation outputs through increased innovation expenditure.[4] The innovation outcome equation can therefore be written as:

$$Innov\_output = X'_3 g + v_i$$

where *innov_output* is measured as log innovative sales per employee and the vector of covariates X'_3 contains: log employment; a group dummy; a dummy for process innovation; and dummies for different types of co-operation (with clients, suppliers, and other private and public agents); the Mills ratio; industry dummies; and actual log innovation expenditure per employee,(or predicted values when correcting for potential endogeneity).

In the third stage the innovation output productivity link is estimated using an augmented Cobb-Douglas production function.

$$ln(sales\ per\ employee) = X'_4 p + v_i$$

The dependent variable is log sales per employee. The right-hand side variables are: firm size; a group dummy; a dummy for process innovation; the Mills ratio, to correct for selectivity; and log innovative sales per employee. To account for the potential endogeneity of log innovative sales per employee, the output production function is estimated using instrumental variables 2-stage least squares (IV 2SLS).

In the last two stages of the model, predicted values (Mills ratio and predicted innovation input) are used. In order to correct standard errors and account for such a feature of the model, bootstrapping of standard errors is performed in both the innovation and the output production functions.[5]

One variant of the model controls for human and physical capital, proxied in most countries by the share of graduates and log investment respectively, and for intermediates in the output production function. However, estimates of this augmented model were only possible for a subset of countries for which the necessary variables were available, either from the innovation survey or from other data sources matched to that survey.

Notes

1. In unreported results a broader definition of innovative firms based on innovation efforts rather than outputs was used. Firms were defined as being innovative if they had positive innovation expenditure, regardless of whether they had positive innovative sales or not.
2. The estimation routines are available at *http://personal.lse.ac.uk/criscuol/* or can be requested from Chiara Criscuolo at *c.criscuolo@lse.ac.uk*.
3. Griffith *et al.* (2006) (GHMP) find that size is insignificant when included in the investment intensity equation.
4. The latter is a very strong assumption since one does not allow international technology transfer to have any other potential role than those arising through formal co-operation agreements.
5. Note that bootstrapping accounts for both selectivity and endogeneity but is not derived from the statistical properties of this model. An alternative way of correcting standard errors is proposed by Lewbel (2007). Conversely, CDM estimated that errors are corrected for selectivity and endogeneity since they are estimated using asymptotic least squares.

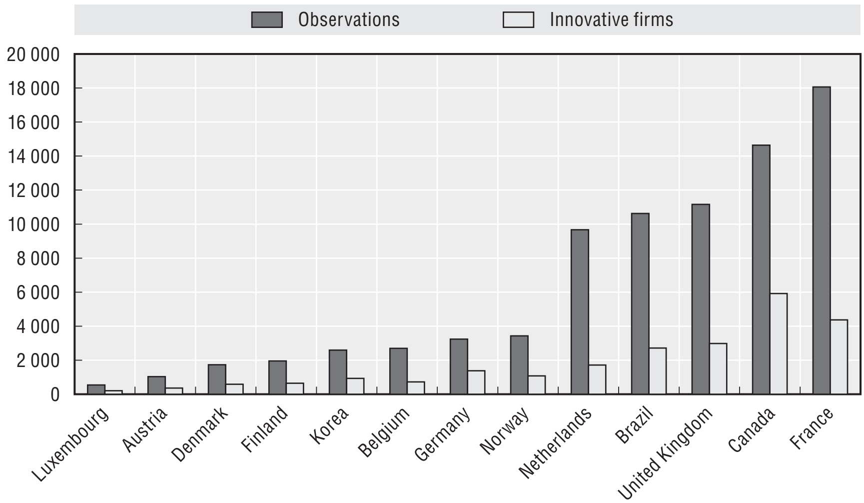
ANNEX 3.A2

Characteristics of the Sample of Surveys Underlying the Econometric Analysis

This Annex provides an overview of the characteristics of the datasets used by the participating countries. These are unweighted descriptive statistics (except for Canada; for Brazil we report both unweighted and weighted figures where available) so they cannot be used to compare percentages across countries. Instead, they highlight some features of innovation surveys and their respondents in participating countries, *i.e.* of the samples used in the econometric analysis. The first is the large difference in sample size across countries (Figure 3.A2.1). This is likely to be the product of the size of the country itself, with larger countries having more firms; the sample frame of the innovation survey; and the mandatory or voluntary nature of the survey. In some cases (*e.g.* France) the innovation survey is mandatory, while in others (*e.g.* the United Kingdom or Germany) responses are voluntary. In the latter case, lower response rates translate into a smaller number of observations.[1]

Figure 3.A2.2 reports the share of innovative firms[2] in the sample. It shows that the group of participating countries demonstrate great heterogeneity in terms of number of innovative firms. At the top of the distribution are the German and Canadian samples, with about 40% of "innovative firms"; at the bottom are the French and the Dutch samples. These rather surprising results may be due to genuine differences among countries in terms of innovativeness. Innovation rates may in fact reflect differences in industry composition, *e.g.* manufacturing *versus* services (for example, for Canada, only data for the manufacturing sectors are available) and high *versus* low-technology manufacturing, or differences in size composition. In the econometric analysis the model is also tested on subsamples for the manufacturing and service sectors, as well as for large and smaller firms.

Figure 3.A2.1. **Innovation sample sizes in participating countries**



Note: The data for Canada are weighted for reasons of confidentiality. For all EU countries except Austria, the data refer to CIS 4 (2002-04). For Austria, the underlying data are CIS 3 (1998-2002). Data for Brazil, Canada and Korea are also for 2002-04.

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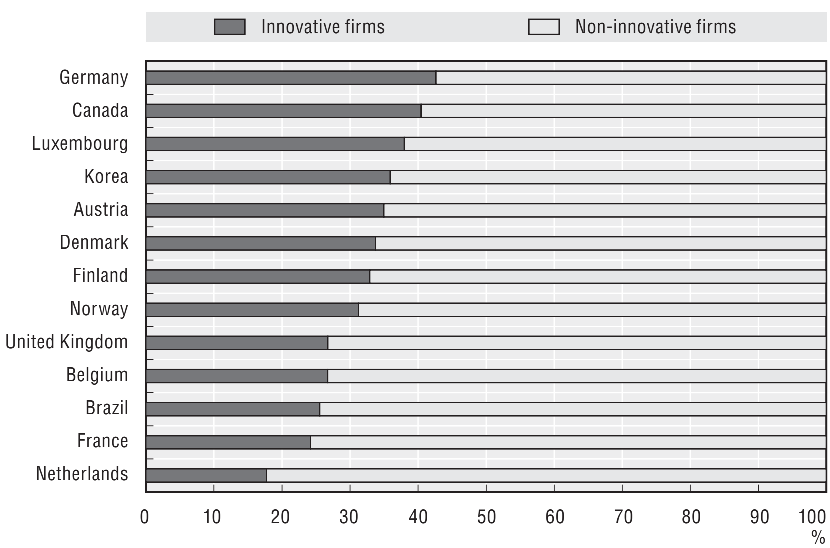
Figure 3.A2.2. **Proportion of innovative firms in the samples**



Note: The data for Canada are weighted for reasons of confidentiality. For all EU countries except Austria the data refer to CIS 4 (2002-04). For Austria the underlying data are CIS 3 (1998-2002). Data for Brazil; Canada; Korea; are also for 2002-04.

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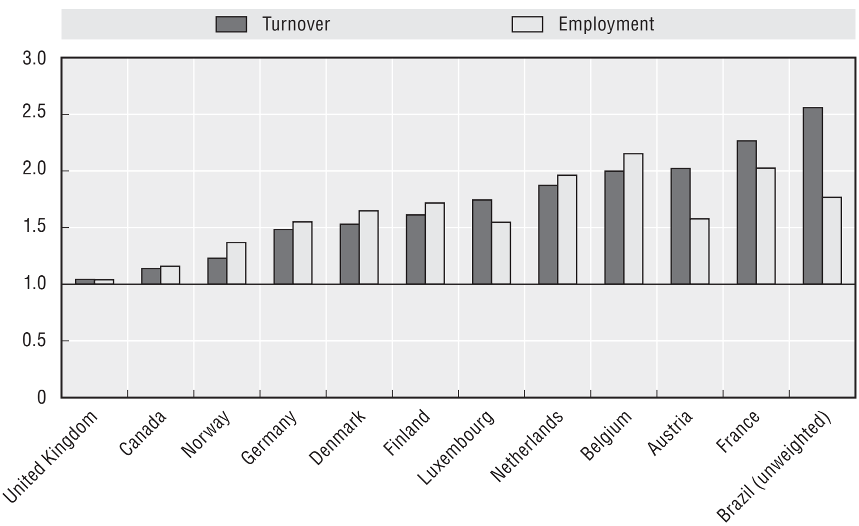
Most of the literature on the relationship between firm size and innovation has found a positive relationship between the two (*e.g.* Scherer, 1980; Acs and Audretsch, 1988). The descriptive evidence presented in Figures 3.A2.3 and 3.A2.4 is in line with this: innovative firms are larger than non-innovative firms. Figure 3.A2.3 looks at both sales and employment. The sales column reports the ratio of average sales of innovative firms relative to average sales for the whole sample. The figure shows that in all countries innovative firms are larger in terms of sales but the difference is less stark in the United Kingdom, Canada and Norway. A similar ranking holds for the employment column.

Figure 3.A2.3. **Relative size of innovative and all sample firms in terms of sales and employment**



Note: The data for Canada are weighted for reasons of confidentiality. For all EU countries except Austria, the data refer to CIS 4 (2002-04). For Austria, the underlying data are CIS 3 (1998-2002). Data for Brazil, Canada and Korea are also for 2002-04. Figures reported in the graph are turnover and employment of innovative firms relative to all firms in the sample for each country (the latter average size of all firms in each sample is normalised to 1 in all countries).

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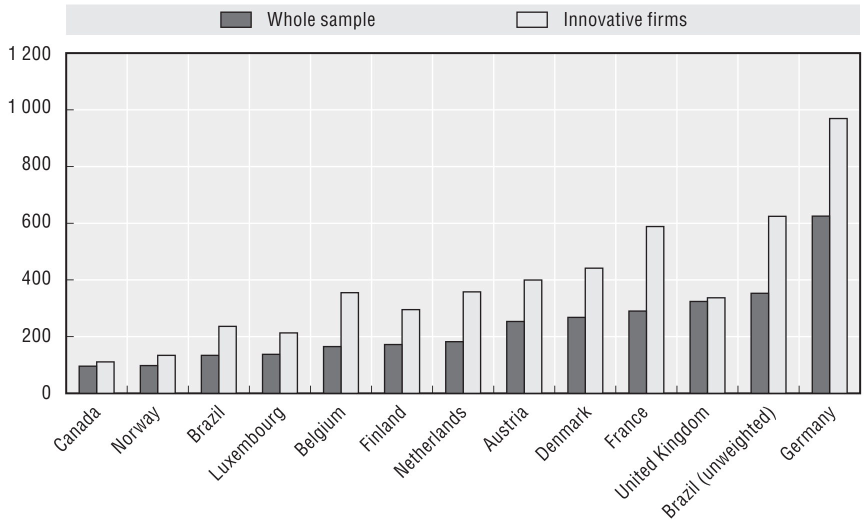
Employment figures can be used to look at the average size of respondent firms across countries. Canada has the smallest average size, but this likely reflects the fact that Canadian data are weighted (for reasons of confidentiality). In fact when comparing weighted and unweighted average sizes for Brazil, the figures drop significantly from an (unweighted) average size of 353 employees to a weighted average of 134. Germany, the United Kingdom and France have the samples with the largest average firm size.

Figure 3.A2.4. **Size of innovative and non innovative firms in the samples**



Note: The data for Canada are weighted for confidentiality reason. For all EU countries except for Austria, the data refer to CIS 4 (2002-04). For Austria, the underlying data are CIS 3 (1998-2002). Data for Brazil, Canada and Korea are also for 2002-04. Figures reported in the graph are the average size in terms of employment for innovative firms and for all firms in the sample of each country.

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When the comparison is restricted to innovative firms, firms in France and Germany (and Brazil, for unweighted figures) are considerably larger.

According to existing evidence firms that are part of a group and firms that serve foreign markets are more likely to be innovative. This holds in the sample used for the analysis with one notable exception. In Brazil, firms that serve foreign markets are, if anything, less likely to be innovative; this result holds for both weighted and unweighted figures and is confirmed in the econometric analysis when controlling for industry composition and other determinants of innovation investment (see Figures 3.A2.5a and 3.A2.5b).

Figure 3.A2.6 shows no distinction between product and process innovation. If there were such a distinction, a negative correlation would be more likely in the case of process innovation, which entails changes in production and the scrapping of old machinery, rather than in the case of product innovation. In the econometric analysis this indeed turns out to be the case.

Figures 3.A2.7a and 3.A2.7b present figures about innovation inputs and innovation outputs as a share of turnover. When looking at the full sample, firms spend on average between 2.5% (in the Netherlands) and 9.5% (in France) of their turnover on innovation. When the sample is restricted to innovative firms (that is, a firm with a product innovation and positive innovation expenditure), spending ranges between 4 and 20% of turnover. A comparison

Figure 3.A2.5a. **Share of firms that are part of a group**

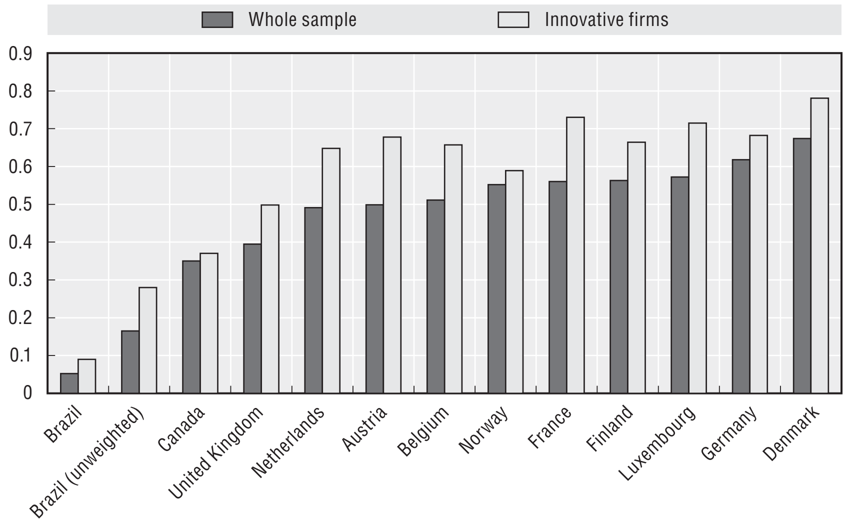

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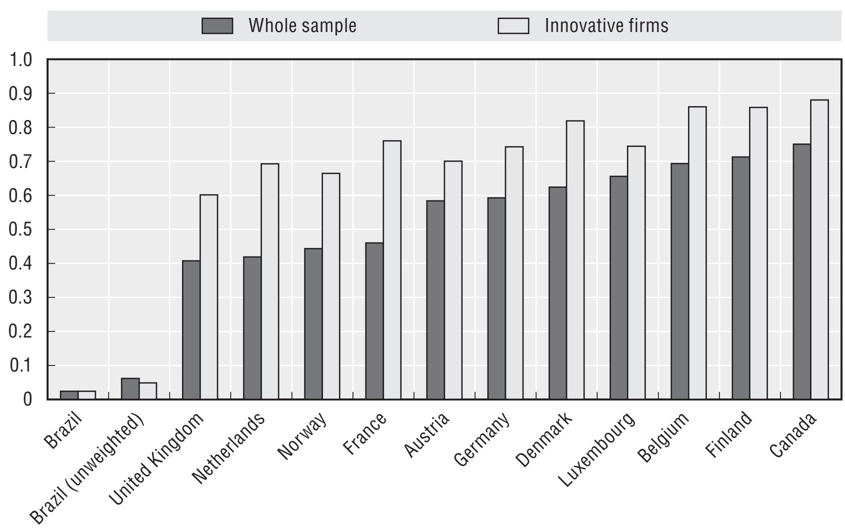
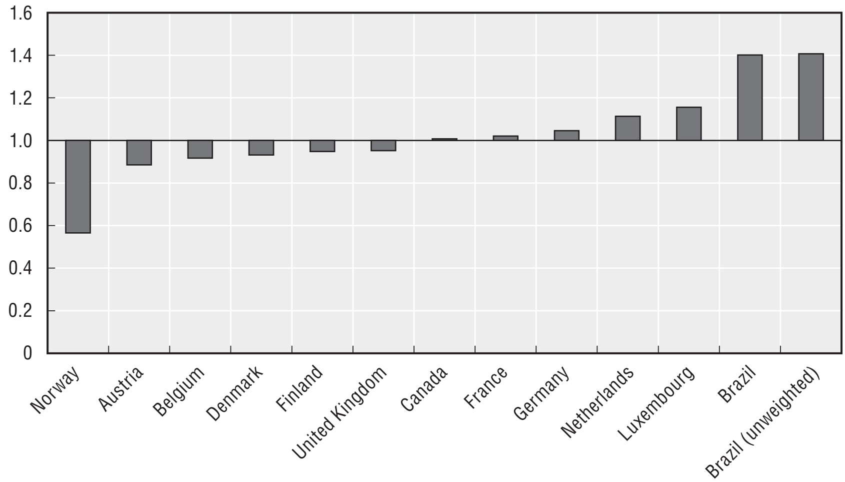
Figure 3.A2.5b. **Share of firms that serve foreign markets**



Notes: The data for Canada are weighted for reasons of confidentiality. For all EU countries except Austria, the data refer to CIS 4 (2002-04). For Austria, the underlying data are CIS 3 (1998-2002). Data for Brazil, Canada and Korea are also for 2002-04. Figures reported in Figure 3.A2.5a are the proportion of innovative and all firms in a country that are part of a enterprise group. Figures reported in Figure 3.A2.5b are the proportion of innovative and all firms reporting that they serve foreign markets.

StatLink http://dx.doi.org/10.1787/546074755251

Figure 3.A2.6. **Labour productivity (sales per employee) of innovative firms relative to whole sample**



Notes: The data for Canada are weighted for reasons of confidentiality. For all EU countries except Austria, the data refer to CIS 4 (2002-04). For Austria, the underlying data are CIS 3 (1998-2002). Data for Brazil, Canada and Korea are also for 2002-04. The graph represents labour productivity, measured as sales per employee, of innovative firms relative to all firms in the sample for each country (the labour productivity of all firms in each sample is normalised to 1 in all countries).

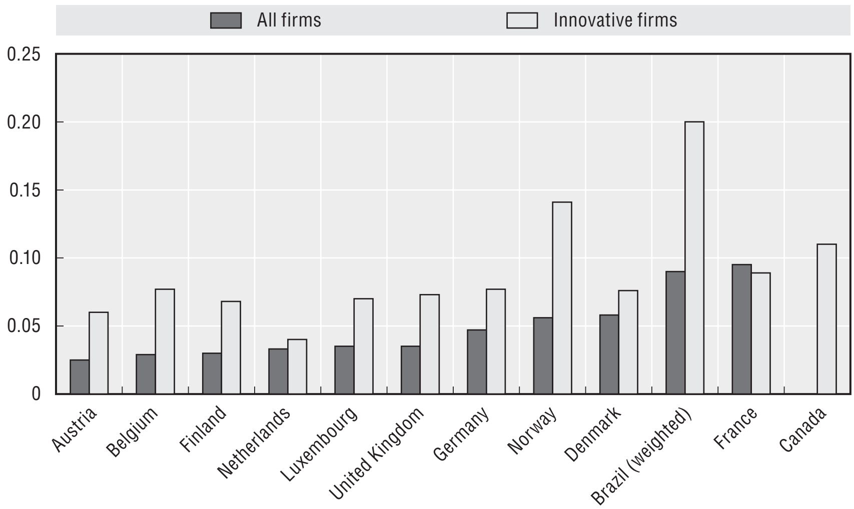
StatLink http://dx.doi.org/10.1787/546078864166

of Figure 3.A2.7a with Figure 3.A2.7b shows a positive correlation between innovation expenditure and innovation output. However, it is not always the case that firms with higher innovation expenditure are characterised by higher innovative sales. In fact, other inputs enter the knowledge production function, in particular external knowledge and co-operation activities.

The ranking presented in Figures 3.A2.7a and 3.A2.7b reflect the characteristics of the innovation survey samples and should not be used for purposes of international comparison. In particular, Finland and the Netherlands, which are generally believed to be highly innovative economies, are at the bottom of the distribution. Similarly, Brazil's weighted average innovation expenditure and innovative sales, relative to total turnover, are the highest among all sample countries.

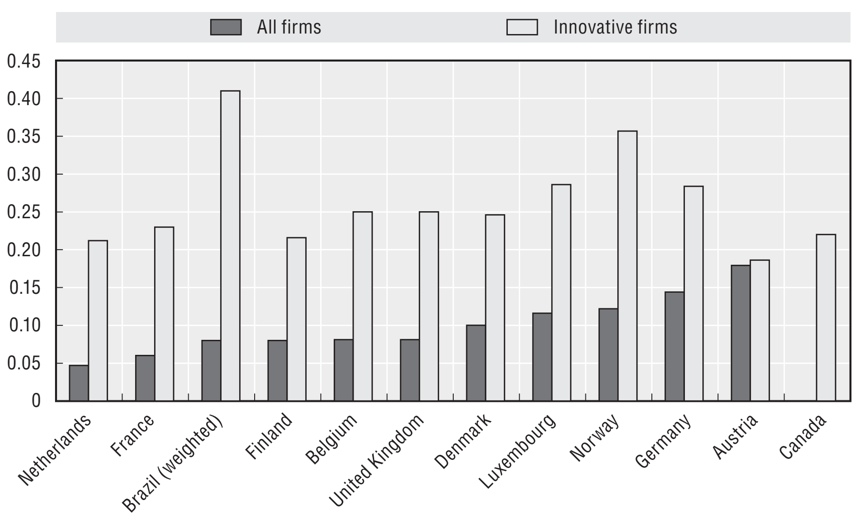
Finally, as a note of caution, all of these sample descriptive statistics are average figures and therefore hide much heterogeneity within countries, as becomes evident when looking at within-country standard deviations. Additional summary statistics, including standard deviations – for each country, for both the full sample and the sample of innovative firms only – related to the inputs into the production and innovation process and the determinants of innovation investment are omitted here for the sake of brevity, but are available from the authors upon request.

Figure 3.A2.7a. **Innovation expenditure as a share of turnover**



StatLink http://dx.doi.org/10.1787/546081171117

Figure 3.A2.7b. **Sales from innovative products as a share of turnover**



Notes: the data for Canada are weighted for reasons of confidentiality. For all EU countries except Austria the data refer to CIS 4 (2002-04). For Austria the underlying data are CIS 3 (1998-2002). Data for Brazil; Canada; Korea; are also for 2002-04.

Figures reported in Figure 3.A2.7a are the average proportion of sales spent in innovative investments. The red bars report averages based on innovative firms only (*i.e.* firms with positive innovative sales) while figures in blue use data from all firms in each country. Figures reported in Figure 3.A2.7b are the average proportion of sales from product innovations for innovative firms and all firms in each country.

StatLink http://dx.doi.org/10.1787/546102362654

Notes

1. However, a mandatory survey may lead to different sources of bias, such as the "untruthfulness" of the answers. Firms that are innovative, but that do not have the time/willingness to answer the questionnaire, may declare themselves non-innovators in order to avoid answering the majority of the questions. Alternatively, they might answer, but offer rough or imprecise figures and bias the estimates.
2. Note that we define as "innovative firms" those firms with innovation expenditure and innovation sales.

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Chapter 4

Innovation and Productivity: Extending the Core Model[1]

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4.1. Background

The OECD core model (see Chapter 3) achieved quite remarkable results even if constrained by international benchmarking requirements (use of a "simpler" model in order to include a number of OECD countries). However, important variables were omitted or simplified to enable international comparisons. Obvious examples are: the use of a sub-optimal productivity equation (value added or total factor productivity variables would have been better candidates for productivity measures than total turnover); omission of important production factors such as measures of human and physical capital; and the use of binary variables when quantitative ones were available for some countries (*e.g.* exports).

Four countries – the Netherlands, Canada, the United Kingdom and Germany – used all available information to estimate and refine their national model on the link between innovation and firm productivity.[2] While all four touched upon the above issues, each has added value by looking more closely at different aspects of the core model. For instance, the Netherlands tested the model with different measures of productivity and estimated the model for the whole sample instead of focusing only on product innovators. Canada tested the robustness of results with different assumptions regarding the endogeneity of some variables and replaced, whenever possible, binary variables with quantitative ones. The UK model used total factor productivity (TFP) growth as the productivity variable, disaggregated innovation outputs by different levels of "novelty" (first-to-market or first-in-the-firm product and process innovations), and made a first attempt at estimating a process innovation equation. Finally, Germany formally estimated a process innovation equation (using cost savings from innovation as the key variable), and dealt partially with time issues (where innovation output and productivity are measured after innovation inputs are implemented).

Results from these extended models are used to compare and test the robustness of results from the core OECD model. Lessons learned from these extended models could be incorporated in a potential second round of internationally comparable models to refine the analysis of the link between innovation and productivity.

The next section takes a detailed look at the extended models used by the four countries and preliminary results. It is followed by a preliminary conclusion with some options for continuing the project.

4.2. Extended models used by selected countries[3]

The Netherlands

The model tested by the Netherlands differs from the OECD core model in two main respects. First, data available in the Netherlands allow for a better productivity equation with the addition of KLEMS variables as production factors (or by using TFP level variables). Second, instead of estimating later stages for product innovators only, the model used a different selection equation in stage 1 and stage 2, and used predicted values of innovation output for all firms (innovators and non-innovators) in the productivity equation. Therefore, predicted innovation input (for all firms) is used in the innovation output equation, and the predicted innovation output (estimated for all firms) is then used in the productivity equation. The model was tested on the manufacturing data sample. The model is summarised formally in Box 4.1.

Box 4.1. The Dutch extended model

Stage 1: Innovation input equations

Selection equation:

Pr(innov expenditure) = *F[Size, Group, Export(Y/N), Hampering_i, IND]* [1a]

Innovation expenditure intensity equation:

LRTOTPE = F[Export(Y/N), Coop, Fin_sup, IND] [1b]

Stage 2: Innovation output equations

Selection equation:

Pr(Innov_sale) = *F[Size, Group, Export(Y/N), Hampering_i, IND]* [2a]

Innovation output intensity equation:

LISPE = F[LRTOTPE_hat; R&D(Y/N), Size, Group, IND] [2b]

Stage 3: Productivity equation

LLPPE = F[LISPE_hat, Pdt_innov(Y/N), Log of (K,L,E,M,S), Group, Foreign] [3]

or

TFP = F[LISPE_hat, Pdt_innov(Y/N), Group, Foreign]

Note: Underlined variables differ from the OECD core model.

Preliminary results show that including other production variables (KLEMS) or using TFP decreases productivity elasticity to innovation output by half but the effect is still positive and highly significant. Moreover, the coefficient is still significant even when innovation output is estimated and the whole sample (of innovators and non-innovators) is used.

Using a different selection equation for the innovation output equation does not change results from those of the OECD core model as the coefficient of R&D intensity is still positive and significant (slight increase in the extended model).

Therefore preliminary results from the refined Dutch model would not change the main results of the OECD core model. Elasticity of productivity in relation to innovation output is somewhat lower than in the one estimated with the OECD core model, but the coefficient is still positive and significant. Elasticity of innovation output in relation to innovation input is still positive and significant. For the Netherlands at least, the model seemed robust enough to use the predicted values for innovation input and innovation output for all firms (instead of restricting it for innovators only) in the productivity equation.

Canada

The Canadian extended model differs from the core OECD model in two main respects. First, as in the Dutch model, it used a better productivity equation (with value added per employees as dependent variable and human and physical capital as factors of production included as independent variables). Second, most binary variables were replaced either by quantitative variables (*e.g.* exports) or by more precise binary variables (*e.g.* the process innovation variable was replaced by one that takes into account the "novelty" of the innovation such as first in North America or world).

Other minor changes from the OECD core model are the use of additional variables such as revenues from the firm's most important client (MIC), whether or not the firm contracted out R&D (in addition to their own R&D expenditures), and the use of private or public sources of information for innovation.

Finally, with this extended model, the authors empirically tested the assumptions of endogeneity (both for innovation input in the innovation output equation and for innovation output in the productivity equation) to better understand the lack of robustness of Canadian results depending on whether the model used observed or predicted variables. The lack of robustness when double endogeneity was applied (for innovation input in stage 2 and innovation output in stage 3) led to unsatisfactory results for several countries.[4]

Results from the Canadian extended model are in line with the Dutch results in which the inclusion of measures of human and physical capital reduce the productivity elasticity of innovation output, which is further reduced when using value added per employee as the productivity variable. However, even if the elasticity is reduced (around half the value from the OECD model), the coefficient is still positive and significant. As in the case of the Netherlands,

Box 4.2. **The Canadian extended model**

Stage 1: Innovation input equations

Pr(positive innovation expenditures and positive innovation sales):

Innov strict = F[Size; intra_sale_firm; export_US(%); export_other(%); direct_sup; indirect_sup; most_imp_client; IND] [1a]

Innovation expenditure intensity equation:

LRTOTPE = F[Size; export_US(%); export_other(%); Coop, direct_sup; indirect_sup; most_imp_client; RD_outsourced; IND] [1b]

Stage 2: Knowledge production function

Innovation output intensity equation:

LISPE = F[LRTOTPE, Size; intra_sale_firm; Source_info_i; Novel_pcs; HC, Log(K), Mills, IND] [2]

Stage 3: Productivity equation

LVAPE = F[LISPE_hat, Novel_pcs; intra_sale_firm; Size; HC, Log(K), Mills, IND] [3]

Note: Underlined variables differ from the OECD core model.

the innovation expenditures variable is still positively related to innovation sales and the coefficient remains unchanged in the extended model.

The use of different process innovation measures, such as one that takes into account the novelty of process innovation (first in North America or the world) does not change the negative coefficient in the productivity equation. Other tests were performed with alternative types of process innovation with the same results. Therefore it seems that, in the case of Canada, the negative coefficient of process innovation is robust to different modelling.

Finally, by using a less "constrained" model (than the OECD core model), coefficients are robust even when endogeneity of both innovation input and innovation output are assumed. Indeed, replacing binary variables by quantitative ones (and adding other relevant variables) in the innovation input equation increased the quality of the predicted innovation input variable, and this can therefore act as a valid instrument.[5] Tests for Canada revealed that while endogeneity of innovation output in the productivity equation could not be rejected (and it was necessary to correct this with estimated innovation output), there were no endogeneity issues between innovation input and innovation output. Therefore, there is no need to replace the observed value of innovation input by its predicted value.[6]

As with the Dutch extended model, results from the refined Canadian model confirmed, with more detail and less uncertainty, the conclusions of the OECD core model. It showed that higher intensity of innovation expenditure is conducive to better innovation outcomes (but again with a lower coefficients than with the OECD model); and high-intensive innovative firms (firms with higher innovative sales per employee) are more productive.

United Kingdom

The UK refined model differs from the OECD core model in three main respects.[7] First, the productivity growth (TFP growth) variable was used as the productivity measure. Second, different innovation output variables were tested. For instance, product innovation was broken down by share of total sales from new to market innovation (%novel product) and by the share of total sales from new-to-firm only innovation (%new product). In the same manner, process innovation was proxied by innovation that is new to the firm's market (novel process) or by the impact on improving production flexibility (flexibility). Third, variables referring to past firm performance variables (*e.g.* market share in previous period, initial productivity level of the firm relative to the median firm in the industry) are added to the model. Finally, in an alternate modelling, the process innovation equation (probability to be a process innovator) was added to the knowledge production function in parallel to the product innovation equation.

One other minor change from the OECD core model worth mentioning is the use of sales (instead of employees) as the denominator of innovation expenditure in stage 1, so that the selection equation in stage 1 changes accordingly.

Preliminary results from the extended UK model reveal that while sales from novel products were positively linked to higher TFP growth, innovative sales from products new to the firm (but not to the firm's market) were not. Those results suggest that novel innovation would play a stronger role than incremental innovation (proxied by the "new-to-firm only innovation sales") for firms' productivity growth.

The role played by process innovation in productivity growth is still uncertain, as using "novelty of process innovation" still produces negative and mostly non-significant coefficients.[8] Other tests on measures of the impact of innovation process (improving production flexibility) revealed that firms with high production flexibility would have higher productivity growth than those with low production flexibility (but again with a weakly significant coefficient).

The productivity growth equation also controlled for initial productivity of the firm relative to median firms in the industry (proxy for the learning capability of the firm). Results from the extended UK model (negative coefficient for that variable) suggest that lagging firms are catching up and growing faster than other firms (firms farther from the production frontier are learning). Adding this variable might decrease the coefficients of the

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Box 4.3. **The UK extended model**

Stage 1: Innovation input equations

Firm's decision to engage in innovation expenditure:

Pr(Innov_expenditures) = F{Fin_sup, HC [S&E(%); Oth_grad(%)]; Mkt_share_prior, Growth_ind, Size, Export(Y/N), IP_i, IND, GP, Foreign, MNE_nat, Herfindahl, age} [1a]

Innovation expenditure intensity:

LRTOTPS = F{Fin_Sup, HC[S&E(%); Oth_grad(%)]; Mkt_share_prior, TFP_prior, Herfindahl, Export(Y/N), IP_i, Source_IND_, IND, GP, MNE_nat, Foreign, Size, age} [1b]

Stage 2: Innovation output equation

Innovation output intensity:

LISPS = F[LRTOTPS_hat; Size, age, Export(Y/N), IP_i, IND, GP, MNE_nat, Foreign] [2a]

Stage 3: Productivity equation

TFP growth = F[%novelproduct; %new product; novel pcs, flexibility, ΔK, age, TFP_prior, Mkt_share_prior]

(Note that the first three innovation output variables in the productivity equation used predicted values to take into account the potential endogeneity issue.)

Note: Underlined variables differ from the OECD core model.

innovation output measures as the concept of learning associated with innovation would already be captured.

Higher innovation input (innovation expenditure per total sales) would still be associated with higher innovation sales as it was for the United Kingdom in the core OECD model. Higher innovation input would also increase the probability of first-to-market process innovation (but the effect would vanish if predicted innovation input is used to control for endogeneity).

Finally the UK extended model also introduced firms' market share at the beginning of the period, the Herfindahl index (industry concentration), and whether the industry to which the firms belonged was growing or not. The addition of these variables captures the impact of the environment in which the firms operate. Preliminary results show that firms with larger market share at the beginning of the period would invest less in innovation activities. Firms in highly concentrated industries would be less likely to invest in innovation activities, but when they do, they invest more.

Germany

Like the UK model, the Germany extended model was able to include several new variables from its rich database. Of particular interest is how the German database allowed for a convincing treatment of the impact of process innovation (cost savings due to innovation).

In most CDM variants (see Box 3.1), the knowledge production function (stage 2 of the CDM model) is mainly based on the success of the product innovation (measured as intensity of innovation sales or patents). Attempts to "model" the innovation process have been based, largely by default, on the probability of introducing a process innovation, not on a quantitative output indicator measuring its success. In contrast, the German extended model used a variable that measures the cost savings from process innovation (scaled by number of employees) to measure the success of product innovation. The usual variables that measure the sales from product innovations (per employee) were also used to measure the success of product innovation. The German extended model therefore used two quantitative output variables in its knowledge production function and took into account the fact that productivity can result from both types of innovation. Predicted innovation outputs (for process and products) were then used as regressors in the productivity equation.

Finally, the German extended model differs from the core OECD model by using partial panel data information (using lagged key variables) and therefore takes into account the time needed for innovation input (2001) to turn into innovation output (2003) and in turn affect productivity (2002 and 2003).

Preliminary results from the German extended model support the OECD core model with a positive and significant coefficient for product innovation output in the productivity equation (result robust to different model specifications) and a positive and significant coefficient of innovation input in the product innovation output equation. The positive links between innovation input, (product) innovation output, and productivity still hold with a model using a more sensitive time structure (taking into account the time between innovation activities and the occurrence of innovation as well as the time between the introduction of the innovation and its effect on the firm's productivity).

For the link between process innovation and productivity, use of a more appropriate measure of success (treated for potential endogeneity issues with the productivity variable) made the coefficient of process innovation positive (but weakly significant). However, contrary to the product innovation equation, spending more on innovation activities or developing the innovation in house would not necessarily lead to higher cost savings from process innovation. Other inputs such as knowledge generated by other

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Box 4.4. **The German extended model**

Stage 1: Innovation input equations

Firm's decision to engage in innovation activities:

$$\underline{\mathit{Innov\_expenditure}_{01}} = F[\mathit{Size}, \underline{\mathit{Export(\%)}}, \underline{\mathit{Fin\_Sup}}, \underline{\mathit{Herfindahl}}, \mathit{Group}, \underline{\mathit{Ownership\_i}}, \underline{\mathit{HC}}, \underline{\mathit{Training}}, \underline{\mathit{age}}, \underline{\mathit{IP\_i}}, \underline{\mathit{source\_i}}, \mathit{IND}]_{00} \quad [1a]$$

Innovation expenditure intensity:

$$\mathit{LRTOTPE}_{01} = F[\underline{\mathit{Export(\%)}}, \mathit{Fin\_Sup}, \underline{\mathit{Herfindahl}}, \mathit{Group}, \underline{\mathit{Ownership\_i}}, \underline{\mathit{HC}}, \underline{\mathit{Training}}, \underline{\mathit{IP\_i}}, \underline{\mathit{source\_i}}, \mathit{IND}]_{00} \quad [1b]$$

Stage 2: Innovation output equations

Product Innovation output intensity:

$$\underline{\mathit{LISPE}_{02}} = F[\underline{\mathit{LRTOTPE\_hat}}; \mathit{Size}, \mathit{Fin\_Sup}, \underline{\mathit{Herfindahl}}, \mathit{Group}, \mathit{PDT\_inhouse}, \mathit{Coop}, \underline{\mathit{ind\_spill}}, \mathit{IND}\ ]_{01} \quad [2a]$$

Process Innovation output intensity:

$$\underline{\mathit{LCSPE}_{02}} = F[\underline{\mathit{LRTOTPE\_hat}}; \mathit{Size}, \mathit{Fin\_Sup}, \mathit{Group}, \mathit{PCS\_inhouse}, \mathit{Coop}, \mathit{IND}]_{01} \quad [2b]$$

Stage 3: Productivity equation

$$\mathit{LLPPE}_{02} = F[\mathit{LISPE\_hat}, \underline{\mathit{LCSPE\_hat}}, \mathit{Size}, \underline{\mathit{Log\ of\ (K,M)}}, \underline{\mathit{HC}}, \mathit{Group}] \quad [3]$$

or

$$\mathit{LLPPE}_{\underline{0302}} = F[\mathit{LISPE\_hat}, \underline{\mathit{LCSPE\_hat}}, \mathit{Size}, \underline{\mathit{Log\ of\ (K,M)}}, \underline{\mathit{HC}}, \mathit{Group}]$$

Note: Underlined variables differ from the OECD core model.

private organisations (*e.g.* imitating rivals' more efficient technologies) seem to be more important for generating greater cost reduction.

Finally, the German extended model used firms and industry-related variables in the innovation input equation. Results on firms' innovation capability mostly confirm the analysis of the OECD core model according to which the incentive to innovate increased with size and stronger international orientation. Firms' capacity to capture government financial support increased their innovation expenditures. For industry-related variables, the German extended model found results similar to the UK results, that is, when German firms in a highly concentrated industry decide to engage in innovation, they invest more in the innovation projects. Other industry-level variables (technological opportunities and intellectual property protection at the industry level) were usually not significant.[9]

Therefore, the German extended model (with the exception of the process innovation coefficients on productivity) confirms, with more detail and precision, most of the conclusions of the OECD core model.

4.3. Conclusion and research agenda

What have we learned from the OECD core model?

The OECD core model on the link between innovation input, innovation output and productivity produced very interesting results. Overall, and in spite of the data constraints imposed for the sake of international comparability and the resulting imperfections, the estimated model yields broadly comparable results for the countries in the sample.

Results from the simplified OECD model gave a strong indication of general trends, such as the positive relationship between firms operating on international markets and higher innovation expenditure intensity; firms with higher innovation sales are also generally those that invest more in innovation; and finally the most successful product innovators are also the more productive firms. These results have been mostly confirmed by the extended models tested by the Netherlands, Canada, the United Kingdom and Germany.

What has been learned from the four extensions presented in this chapter?

While the extended models confirmed the general trends, they also revealed that refining the model (by adding relevant variables and increasing the precision of variables already used) usually decreased the estimated coefficients. Caution is needed when trying to compare countries' responses for a given variable (for instance, when comparing elasticity values). Given that all robustness checks showed that refining the model would decrease elasticity values, results from the core OECD model should be treated at least as upper bound values.

In addition to robustness checks on the OECD core model, the extended models also allowed for additional and more refined relationships at each stage of the model. For instance, using market structure and more precise industry-related variables in the innovation input equation added another dimension to the model. Technology opportunities, innovation appropriation, and competitive pressures are certainly important determinants of a firm's decision to invest in innovation.

If using information from the entire population (instead of only from innovators) is seen as important or more credible when providing advice to policy makers, it is crucial to have the best innovation input equation. Failure to get reliable predicted innovation input would cast doubt, in later stages, on the validity of the results of the model ("cascading biases" due to measurement errors from inadequate innovation input equations, since the predicted innovation input is the main predictor of innovation output, which in turn is used in the productivity equation).

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In addition to testing interesting industry-related variables in the innovation input equation, these extended models also improve the innovation output equation(s) by adding refined measures that proxy firms' innovation capability. Knowledge flows used by firms (detailed sources of information for innovation) as well as in-house capacity (whether firms mainly developed the product and/or process innovation in house or singled out a particular innovation activity, such as performance of R&D) were revealed to be highly relevant in the innovation output equations. When available, using prior year values for these variables is certainly interesting as it partially controls for the endogeneity issue. Modelling a process innovation equation parallel to the product innovation equation to assess the knowledge production stage is another improvement of the overall model.

Finally, the use of a better productivity equation is certainly one of the most important contributions of the four extended models. Adding production factors to the equation (or conversely using a more appropriate productivity measure) adds credibility to the whole model. Using an alternative process innovation output variable (or its predicted value if endogeneity is assumed) does not usually change its negative coefficient. Only when using a more appropriate variable dealing with the success of process innovation (cost savings from the innovation process) does the coefficient turn positive, but this result was not robust when subjected to different specifications.

While new lessons were learned with each of the four extended models, changes in the models made it hard to compare the results of the four countries. Key dependent variables (most notably the productivity variable) and econometric specifications differ so that only general trends can be perceived. International comparison was not the stated objective of the extended models, but they show how much one model can differ from another even when both rely on the same (CDM) theoretical framework.

Looking forward: a research agenda

For the next stages of the project, there are several options. The short-term strategy would be to build on what has been achieved so far by incorporating new countries, both OECD and non-member economies (with innovation survey databases) in the analysis.

It would also be possible to improve the model marginally by incorporating industry-related variables available through official statistics offices and OECD databases (*e.g.* Herfindahl index, industry growth) or by tabulating innovation survey variables at the industry level (*e.g.* intellectual property tools, type of knowledge used). Adding these variables would allow for better control of the firm's environment (instead of just using industry dummies) which is thought to be important for firms' innovation investment behaviour.

While the short-term strategy would focus on including as many countries as possible and marginally improving the model, a second strategy (over the medium term) would involve the development of different extended models dealing with specific policy questions. There is a risk of losing countries in the process but the analysis of the results from the participating countries would provide additional insights for policy advice and would therefore be of great interest to the policy community.

In order to ensure international comparability and include as many countries as possible, extended models should incorporate mandatory variables (such as all dependent variables and key factors of production) but allow some flexibility for other variables. Flexibility in the choice of most independent variables would allow participating countries to have a richer model without sacrificing too much for the sake of international comparability.

A group of countries can work on more than one "extended" model. Each sub-project must target a clear and distinct policy question (*e.g.* importance of continuous innovation activities; the role of competition in innovation; the impact of public support for innovation; location of knowledge-based institutions; export, globalisation and innovation; etc.). Defining the policy question from the start can help to focus on a clear model and an understanding of the mandatory variables to be included.

Each sub-project would therefore develop its own model but results from the core OECD and the extended models tested so far suggest that the next iteration of models would gain, when possible, from incorporating some of the following variables:

1. Industry and market structure (such as Herfindahl index, growth or decline of industries, use of CIS-related variables at the industry level, etc.).
2. Past economic performance (market share of the firm in prior period, position of the firm relative to the industry to capture the "catching-up process", etc.).
3. Past innovation performance and innovation activities (to proxy the technology path, to proxy continuity in innovation activities over time, to distinguish continuous innovators from frequent to one-time technology adopters).
4. Factor of production in the productivity equation (the cost of capital, labour, energy, materials and services if labour productivity is used; or the cost of capital and labour if value added is used).

Exploiting more waves of CIS-like surveys (to get past innovation performance and activities) would have several advantages. On the one hand, it would allow more realistic timing assumptions to deal with the lag between innovation investments and innovation outcomes. On the other, it would

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provide opportunities to control for endogeneity (in the form of lagged variables) and missing variables (fixed effects). However, this would more likely lessen the number of countries able to participate.

In conclusion, the link between innovation input, innovation output and productivity can be expected to continue to be a relevant policy issue in the future, and the need for sound, comparable empirical analysis will therefore not vanish. Work done so far in this project adds to the knowledge base mostly because of its comparative scope across a large number of countries. Building from what has been done so far by improving the model and pursuing new sub-projects on clear policy-relevant questions would certainly be of interest to member countries and as part of the OECD Innovation Strategy.

Notes

1. Papers discussed in this document are those presented at a special session on innovation and productivity at the Warsaw Atlantic Economist Association conference (April 2008). Extensions were presented for the Netherlands (Polder, 2008); for Germany (Peters, 2008); for the United Kingdom (Criscuolo, 2008); and for Canada (Therrien and Hanel, 2008). We thank them for their invaluable input, and in particular Chiara Criscuolo, who also provided comments on the previous version of this chapter. The views expressed here are those of the authors and do not necessarily reflect those of Industry Canada, the government of Canada or the University of Sherbrooke.
2. A fifth country (Sweden: Hagén *et al.*, 2008) also worked on an extended model using additional variables and a better productivity variable. While the focus of this chapter is to present findings from the Warsaw conference (Sweden was not present), general results from the Sweden extended model are included in final section.
3. Papers presented at the Warsaw conference were draft versions only, and the models and results may vary in the final versions. Preliminary results are discussed only to give a sense of the impact of using refined models. See Annex Tables 4.A1.1 and 4.A1.2 for a summary of important variables used in each model along with a short definition.
4. Predicted innovation output (from observed independent variables and the predicted innovation input variable in stage 1) resulted in unreliable coefficients from the productivity equation for most countries – generally a non-significant and often negative sign for the innovation output coefficients. Therefore, it was ruled out as too demanding for the model to deal with two endogeneity issues.
5. In the core OECD model, the predicted innovation input variable failed the identification tests and therefore was not a valid instrument for the innovation output equation.
6. It is important to make the distinction between using the predicted value of innovation input for dealing with endogeneity and using this predicted value in order to use the information from all firms (as the Netherlands did).
7. In addition to these three respects, the United Kingdom used the CIS 3 (for 1998-2001) which was linked to production data (ARD database) to construct the TFP growth variables. In the OECD model, the United Kingdom used data from CIS 4 (for 2002-04).

8. The interpretation of novel process innovation in relation to productivity may be different from that of novel product innovation. The more novel the process innovation, the more it is likely to have a disruptive effect on production in the short term and therefore on the productivity measure. If it is not possible to assess the long-term effect, low novelty process innovation might give a better result for productivity in the short term.
9. Given the strong theoretical foundation for including industry-based variables that take into account the environment in which firms operate in order to explain innovation intensity, more work on this issue might be needed.

References

Criscuolo, C. (2008), "Innovation, Knowledge Flows and Productivity Growth: Evidence from the UK CIS", paper presented at the Warsaw Atlantic Economist Association conference (May 2008).

Hagén, H.O. *et al.* (2008), "Innovation Matters: An Empirical Analysis of Innovation 2002-04 and its Impact on Productivity", paper presented at the Statistics Canada socio-economic conference (June).

Peters, B. (2008), "Product and Process Innovation Outcome and Firm Performance", paper presented at the Warsaw Atlantic Economist Association conference (May 2008).

Polder, M. (2008), "Innovation and Productivity: Firm-Level Evidence and Aggregate Implications", paper presented at the Warsaw Atlantic Economist Association conference (May).

Therrien, P. and P. Hanel (2008), "Innovation and Establishments' Productivity in Canada, Results from the 2005 Survey of Innovation", paper presented at the Warsaw Atlantic Economist Association conference (May).

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ANNEX 4.A1

Tables

Table 4.A1.1. **Variables used in all models (list and definition)**

Variables	Description
Potentially endogenous variables	
Innov. expenditures	Innovation input: usually log innovation expenditure per employee[1]
Innovation sales	Innovation output: usually log innovation sales per employee[1]
process (LCSPE)	Process innovators (binary)[1] or log (cost saving_innovation/employee)
%novel_pdt	Share of innovation sales from first-to-market innovation (over total sales)[1]
%new_pdt	Share of innovation sales from first-to-firm innovation (over total sales)[1]
novel_pcs	First to market process innovation (or for Canada: first to North America)[1]
flexibility	impact of process innovation on production flexibility (high impact only)[1]
org_inn	organisational innovation[1]
Exogenous variables	
Firm general characteristics	
SIZE	Log (employees)[1]
IND	Industry dummies (10 industrial groups)
Herfindahl	Herfindahl index
Rating	Credit rating index
Export	firm active in international market (binary variable or share of total sales)[1]
Fin_sup	firm received financial support from government for innovation[1]
nonFin_sup	firm received non financial support from government for innovation[1]
Direct_sup	firm received direct financial support from government for innovation[1]
Indirect_sup	firm received indirect financial support (R&D tax credit) from government[1]
Group (or intrafirm sale)	Firm is part of a larger organisation[1] (share of sale from intra firm)
FOREIGN	Foreign-owned enterprise
PLC	firm is a public limited company
LTD	firm is a private limited company
mneNAT	Multinational enterprise domestic-owned
AGE	age of the firm
Most_imp_client	share of sales from firm's most important client
INDSPILL	share of sales from customer/suppliers relative to industry average
mkt_share_prior	Firm's market share (period prior to innovation)
Growth_ind	Industry growth (Y/N)
Firm innovative capabilities	
TRAIN	Training expenditures per employee
PD_INHOUSE	Product innovation mainly developed in-house[1]
PCS_INHOUSE	Process innovation mainly developed in-house[1]
RD_performer	Firm is R&D performer[1]
HAMPERING_i	Obstacles for innovation (knowledge, market, cost-based, prior innovation)[1]
COOP (COOP_i)	Firm collaborate for innovation[1] (partners of collaboration-private/public)[1]
RD_outsource	Firm outsourced R&D
IP_i	IP protection (legal, strategic)
SOURCES_i	Source of innovation for innovation (private, public)[1]
Production factors and prior productivity measures	
K	Capital
L (or HC)	Labour cost (or share of graduate over total firm workforce)[1]
E	Energy
M	Material
TFP_prior	Firm's TFP relative to the median firm in industry (period prior to innovation)

1. Usually included in innovation surveys. Otherwise variables from national production survey.

Table 4.A1.2. **List of main variables used by models**

	OECD				The Netherlands				Canada				United Kingdom					Germany				
	[1a]	[1b]	[2]	[3]	[1-2]	[1b]	[2b]	[3]	[1a]	[1b]	[2]	[3]	[1a]	[1b]	[2a]	[2b]	[3]	[1a]	[1b]	[2a]	[2b]	[3]
Potential endogenous variables																						
Innovation input																						
Innov. expenditure			X				X				X				X	X				X	X	
Product innovation																						
Innovation_sales				X				X				X										X
%novel_pdt																	X					
%new_pdt																	X					
Process and organisational innovation																						
process (or LCSPE)			Xd	Xd													Xd					X
novel_pcs											Xd	Xd					Xd					
Flexibility																	Xo					
Organisational																	Xo					
Exogenous variables																						
Firm characteristics																						
SIZE	X		X	X	X		X		X	X	X	X	X	X	X	X		X		X	X	X
IND	Xd	Xd	Xd	Xd	Xd	Xd	Xd	Xd	Xd	Xd	Xd	Xd	Xd	Xd	Xd	Xd	Xd	Xd	Xd	Xd	Xd	Xd
Herfindahl													Xi	Xi				Xi	Xi	Xi		
Rating																		X				
EXPORT	Xd	Xd			Xd	Xd			X	X			Xd	Xd	Xd	Xd		X	X			Xo
Fin_sup		Xd				Xd								Xd				Xd	Xd			
nonFin_sup															Xd	Xd						
Direct_sup									Xd	Xd												
Indirect_sup									Xd	Xd												
Group (intra_sale)	Xd	Xd	Xd	Xd	Xd		Xd	Xd	X		X	X	Xd	Xd	Xd	Xd		Xd	Xd	Xd	Xd	Xo
FOREIGN								Xd					Xd	Xd	Xd	Xd		Xd	Xd			
PLC/LTD																		Xd	Xd			
MneNAT													Xd	Xd	Xd	Xd						
AGE													Xd	Xd	Xd	Xd	Xd	Xd				
Most_imp_client									X	X												
INDSPILL																				X		
mkt_share_prior													X	X			X					
Growth_ind													X	X								
FIRM INNOV CAPABILITY																						
TRAIN																		X	X			
PDT_INHOUSE																				Xd		
PCS_INHOUSE																					Xd	
RD_performer							Xd															
HAMPERING_i	Xd				Xd																	
COOP (COOP_i)		Xd	Xd			Xd				Xd					Xd	Xd				Xd	Xd	
RD_outsource										Xd												
IP_i													Xi	Xi				Xi	Xi			
SOURCES_i									Xd		Xd		Xi	X	X	X		Xi	Xi			

Table 4.A1.2. **List of main variables used by models** *(cont.)*

	OECD				The Netherlands				Canada				United Kingdom					Germany				
	[1a]	[1b]	[2]	[3]	[1-2]	[1b]	[2b]	[3]	[1a]	[1b]	[2]	[3]	[1a]	[1b]	[2a]	[2b]	[3]	[1a]	[1b]	[2a]	[2b]	[3]
Production factors and prior productivity measures																						
K								X			X	X										X
L (orHC)				Xo				X			X	X	X	X			Xo	X	X			Xo
E								X														
M								X														X
TFP_prior													X	X			X					

Note: Xd = binary variable used in the equation; X = quantitative variable; Xi = industry-level variable; Xo = optional.
Dependent var:

OECD core: [1a] probability to be innovator strict; [1b] log (innovation expenditures/employee); [2a] log (innovation sales/employee); [3] log (turnover/employee).

The Netherlands: [1a] probability to invest in innovation (innovation expenditure); [1b] log (innovation expenditure/employee); [2a] probability of positive innovation sales); [2b] log (innovation sales/employee; [3a] log TFP, [3b] log(sales/emp); [3a] and [3b] include the same variables; except that [3a] includes the KLEMS variables on the RHS.

Canada: [1a] probability to be innovator strict; [1b] log (innovation expenditures/employee); [2a] log (innovation sales/employee); [3] log (value added/employee).

UK: [1a] probability to invest in innovation activities; [1b] log (innovation expenditures/sales); [2a] log (innovation sales/sales; [2a] probability (process innovators); [3] log (TFP growth).

Germany: [1a] probability to invest in innovation activities; [1b] log (innovation expenditures/employee; [2a] log (innovation sales/employee); [2b] log (cost reduction from innovation/employee); [3] log (turnover/employee).

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Innovation in Firms: A Microeconomic Perspective

Chapter 5

Innovation and Intellectual Property Rights[1]

by
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5.1. Background

"*Patent regimes play an increasingly complex role in encouraging innovation, diffusing scientific and technical knowledge, and enhancing market entry and firm creation. As such, they should be subject to closer scrutiny by science, technology and innovation policy makers*." (Meeting of OECD Ministers of Science and Technology, January 2004).

The question of whether the patent system stimulates or impedes innovative activity has a long history but is still timely given the secular (increasing) trend in patent use, controversy about the potential extension of patentability, and recent important legal reforms that affect several patent offices (*e.g.* in Europe, Japan, the United States). Patents provide incentives to innovate and can facilitate the diffusion of technology, firm creation and markets for technology, but they can also be used anti-competitively, create monopoly distortions and block follow-on innovation.

This chapter presents the findings on innovation and intellectual property rights (IPRs). It exploits information collected in innovation surveys to assess the economic impact of patents on firms' innovative behaviour. Aggregate indicators of patent applications provide a synthetic picture of a complex pattern of behaviour and simultaneous relations: *i)* the intensity of a firm's effort; *ii)* a firm's ability to convert its innovative efforts into valuable, marketable innovations; *iii)* a firm's strategic choice to protect its inventions (*i.e.* the propensity to apply for a patent); and *iv)* the incentive effect of the patent system, and of other public interventions, on the innovative behaviour of firms. The use of firm-level data can help disentangle these various effects.

First of all, access to micro-data makes it possible to compute a number of indicators on various sub-populations of firms, *e.g.* manufacturing industries *vs.* service industries or SMEs *vs.* large firms. This approach is a first way of controlling for the structural effects that may drive differences in aggregate patenting performances. Furthermore, computing indicators of IPR use across the various sub-population of innovators, allows for analysing the patenting behaviour of firms, controlling for their ability to innovate and for the incentive provided by the patent system.

However, the potential offered by firm-level data concerns not only this larger "degree of freedom" for computing aggregate indicators, but also their direct use at the micro level. More precisely, to assess the incentive effects of patents (with cross-sectional data alone) requires a structural model that can only be estimated with firm-level data. The main objective of this contribution, therefore, is to define a simple structural model that may be estimated on the harmonised innovation data available in several OECD and non-member countries.

5.2. The link between innovation and IPRs

Empirical studies aimed at assessing the incentive effect of patents are quite scarce, especially studies that allow for international or cross-sectoral comparisons. Among these, Ginarte and Park (1997) propose a quantitative IPR strength index and analyse its correlation with R&D capital and growth. The correlations obtained are positive, although later studies using the same data have shown the sensitivity of the results to country characteristics (market size, level of development, etc.). The main concern about this approach is that national patent strength may be driven by technology level and country-level R&D investment (Ginarte and Park, 1998), so that the results may be affected by severe endogeneity biases. The instrumental variable approach used by Lerner (2000) is an attempt to address this issue. Analysing patent policy shifts in 60 countries between 1850 and 2000, the author finds that when a country strengthens its patent system, it receives more inventions from other countries. However, domestic inventors do not seem to patent more either in their country or abroad, which suggests that there is no significant impact on domestic innovation.

Another set of empirical studies relies on an estimation of the impact of changes in patent policy on firms' innovation behaviour. However, the main limitation of these studies is that the evidence is only valid "locally", for particular countries and industries, and at specific points in time. Grabowsky and Vernon (1985) show that the 1984 extension of patent duration for pharmaceuticals in the United States should in theory have a positive effect on innovation in this industry. Lerner and Zhu (2007) find that the firms in the software industry that were most affected by the reduction of copyright protection following Lotus *vs.* Borland disproportionately accelerated their patenting activity in subsequent years, and this increased reliance on patents is found to be correlated with positive outcomes for firms. Other empirical enquiries give less positive results. Branstetter and Sakakibara (2001) show that the increase in patent scope in Japan in 1988 had a modest effect on firms' R&D, and Hall and Ziedonis (2001) argue that changes in patent policy in the United States in the 1980s doubled the ratio of patenting to R&D in the semiconductor industry, owing to fears of litigation and the need for patent portfolios for cross-licensing. Moreover, in this industry, which is characterised by rapid technological change and cumulative innovation, patents were considered as taxes on firms' innovative activity. The main positive consequence of patent strengthening was that it facilitated the entry of specialised design firms. Finally, Bessen and Hunt (2004) obtain the most unfavourable conclusion for software, an industry which they argue is known for frequent strategic patenting. The large increase over time in the propensity to patent software, and particularly since software became patentable in the United States in the 1990s, is poorly explained by changes in R&D investments, employment of computer programmers or productivity growth. The authors even argue that software patents substitute for R&D at the firm level as they seem to be associated with lower R&D intensity.

However, the approach proposed here is most closely related to Arora *et al.* (2007) and directly derived from Duguet and Lelarge (2006); it also (unsuccessfully) extends the empirical analysis to trademarks. All of these studies, including the present one, rely on the estimation of empirical equations that are derived from more "structural" models. Empirical identification of the "incentive effect" of patents relies on exclusion restrictions that are theoretically motivated, and also, on the data side, on disaggregated information about the strength of IPR. More precisely, in Arora *et al.* (2008) as well as in Duguet and Lelarge (2006), both of which use firm-level cross-sectional data, empirical identification of the "incentive effect" is due to the industry level variation of the indicator of IPR strength, whereas firm level controls only make it possible to obtain more precise estimates of structural parameters. In other words, identification of the incentive effect of patents relies on the fact that the effectiveness of patent protection varies across industries.[2]

The OECD project adds to previous evidence on this topic by exploiting simultaneously, although in a differentiated way, industry-level and country-level heterogeneity. For legal reasons, data for each participating country could not be pooled, so that (in particular) it has only been possible to estimate a common model in each national sample.[3] However, the methodology, which is based on highly harmonised data and estimation procedures, ensures that national differences can safely be interpreted as true differences in the underlying economic behaviour rather than as statistical artefacts.

In terms of interpretation, it should be noted that although only the potential effect of the patent system on the intensity of innovative effort is considered here, patents and IPRs may also affect other dimensions of firms' innovative activity. For example, Moser (2005) shows that patents (or the lack of patent protection) tend to distort the direction of technological effort. Her analyses of exhibition data for a panel of countries in the 19th century indicate that inventors in countries without patent laws focused on a small set of industries (scientific instruments and food processing) for which patents were less important, while innovation in countries with patent laws appeared to be much more diversified.

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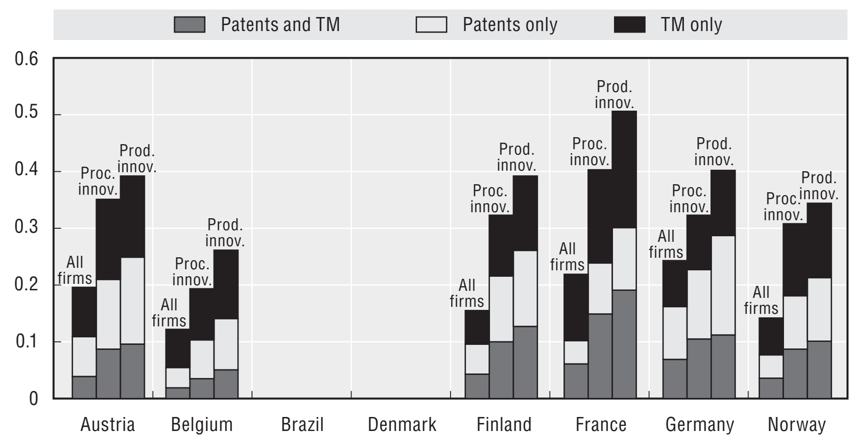
5.3. A first look at countries' and firms' propensity to patent

Direct access to firm-level microdata makes it possible to compute a series of refined indicators of IPR use. Simple propensities to patent (see first bar in Figure 5.1) computed for the whole population of firms have the same "economic" content as standard patent ratios (*e.g.* number of patent applications related to GDP or population, see Figure 5.2), *i.e.* they both relate an indicator of patenting performance (number of patenting firms or number of patents) to an indicator of size (total number of firms, GDP or population). However, indicators based on innovation surveys are in a sense less precise in that the number of patent applications per firm is not available. More importantly, they focus on specific actors, namely firms (operating in specific industries and with more than ten employees). The standard ranking of countries is globally preserved, but differences in performance seem to be attenuated.

Figure 5.1. **Propensity to use IPR (patents and trademarks)**

All core industries



Source: Respective national innovation surveys, 2002-04 (except Austria, 1998-2000).

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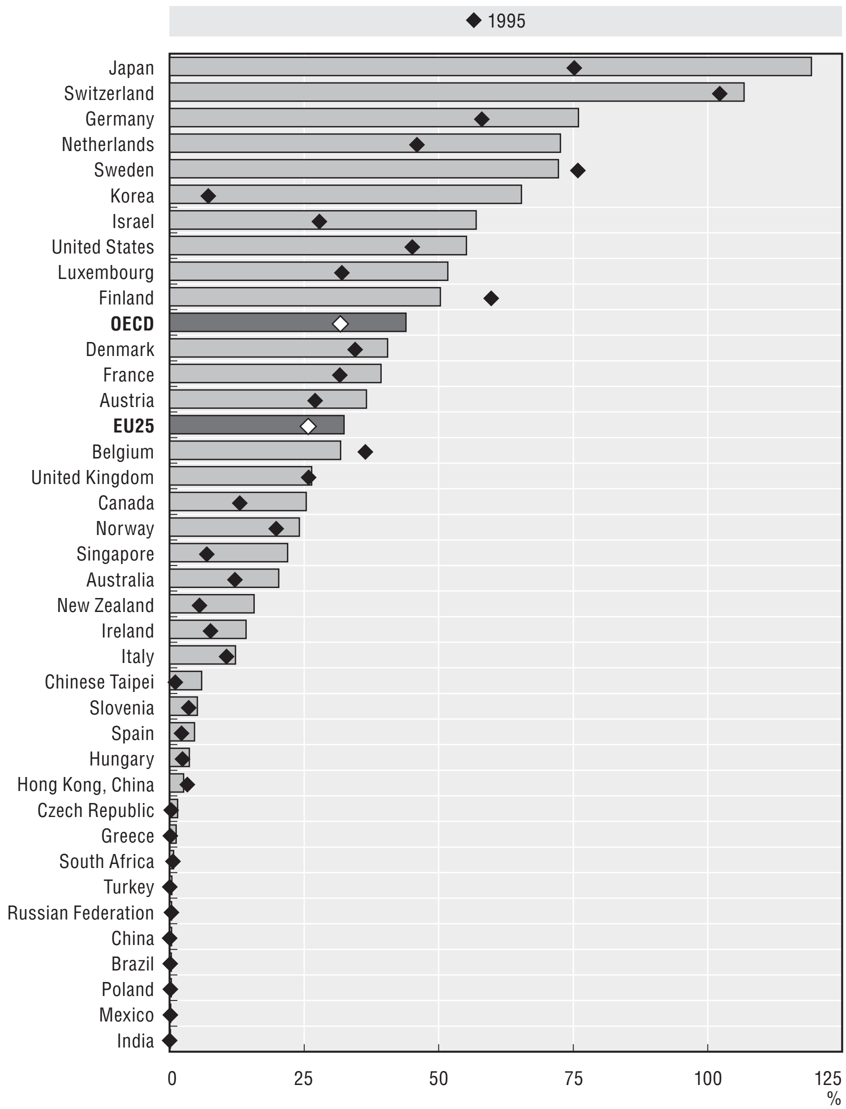
Controlling for the innovative behaviour of firms, IPR protection is more frequent on average among product innovators than among process innovators. Ranking countries in terms of propensity to patent among innovators is quite different from ranking in terms of gross shares of patenting firms. For example, French product innovators patented slightly more than German ones (30 and 29%, respectively) but France's share of patenting firms in the total population was smaller than Germany's (10 and 16%, respectively). The same applies for the use of IPRs in general (Box 5.1). This would suggest that the difference in patenting between France and Germany is more likely

Figure 5.2. **Patent families per million population**

1995 and 2005



Note: Triadic patent families are patents filed at the European Patent Office (EPO), the US Patent and Trademark Office (USPTO) and the Japan Patent Office (JPO) that protect the same invention. Data for 2005 are OECD estimates.

Source: *OECD Science, Technology and Industry Scoreboard*, 2007 and *OECD Compendium of Patent Statistics*, 2007.

StatLink http://dx.doi.org/10.1787/546134115640

Box 5.1. **Country-level heterogeneity in terms of IPRs**

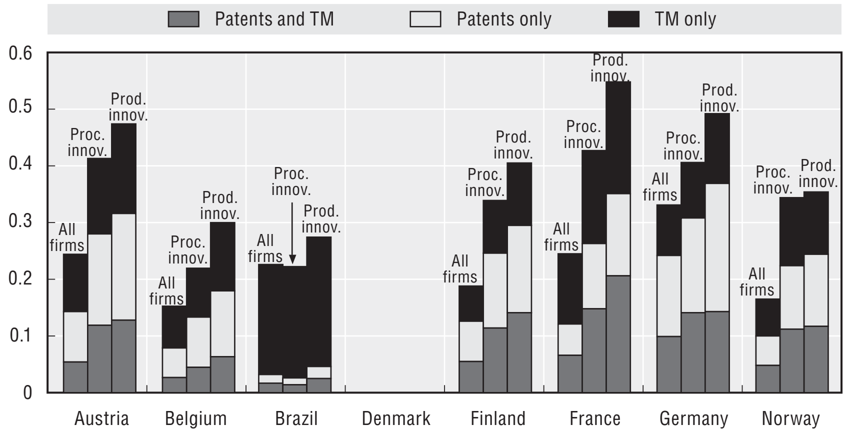
How should country-level heterogeneity be interpreted? It may be due to differences in industry structure, but also to differences in national institutions that may explain differing behaviour of firms. Among these institutions, patent offices may play the most important role. Variations in the strength of the IPRs available in each country provide an additional dimension of identification when assessing their incentive efficiency. Ginarte and Park (1998) propose a synthetic index (which they have updated to 2005) for each country using a coding scheme which is applied to national patent laws. The index ranges in value from zero to five, with higher values indicating stronger levels of protection. Among countries covered in the present analysis, their index ranges from 3.59 for Brazil, to 4.17 for Norway, 4.33 for Austria, 4.50 for Germany and 4.67 for Belgium, Denmark, Finland and France. The countries covered by the present analysis benefit from an interesting source of variation between Brazil and European countries, but also among European countries themselves, since a difference of 0.5 in a 0 to 5 index (*i.e.* 10% of the total potential variation of the index) is not negligible.

However, this index focuses on patents and therefore only provides a partial description of the effectiveness of the various IPRs available in each country. Moreover, there may be other sources of country-level heterogeneity, such as the average technology level, as suggested by Acemoglu and Akcigit (2006). Various indicators can be used to measure the technology level of each national economy, *e.g.* labour productivity or patent applications per million population. Here, there is a large gap between Germany (76 patent triadic families per million population in 2005) and Brazil (0.3 patent triadic families per million population). However, the ranking based on labour productivity is quite different (especially among EU countries) but is also suggestive of a large potential heterogeneity among the eight countries involved in the analysis.

due to a deficit of innovating firms than to a lower propensity to patent among innovators. However, this interpretation should be treated with caution since differences in industry or size structure are not taken into account in this descriptive approach. Furthermore, and more importantly, these partial correlations are likely to be driven by phenomena of selection: the few French innovators may be a more "selected" sub-set of firms than the numerous German innovators, and they may therefore be able to introduce patentable innovations, *i.e.* innovations meeting the novelty requirement, more often.

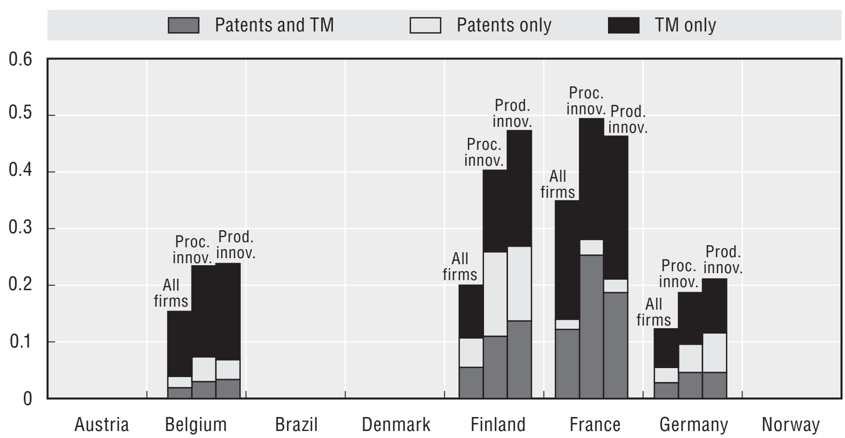
Replicating the analysis with a more limited scope, in the manufacturing (Figure 5.3) and (high-technology) service industries (Figure 5.4), patents are seen to be used less frequently in services, at least in Germany, but France and Finland are notable exceptions. Another striking observation is that product

Figure 5.3. **Propensity to use IPR (patents and trademarks)**
Manufacturing industries



Source: Respective national innovation surveys, 2002-04 (except Austria, 1998-2000).
StatLink http://dx.doi.org/10.1787/546222230055

Figure 5.4. **Propensity to use IPR (patents and trademarks)**
Service industries



Source: Respective national innovation surveys, 2002-04 (except for Austria, 1998-2000).
StatLink http://dx.doi.org/10.1787/546242883035

and process innovators have quite similar appropriation strategies in services; this may be due to the fact that the difference between their product and process innovations is less clear-cut than in manufacturing. Lastly, SMEs in manufacturing industries (Figure 5.5) tend to patent less frequently than the average. However there is no difference between large and smaller firms in terms of trademark use.

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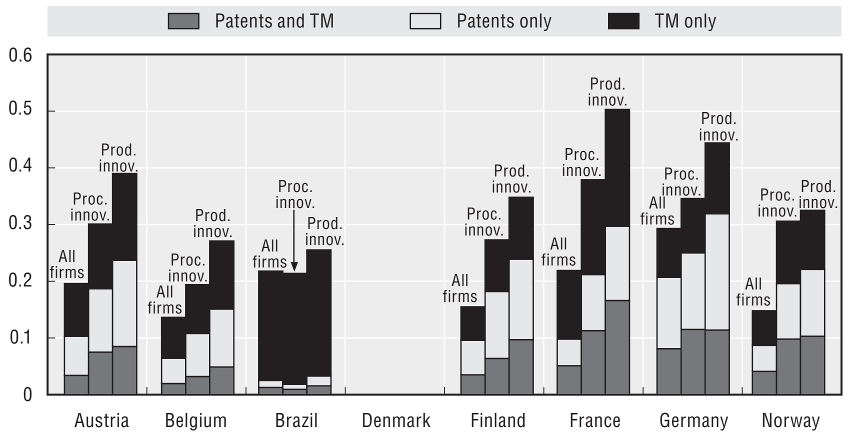
Figure 5.5. **Propensity to use IPR (patents and trademarks)**

SMEs, manufacturing industries



Source: Respective national innovation surveys, 2002-04 (except Austria, 1998-2000).

StatLink http://dx.doi.org/10.1787/546267282330

To conclude, such a descriptive approach is highly informative about firms' appropriation strategies and the relevance of patents or trademarks to protect innovations, and it can be refined by taking into account firms' activities and types of innovation. However, it does not provide much insight for assessing the incentive effects (in terms of innovation effort) provided by IPRs. This is the rationale for the more "structural" approach which follows.

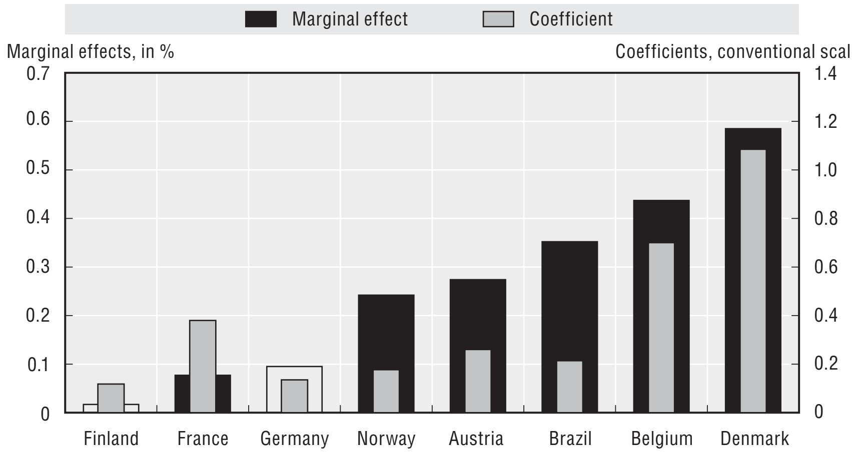
5.4. Main findings from the regression analysis

Figures 5.6 to 5.8[4] report some of the results obtained for equations explaining firms' innovative effort. These estimations are for all core industries, *i.e.* manufacturing sectors and high-technology services. Each corresponds to a different variant of the baseline model (and therefore to a different regression). Figure 5.6 synthesises the results obtained when investigating the incentive effect of patents on firms' total innovative effort; Figure 5.7 the results obtained for the R&D component of this effort; and Figure 5.8 the incentive effect of trademarks on firms' total innovative effort.

In each case, both the coefficient obtained for the expected patent premium in the underlying "structural" model (see Box 5.2) and the corresponding marginal effects are reported. The structural parameter is informative of the importance of IPR as a driver of firms' innovative behaviour for the whole population of firms. However, it does not have any straightforward quantitative interpretation. On the contrary, marginal effects represent, for each national industry structure, the average increase in the proportion of innovation-active firms that would result from more effective

Figure 5.6. **Incentive effects of patents on firms' total innovative effort**

All core industries (manufacturing and high-technology services)

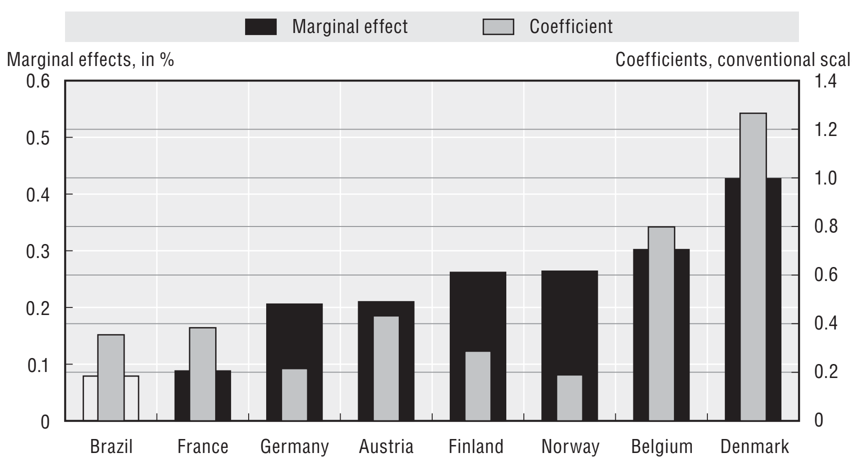


Source: Respective national innovation surveys, 2002-04 (except Austria, 1998-2000). The figures reported in the graph are the marginal effects and coefficients associated with the expected patent premium in an innovation input equation. Also included are a variety of additional controls (size, group membership, hampering factors, market scope, industry dummies). Non-significant coefficients or marginal effects are reported as transparent bars.

StatLink http://dx.doi.org/10.1787/546277266141

Figure 5.7. **Incentive effects of patents on firms' R&D effort**

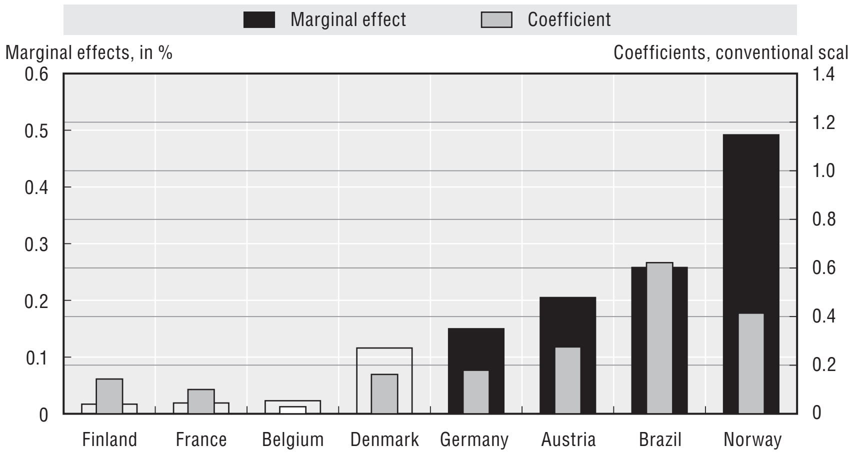
All core industries (manufacturing and high-technology services)



Source: Respective national innovation surveys, 2002-04 (except Austria, 1998-2000). The figures reported in the graph are the marginal effects and coefficients associated with the expected patent premium in an innovation input equation. Also included are a variety of additional controls (size, group membership, hampering factors, market scope, industry dummies). Non-significant coefficients or marginal effects are reported as transparent bars.

StatLink http://dx.doi.org/10.1787/546285856446

Figure 5.8. **Incentive effects of trademarks on firms' total innovative effort**



Source: Respective national innovation surveys, 2002-04 (except Austria, 1998-2000). The figures reported in the graph are the marginal effects and coefficients associated with the expected patent premium in an innovation input equation. Also included are a variety of additional controls (size, group membership, hampering factors, market scope, industry dummies). Non-significant coefficients or marginal effects are reported as transparent bars. Crosses denote models that are statistically rejected.

StatLink http://dx.doi.org/10.1787/546301045885

Box 5.2. **The model**

Representation of firms' innovative behaviour (see Annex 5.A1)

The model is based on a simple representation of firms' decision process which is useful for defining precisely what is measured as the "incentive effect" of patents. It also makes it possible to resolve estimation problems. As in Duguet and Lelarge (2006), the assumption is that firms face a three-step decision process:

1. In the first step, the firm decides whether to invest in innovative activities (R&D, acquisition of innovative machinery and equipment, *i.e.* incorporated innovation).
2. Next, the innovation output is known, *i.e.* whether the innovative efforts have been successful or not.
3. In the last step, the firm defines its appropriation strategy (patent or trademark).

Firms anticipate the IPR premium they can expect from the patent or trademark systems when they decide on their innovative effort. The incentive properties of IPRs are therefore assumed to affect the firms' innovative effort only through this "anticipation channel". More precisely, it is assumed (and tested) that optimal innovative investments depend directly

Box 5.2. **The model** *(cont.)*

on the (expected) IPR premium – and on various additional firm-level indicators – but are only indirectly affected by the efficiency of the IPR system through its impact on the IPR premium.

Empirical analysis (see Annex 5.A2)

A system of three equations is directly derived from the previous representation of firms' behaviour:

1. An "innovative input" equation explains a firm's decision to be involved in innovative activities, either in a broad sense (*i.e.* including R&D, acquisition of innovative machinery and equipment, acquisition of other external knowledge, etc.) – or, more specifically, R&D effort. The main explanatory factors considered are the expected IPR premium (which is consistently estimated in the two-step estimation process), indicators of potential hampering factors (related to costs, knowledge or market), and other firm-level characteristics, such as their size, whether they belong to a larger group, and a description of their market scope.
2. The "innovation output" equation relates the firm's innovative effort (and other characteristics, such as its size and group membership, to the product or process innovations it has been able to introduce.
3. Lastly, the "IPR" equation describes the firm's appropriation strategy, which depends on innovations that have actually been implemented, on the effectiveness of IPRs, and on other firm-level indicators (size, group membership, and market scope).

The first equation is obviously of the most interest, particularly the parameters associated with the expected patent premiums. However, estimating and testing the statistical relevance of the whole system is one of the few checks that can be performed to assess the overall validity of the approach.

IPRs.[5] Therefore, their magnitude results both from firms' behaviour (the structural model, and in particular the coefficient associated with the expected patent premium) and from the country's industry structure.

First, patents seem to be a significant "structural" driver of firms' overall innovative effort (Figure 5.6). However, there are large discrepancies among countries: patents are important in smaller countries such as Belgium and Denmark, but seem less so in the northern European developed economies (Finland, Germany and Norway). In terms of the economic significance of the incentive effect, the smallest significant marginal effect is obtained for France, and the largest for Denmark. In France, if patent protection was more effective, and led to an additional 1 percentage point of patent-using firms,[6] the proportion of firms involved in innovating activities would increase by around 0.1 percentage point. In Denmark, the proportion would increase by close to 0.6 percentage point. Sample descriptive statistics reveal that the average industry share of patenting firms varies between 8% (Belgium) and 28% (Germany). Therefore, other things being equal, the "incentive effect of patents" would explain between 1.5 and 12 percentage points of the cross-country differences in the shares of firms involved in innovating activities. Since the base is around 50%, this represents a sizeable effect (ranging from 3 to 23% of the total share of innovation-active firms).

In the case of R&D (Figure 5.7), the estimated structural parameters are always higher than in the previous specification, which means that the R&D component of firms' innovative effort is most incentivised by the patenting system. However, marginal effects are not always higher, which suggests that the average firm is not always able to benefit fully from these incentives. Unsurprisingly, patents stimulate the R&D efforts of firms in Finland, France, Germany and Norway more than those in Belgium, Brazil or Denmark.

Results obtained for trademarks are presented in Figure 5.8, although the model did not work well for most countries,[7] which suggests a more subtle link between trademarks and innovation than what can be captured by the restricted approach used for the purpose of international comparison. The incentive effect obtained is also smaller, except in Brazil and Norway, where it is found to be twice as large as for patents. This does not mean that trademarks do not have an impact on other aspects of firms' behaviour or strategies (besides their innovative effort), and more broadly on their economic performance.

Further analyses were performed in order to compare manufacturing and service industries, and SMEs and larger enterprises. However, the sample sizes were often too small to provide accurate comparative statistics. Results indicate that in the high-technology "engineering, technical testing and analysis" service activities, trademarks do not play an important role, unlike patents. Moreover, IPRs may be a strategic asset for French and Austrian SMEs, but this result is not confirmed for firms in Finland and Germany.

5.5. Conclusions and research agenda

This section summarises the main findings of the part of the OECD Innovation Microdata Project dealing with innovation and IPRs. In spite of data and methodological limitations, some very interesting results were obtained. The incentive effects of patents are most often positive and significant, with quite different models in northern European economies, where the estimated structural ("behavioural") parameter is low but the marginal effect is not negligible owing to their industry structure, and in the other European countries, where the opposite situation generally prevails. Unsurprisingly, this incentive effect is particularly large for the R&D component of firms' innovative effort, and evidence is also found of some complementarities between patents and trademarks. Brazil is also a specific case for which R&D effort is barely incentivised by patents, but where trademarks seem to be particularly relevant appropriation tools.

As mentioned, many aspect of the methodology could be improved. In particular, more attention should be devoted to the treatment of differences in sampling schemes in innovation surveys. It would also be interesting to further investigate country-level differences, in particular in cases in which the harmonised framework is statistically rejected by the data.

The most promising next steps might involve the matching of CIS data with complementary datasets, *e.g.* patent applications and other firm-level indicators that would enrich the information available for the estimation of the proposed model. The analysis of the potential complementarities between patents and trademarks requires further investigation and a more appropriate empirical framework. Lastly, the analysis of the impact of patents on market entry and firm creation is not addressed, since the surveys focus on large incumbent firms, but this is another promising area for future work.

Notes

1. Teams of researchers and statisticians from eight countries contributed to this work. Special thanks go to Martin Berger (Joanneum Research) for Austria; Jeoffrey Malek Mansour-Kadjar for Belgium; João Alberto De Negri, Eric Jardim, Bruno Cesar Araújo and Alexandre Messa (IPEA) for Brazil; Carter Bloch (Danish Center for Studies in Research and Research Policy) for Denmark; Mariagrazia Squicciarini and Olavi Lehtoranta (VTT) for Finland; Bettina Peters (ZEW) for Germany; Eric Iversen (NIFU-STEP) for Norway. This part of the project was led by Claire Lelarge (SESSI-CREST, for France) who co-ordinated the modelling effort, provided advice to the teams throughout the project and carried out the analysis for France.
2. Moser (2005) uses the same kind of identification strategy.
3. This also implies that it was not possible to exploit (in terms of accuracy for all estimates) the large number of available observations that would have resulted from the pooled dataset.
4. See Annex 5.A4.
5. An experiment in which IPRs are more effective and lead to a 1 percentage point increase in the share of IPR-using firms was implicitly considered.
6. This reasoning/quick computation is only valid in a partial equilibrium framework.
7. The chosen empirical strategy is often (statistically) rejected by the data.

References

Acemoglu, D. and U. Akcigit (2006), “State-Dependent Intellectual Property Rights Policy”, NBER Working Paper, No. 12775.

Arora, A., M. Ceccagnoli and W.M. Cohen (2008), “R&D and the Patent Premium”, *International Journal of Industrial Organization*, Vol. 26(5), pp. 1153-1179.

Bessen, J. and R.M. Hunt (2004), "An Empirical Look at Software Patents", *Research on Innovation*, mimeo.

Branstetter, L. and M. Sakakibara (2001), "Do Stronger Patents Induce More Innovation?", *Rand Journal of Economics,* Vol. 32(1), pp. 77-100.

Cohen, W.M., R.R. Nelson and J.P. Walsh (2000), "Protecting Their Intellectual Assets: Appropriability Conditions and Why Firms Patent or Not?", NBER Working Paper, No. 7552.

Duguet, E. and C. Lelarge (2006), "Does Patenting Increase the Private Incentives to Innovate? A Microeconometric Analysis", CREST Working Paper 2006-09.

Ginarte, J.C. and W.G. Park (1997), "Intellectual Property Rights and Economic Growth", *Contemporary Economic Policy*, Vol. XV, pp. 51-61.

Ginarte, J.C. and W.G. Park (1998), "Determinants of Patent Rights: A Cross-National Study", *Research Policy*, Vol. 26, pp. 283-301.

Gouriéroux, C., A. Monfort and A. Trognon (1985), "Moindres Carrés Asymptotiques", *Annales de l'Insee*, Vol. 58, pp. 91-122.

Grabowsky, H. and J. Vernon (1986), "Longer Patents for Lower Imitation Barriers: The 1984 Drug Act", *AEA Papers and Proceedings*, Vol. 5, pp. 195-198.

Hall, B.H. and R.H. Ziedonis (2001), "The Patent Paradox Revisited: an Empirical Study of Patenting in the US Semiconductor Industry, 1979-95", *Rand Journal of Economics*, Vol. 32(1), pp. 101-128.

Lerner, J. (2000), "150 Years of Patent Protection", NBER Working Paper No. W7478.

Lerner, J. and F. Zhu (2007), "What is the Impact of Patent Shifts? Evidence from Lotus *vs.* Borland", NBER Working Paper, 11168.

Levin, R.C. *et al.* (1987), "Appropriating the Returns to Industrial R&D", *Brookings Papers on Economic Activity*, Vol. 3, pp. 783-820.

Moser, P. (2005), "How do Patent Laws Influence Innovation?", *American Economic Review*, Vol. 95(4)

OECD/Eurostat (1997, 2nd ed., 2005, 3rd ed.), Oslo Manual, Proposed Guidelines for Collecting and Interpreting Technological Innovation Data, OECD, Paris.

OECD (2007), *Science, Technology and Industry Scoreboard. Innovation and Performance in the Global Economy*, OECD, Paris.

OECD (2007), *Compendium of Patent Statistics*, OECD, Paris.

ANNEX 5.A1

Economic Modelling

The proposed estimations are based on a simple representation of firms' decision process which aims first, to define precisely the measure of the "incentive effect" of patents, and second, to address simultaneity and endogeneity problems.

As in Duguet and Lelarge (2006), we assume that firms face a three-step decision process:

1. In the first step, the firm decides whether to invest in innovative activities (R&D, acquisition of innovative machinery and equipment, *i.e.* embodied innovation).
2. Next, the innovation output is known, *i.e.* whether the innovative efforts have been successful or not.
3. In the last step, the firm defines its appropriation strategy.

The optimal innovative and appropriation strategies are obtained by backward induction. In other words, firms anticipate the IPR premium they can expect from the patent or trademark systems when they decide on their innovative effort. In the present setting, the incentive properties of IPR are therefore assumed to affect firms' innovative efforts only through this "anticipation channel".

The estimated equations are derived from a simple formalised version of the previous descriptive model.

Let v_i^* be the value of (product or process) innovations implemented by firm *i*. They are produced thanks to an innovation production function involving the firm's innovative effort r_i^*. Assuming a Cobb-Douglas specification, we get:

$$ln\ v_i^* = \alpha.ln\ v_i^* + X_i^{output}.b + \varepsilon_i$$

where α is the elasticity of the value of the firm's innovations to its innovative effort and X_i^{output} are other firm level characteristics (such as size and larger group ownership) which potentially affect the firm's ability to convert its innovative effort into valuable innovations. Lastly, ε_i denotes unobserved firm-level heterogeneity.

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Furthermore, IPR protection is assumed to incur a "premium" x_i^* over the innovation value. Therefore, the value of protected innovations takes the following form:

$$V_i^* = x_i^*.v_i^*$$

We further assume that the IPR premium x_i^* itself depends on the value v_i^* of the innovations actually implemented, on the efficiency of the IPR system (Sh_pat_k, Sh_tm_k) and on other firm-level characteristics X_i^{appro} (size, market scope, larger group ownership) which potentially determine the patenting "costs" or expected profits (in a broad sense):

$$X_i^* = IPR\_P[v_i^*, exp(Sh\_pat_k), exp(Sh\_tm_k), exp(X_i^{appro})].exp(\eta_i)$$

In this expression, η_i is a random component representing the degree of appropriability of the innovations considered. It is not observed by the firm when taking its R&D decision, but it is observed when defining its appropriation strategy. However, it is never observed by the econometrician; it is assumed below that it follows a Gaussian distribution.

With a Cobb-Douglas specification, the latter equation can be re-written in a logarithmic form as follows (first-order approximation):

$$\ln x_i^* = \underbrace{\beta.\ln v_i^* + c_1.Sh\_pat_k + c_2.Sh\_tm_k + X_i^{appro}.c_3}_{\ln \mu_i^*} + \eta_i$$

In this expression, β stands for the elasticity of the IPR premium relative to the value of the protected innovation.

The firm decides upon its innovative effort through expected profit maximisation:

$$\max_{r_i^*}\left\{\int_{x_i^*>1} x_i^*.v_i^*.\varphi(\eta)\,d\eta + \int_{x_i^*\leq 1} v_i^*.\varphi(\eta)\,d\eta - F\left(r_i^*, X_i^{input}\right)\right\}$$

$$S.T.\ \ln v_i^* = \alpha.\ln r_i^* + X_i^{output}.b + \varepsilon_i$$

$F(.)$ is the cost function associated with innovative activities r_i^*, it depends on the level of innovative investment, but also on other firm-level characteristics denoted by X_i^{input} such as the magnitude of technological opportunities, the firm's access to qualified workers and researchers; or (negatively) on various "hampering factors" (obstacles).

Duguet and Lelarge (2006) show that the optimal innovative investment r_i^* can be expressed as a function of μ_i^*, X_i^{output} and X_i^{input}:

$$\ln r_i^* = \frac{1}{\alpha\beta}.\ln \mu_i^* + X_i^{output}.c_1 + X_i^{input}.c_2 + \omega_i$$

where ω_I is a random firm-level component that is potentially correlated to ε_i.

We therefore have the following three-equation system:

$$\begin{cases} \ln r_i^* = \frac{1}{\alpha\beta}.\ln \mu_i^* + X_i^{output}.c_1 + X_i^{input}.c_2 + \omega_i \\ \ln v_i^* = \alpha.\ln r_i^* + X_i^{output}.b + \epsilon_i \\ \ln x_i^* = \beta.\ln v_i^* + c_1.Sh\_pat_k + c_2.Sh\_tm_k + X_i^{appro}.c_3 + \eta_i \end{cases}$$

Replacing the unobserved expected IPR premium in the first equation by its actual counterpart, we obtain:

$$\begin{cases} \ln r_i^* = \frac{1}{\alpha\beta}.\ln x_i^* + X_i^{output}.c_1 + X_i^{input}.c_2 + \omega_i - \frac{1}{\alpha\beta}.\eta_i & \text{Eq. type 1} \\ \ln v_i^* = \alpha.\ln r_i^* + X_i^{output}.b + \epsilon_i & \text{Eq. type 2} \\ \ln x_i^* = \beta.\ln v_i^* + c_1.Sh\_pat_k + c_2.Sh\_tm_k + X_i^{appro}.c_3 + \eta_i & \text{Eq. type 3} \end{cases}$$

Two versions of this three-equation system are estimated below: the first to study the patenting behaviour of firms (and the incentive effect of patents on firms' innovative effort), and the second to further analyse the use of trademarks and their respective potential impact on innovation behaviour.

The estimation strategy explained in Annex 5.A2. relies on the following main features ("exclusion restrictions") of this last system of equations:

- Optimal innovative investments depend directly on the (expected) IPR premium and on various additional firm-level indicators, but are only indirectly affected by the efficiency of the IPR system (through the impact of this indicator on the IPR premium).
- Note also that the measure of the "incentive effect" conveyed by IPRs relies on the estimation of the parameter denoted by $(\frac{1}{\alpha\beta})$.
- Innovation outputs are directly affected by innovative investment, but hampering factors hinder innovative outputs only indirectly, through their negative impact on innovative inputs.
- Lastly, there is no direct effect of innovative inputs or hampering factors on patent and trademark use: they only affect firms' appropriation strategy through their (direct or indirect) impact on innovation outputs.

It is also worth noticing that the error terms of all equations are generically correlated.

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ANNEX 5.A2

Empirical Strategy

From latent to observable variables

The empirical counterparts of the variables introduced in the "theoretical" model are defined by the following relationships:

Innovative inputs:

$$\breve{r}_i^* = \begin{cases} 1 & \text{if } \ln r_i^* > 0 \ (\leftrightarrow r_i^* > 1) \\ 0 & \text{otherwise} \end{cases}$$

Innovative outputs:

$$\breve{v}_i^* = \begin{cases} 1 & \text{if } \ln v_i^* > 0 \ (\leftrightarrow v_i^* > 1) \\ 0 & \text{otherwise} \end{cases}$$

Patenting indicator:

$$\breve{x}_i^{*P} = \begin{cases} 1 & \text{if } \ln v_i^* > 0 \text{ and } x_i^{*P} > 1 \\ 0 & \text{otherwise} \end{cases}$$

This empirical patenting dummy leads to a "double hurdle" model since:

- Only innovations that meet the novelty requirement are patentable.
- Firms only apply for a patent when the net patent premium exceeds one (*i.e.* if patenting is profitable).

Trademark indicator:

$$\breve{x}_i^{*TM} = \begin{cases} 1 & \text{if } x_i^{*TM} > 1 \\ 0 & \text{otherwise} \end{cases}$$

The main difference with the patenting indicator lies in the fact that there is no novelty requirement in the case of trademarks.

Estimation method

The estimation of the previous system of equations is performed in two steps:

- In a first step, the "reduced form" of the model is estimated (all endogenous variables against all exogenous variables). At this stage, we account for the various selections affecting the empirical limited dependent variables (dummy variables) under Gaussian assumptions.
- In a second step, the structural parameters are retrieved using a minimum distance estimator (Gouriéroux *et al.*, 1985) relying on the "exclusion restrictions" pointed out in the theoretical framework.

An interesting feature of this estimation strategy is that the statistical validity of the exclusion restrictions (and the implied validity of the instrumental variables used in each equation) can be tested with a standard Sargan over-identification statistic. A complete exposition can be found in the appendices of Duguet and Lelarge (2006).

In the setting presented here, first-step estimates are obtained by standard probit maximum likelihood estimation of each equation in the case of trademarks. In the case of patents, the fact that the patenting dummy is censored by the innovation indicator is taken into account. Therefore, the estimation of the last two equations (innovative output and IPR strategy) has to be performed jointly, using a "Heckman Probit" estimator.*

The overall structure of the final model is summarised in Table 5.A2.1.

Computation of marginal effects

Lastly, computations of marginal effects are provided in order to have a more precise quantitative assessment of the incentive effects conveyed by IPRs. This step is particularly important since the empirical model is estimated on many binary variables using latent index models. Therefore, the coefficients estimated directly do not have any straightforward economic interpretation.

Marginal effects are computed at the sample means (see Annex 5.A3 below) and are interpreted as the increase in percentage points of the probability for the "average firm" to be involved in R&D activities implied by a

* The probability to apply for a patent can be written as follows:

$$\underbrace{\mathrm{P}\left(\breve{x}_i^{*P} = 1\right)}_{\text{estimates for IPR eq.}} = \underbrace{\mathrm{P}\left(x_i^{*P} = 1 \mid \breve{v}_i^{*} = 1\right)}_{\text{fonc. IPR eq.'s estimates}} . \underbrace{\mathrm{P}\left(\breve{v}_i^{*} = 1\right)}_{\text{estimates for Innov. Output eq.}}$$

Both terms involve the standard Gaussian cumulative distribution function only.

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one percentage point increase of the indicator of patent effectiveness. This can be generically written as:

$$\widehat{ME}(\bar{x}) = \Phi\big((\bar{x} + \Delta_x).\hat{\gamma}\big) - \Phi(\bar{x}.\hat{\gamma})$$

Standard deviations are computed using a delta-method.

Table 5.A2.1. **Structure of the estimated empirical model**

Patents			Dependent variable	Trademarks		
Innovative input decision *Eq. type 1*	Innovation output *Eq. type 2*	IPR use *Eq. type 3*		Innovative input decision *Eq. type 1*	Innovation output *Eq. type 2*	IPR use *Eq. type 3*
	◆		Innovative input		◆	
		◆	Innovative output			◆
◆			IPR premium	◆		
			Appropriation indicators:			
		◆	Patent effectiveness indicator	◆		◆
◆		◆	TM effectiveness indicator			◆
			Innovation hampering factors *(ref. none)*:			
◆			Cost hampering factors	◆		
			Knowledge hampering factors			
◆			Market hampering factors	◆		
◆			Other hampering factors	◆		
			Other (lagged) controls:			
◆	◆	◆	Size (in employment)	◆	◆	◆
◆	◆	◆	Affiliate of an enterprise group	◆	◆	◆
◆		◆	International markets	◆		◆
0/1	0/1	0/1, censored	**Type of limited dependent variable**	0/1	0/1	0/1
Probit	"Heckman Probit"		**First-step estimation method**	Probit	Probit	Probit

ANNEX 5.A3

Data and Variable Definitions

Data sources

The data used are from the last waves of innovation surveys launched in each country. For EU countries, these surveys are part of the Community Innovation Surveys supervised by Eurostat and using the standards defined in the 2nd edition of the *Oslo Manual* (1997). In Brazil, the national innovation survey also relies on these internationally harmonised standards, so that the questionnaire is very close to the European version or at least, not less comparable than the various European versions of the CIS questionnaires themselves.

In all countries, data refer to the 2002-04 period (as EU CIS4 data), except for Austria, where CIS3 data referring to the previous 1998-2000 period were used.

Although the national specificities created a number of difficulties which are explained below, the harmonised national data make it possible to define:

- A common scope of analysis in terms of *time period* (2002-04), *size classes* (firms having more than 10 employees) and *industry coverage*, although national specificities on these points, largely due to differences in industry structure, still imply care when interpreting the results.[1]
- Highly comparable innovation indicators and control variables.

Industry coverage

For reasons of homogeneity, the empirical analysis is restricted to the Eurostat "core" industries, with further exclusion of wholesale trade industries (NACE 51) and financial intermediation industries (NACE 65 to 67), because the previous representation of firms' behaviour was too schematic to fit the economic functioning of these sectors.

The final complete sample thus includes the following sectors:

- Mining and quarrying (NACE 10-14).

- Manufacturing (NACE 15-37).
- Electricity, gas and water supply (NACE 40-41).
- Transport, storage and communication (NACE 60-64).
- Computer and related activities (NACE 72).
- Architectural and engineering activities (NACE 74.2).
- Technical testing and analysis (NACE 74.3).

Furthermore, sensibility analysis is performed by running the same empirical model on various sub-samples defined in the following way:

- The "manufacturing" sub-sample is restricted to NACE 15 to 37.
- The "services" sub-sample is restricted to NACE 72, 74.2 and 74.3, except for Germany, which also includes Transport, storage and communication.
- *This definition also implies that the "services" industries considered here are particularly "high-technology" business services*.
- "Small and medium-sized enterprises" are defined as firms having fewer than 250 employees.

Note that the independence criterion of the EU definition is not taken into account.[2]

This harmonised industry scope is more or less adequate depending on the country considered.[3] In Norway, for example, because of the importance of oil-drilling activities, a large share of the patenting population of firms belongs to NACE 11.2 (Service Activities Incidental to Oil and Gas Extraction) and is thus excluded from the sub-sample analysis (services *vs.* manufacturing). An additional 10% of Norwegian patenting firms belong to NACE 51 (Wholesale trade) which is therefore excluded from the empirical analysis.

Moreover, despite these attempts at harmonising the scope of analysis in the eight participating countries, large discrepancies persist in terms of sample sizes, owing to national specificities in terms of industry structure or of the sampling schemes chosen for the various national versions of the innovation survey[4].

The consequences of these national differences are as follows:

- For descriptive statistics, the national sampling weights were used. Therefore, the figures that are reported are a compound indicator of both the specific economic behaviour of firms in each country considered (*i.e.* the "true" underlying economic models in each relevant sub-population of firms[5]), and its industry structure (*i.e.* the "weight" of each of the relevant sub-population of firms in each economy considered).

The main advantage of the descriptive statistics analysis is that these synthetic indicators enable comparisons of each country with another on the

Table 5.A3.1. **Synthesis of the composition of the eight national samples**

	Full sample	Manufacturing industries	SMEs in manufacturing industries	Service industries
Austria (CIS3)	576	391	281	–
Belgium	1 846	1 323	–	236
Brazil	10 624	10 377	8 061	–
Denmark	1 150	768	–	–
Finland	1 918	1 277	–	218
France	9 196	6 718	5 058	610
Germany	2 470	1 876	1 355	594
Norway	3 096	1 784	1 659	–

CIS4 or national innovation survey relating to the 2002-04 period except when explicitly mentioned (Austria, 1998-2000).

StatLink http://dx.doi.org/10.1787/547027065718

basis of a single index, or even more convincingly, an analysis of the change over time of each national indicator. The main limitation of this simple approach is that differences among countries cannot be directly interpreted. In particular it is impossible to assess the relative contributions of the two previously described components (behaviour and industry structure) in explaining these differences.

- In the case of regressions, the initial choice was not to use the sampling weights, mainly because it was initially suggested, and still planned (although not yet done), to match the innovation survey data with complementary firm-level datasets. This process would unavoidably imply the loss of at least a few observations, which would also imply that the initial CIS sampling weights would no longer be valid. Correcting them requires precise knowledge of the initial sampling scheme, information which is almost never available.[6]

Assuming that the "structural" model is correctly specified and, more precisely, that the true underlying parameters are common to all firms included in the estimation sample, the cost of running unweighted regressions is not very high for the estimation of the coefficients. Indeed, it does not imply any bias, but only a slower statistical convergence of the estimates, and a larger standard deviation, especially in the case of small samples.

The main problem lies rather in the computation and interpretation of marginal effects,[7] and more specifically in the choice of the point at which these marginal effects are computed. The current simple choice is to follow common practice (*e.g.* STATA built-in routines) and to compute them at the sample unweighted mean. This choice is not particularly adequate, since these simple averages are in no way economically interpretable. A better choice would have been to use the available weights in order to get correct country-level averages that synthesise their industry structure. Another solution would have been to choose a common benchmark for all participating countries in order to get another "pure" indicator of firms' behaviour.

Innovation indicators and firm-level control variables

The empirical analysis relies on the following indicators:

- **IPR indicators:** The patent variable indicates whether the firm considered had applied for at least one patent over the 2002-04 period (1998-2000 for Austria). In the case of trademarks, the dummy variable indicates whether the firm had registered (at least) a new trademark over the same observation period.
- **Innovation output indicator:** The innovation output indicator was constructed using the product (good or service, new to the firm or to its market) and process innovation variables. Therefore, innovation in the regression framework is defined as the introduction of at least one product (in a broad sense) or process innovation over the observation period.
- **Innovation input indicators:** Three different innovative input indicators are introduced. The first is equal to one when firms report "innovative expenditures" in the broadest sense, *i.e.* including intramural and extramural R&D,[8] "acquisition of advanced machinery, equipment and computer hardware or software to produce new or significantly improved products and processes" or "acquisition of other external knowledge". Alternative specifications of the empirical model introduce a dummy variable denoting either that the firm was involved in internal R&D activities over the observation period, or that the firm was *not* involved in internal R&D activities, but that it strictly had nevertheless positive innovative expenditures.
- **Hampering factors:**[9] The innovation input equation contains the same indicators of hampering factors as in Chapter 3. The "cost" indicator summarises whether lack of funds within the enterprise or group, lack of external finance or excessive innovation costs hampered the firm's innovation activity. The "knowledge" variable indicates whether the firm experienced the following hampering factors: lack of qualified personnel, lack of information on technology, lack of information on markets, or difficulty in finding co-operation partners for innovation. The "market" variable indicates whether the firm's market was dominated by well-established enterprises or whether demand for innovative goods or services was perceived as uncertain, thus increasing the risk associated with innovation projects. Finally, the "other reasons not to innovate"

variable equals one when the firm reports that there was no need to innovate owing to prior innovations or to lack of demand for innovations.

- **Firm-level controls:** The few firm-level indicators included in the CIS questionnaires and available for all (innovative or non-innovative) firms are also included. Among these are: (logarithm of) firm level employment (size control), group ownership, and international market scope ("Other European Union [EU] countries, EFTA, or EU candidate countries" or "All other countries" as opposed to "local, regional" or "national" markets).[10]

Indicator of IPR effectiveness

The last variables needed in the regression framework are indicators of IPR effectiveness. They are at the core of the identification strategy.

There is a large body of literature analysing firms' perception of patent effectiveness. For example, Levin *et al.* (1987) use the Yale Survey[11] and show that lead time, secrecy, learning advantages, and sales and service efforts are typically more important as means of appropriation than patents, except in a few sectors, such as pharmaceuticals. Cohen *et al.* (2000) also found that patents were the least important means of appropriability, except for medical equipment and drugs, with secrecy and lead time at the top, in a sample of 1 478 large R&D labs interviewed in the US manufacturing sector in 1994 (Carnegie Mellon Survey).[12] The study by Arora *et al.* (2008) relied on the same data and therefore also benefited from a direct indicator of patent effectiveness.[13]

An important limitation of the CIS data is that no such firm-level direct indicator of IPR effectiveness is available. This study therefore relied on an industry-level proxy of IPR effectiveness, namely the (four- or three-digit) industry-level share of patenting (or trademark-using) firms. This choice was motivated by the fact that Arora *et al.* (2008) found that higher patent effectiveness scores were characterised by higher patent premiums, and therefore more frequent patent applications.

A potential weakness of this indicator is that it is at the same time a measure of the innovative performance of the industry considered and of the firms' reliance on the patent system. A theoretically preferable proxy was also tested, the industry share of IPR-using firms among innovative firms, but the estimation of this ratio was too noisy[14] to serve as a powerful instrumental variable in the regression framework.

However, a potential strength of this industry-level indicator is that endogeneity problems are less likely than for firm-level assessment. It could indeed be argued that innovative or patenting firms are actually more likely to be able to assess the IPR system because of their experience. This would cause firm-level assessment of IPR to be clearly endogenous in all three estimated equations.

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Table 5.A3.2. **Full sample descriptive statistics**

Sample means	Austria	Belgium	France	Germany	Norway
Number of observations	576	1 928	9 196	2 470	2 996
Sample average of firm level variables					
Share of firms involved in innovative activities	50.52	45.28	42.93	68.34	47.30
Share of product or process innovators	50.02	49.48	49.26	72.55	41.86
Share of patenting firms	39.61	8.92	17.92	29.19	10.11
Log of employment *(Median of employment)*	4.39 *(64)*	3.86 (35)	4.41 (62)	4.48 (70)	3.72 (34)
Share of firms belonging to a larger group	42.53	50.05	58.75	62.59	54.67
Share of exporting firms	66.49	71.58	62.05	68.70	47.33
Share of firms experiencing cost-hampering factors	40.45	26.71	36.35	43.08	19.86
Share of firms experiencing (lack of) knowledge-hampering factors	24.31	18.98	21.12	13.32	8.14
Share of firms experiencing market-hampering factors	–	21.27	27.25	16.36	10.51
Share of firms experiencing other hampering factors	6.60	14.99	17.45	12.63	5.41
Sample average of industry level variables					
Industry share of patenting firms	15.82	7.81	13.76	28.21	10.02
Industry share of TM-using firms	17.50	9.99	22.62	20.99	11.62

Note: All industry level variables are defined at the four-digit level, except for Austria and Norway (at the three-digit level).

Source: Respective national innovation surveys, 2002-04 (except Austria, 1998-2000).

StatLink *http://dx.doi.org/10.1787/547100088562*

Notes

1. See below for a discussion of how this specific point could be further improved.
2. Another choice would have been to exclude all firms belonging to a group, but this is not strictly the EU definition either. The EU definition of SMEs corresponds to Commission Recommendation of 6 May 2003, OJ L 124 of 20.5.2003, p. 36. It is available on-line at *http://europa.eu/eur-lex/pri/en/oj/dat/2003/l_124/l_12420030520en00360041.pdf*.
3. In other words, a highly harmonised analysis does not always provide relevant insight for each country considered separately from the others.
4. However, Eurostat and the EU regulation on STI statistics impose a precise level of accuracy for the delivery of STI statistics, and propose a sampling strategy (size classes and industry two-digit level stratifications) in order to achieve this requirement.
5. These "relevant sub-populations of firms" correspond to sets of enterprises that are characterised by homogenous economic behaviour. Ideally, the sub-sample empirical analysis, where one specific empirical model is estimated on particular sets of enterprises, should allow for recovering these "relevant sub-populations".
6. Very few countries, if any, apply the simple stratified sampling scheme suggested by Eurostat directly without any modification. A second practical reason not to use the sampling weights in the regression analysis was that it would have increased the complexity of the estimation programmes, which had to be very quickly available owing to the expected project deadline. For this work, most of the routines were not directly built-in in STATA and had to be written manually.

7. Differences in structural estimated coefficients can be interpreted in terms of differences between firms' economic behaviour, whereas differences in marginal effects result from both "structural" economic behaviour and industry structure.

8. Intramural R&D is defined as "creative work undertaken within your enterprise to increase the stock of knowledge and its use to devise new and improved products and processes (including software development)".

   Extramural R&D is defined as "same activities as above, but performed by other companies (including other enterprises within your group) or by public or private research organisations and purchased by your enterprise".

   Finally, "acquisition of other external knowledge" is defined as "purchase or licensing of patents and non-patented inventions, know-how, and other types of knowledge from other enterprises or organisations".

9. In the Austrian case, the following CIS3 equivalents are used:
   - For costs factors: the CIS3 "lack of funds" item was used.
   - For knowledge factors: no variable about the difficulties in finding co-operation partners for innovation was available.
   - For market factors: no equivalent proxy was found.
   - For "other reasons not to innovate": only non-innovating firms can report that there was no need to innovate owing to prior innovation. Furthermore, the item corresponding to "no demand for innovations" had a different wording in CIS3 ("lack of customer responsiveness to new goods").

10. For Austria, the international market scope indicator corresponds to positive reported exports, or "international market" reported as the firm's "most significant market".

11. Their sample consisted of 650 large US manufacturing firms in the early 1980s.

12. Other common features of the results obtained with both the Yale and Carnegie Mellon surveys were that:
    - Firms put relatively greater emphasis on secrecy for process innovations than for product innovations (processes are less subject to public scrutiny).
    - Patents were reported to be less effective for processes than for products (patent infringements for processes are more difficult to detect).

13. This is the same in Duguet and Lelarge (2006).

14. This industry shares were estimated from the innovation survey data using the sampling weights. When the level of accuracy was high enough (*i.e.* sample size large enough), these industry level controls were computed at the four-digit level, and at the three-digit level otherwise. It should be noted that the accuracy of "simple" industry-level indicators (*e.g.* proportions as in the case of "share of patenting firms") is much higher than for more complex indicators. As the share of IPR-using firms among innovative firms is a ratio of two estimated quantities, even when both the numerator and denominators are rather precisely estimated, the accuracy of their ratio drops dramatically.

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ANNEX 5.A4

Full Set of Estimation Results

Table 5.A4.1. **Estimation of the innovative input equation**

Broadest indicator of innovative expenditures, full sample

Coefficient (standard deviation)	Innovative expenditures (Equation type 1)							
	Austria (1)	Belgium (2)	Brazil (3)	Denmark (4)	Finland (5)	France (6)	Germany (7)	Norway (8)
Patents	0.260***	0.700***	0.214**	1.085***	0.118***	0.380***	0.135**	0.177***
	(0.074)	(0.166)	(0.065)	(0.237)	(0.034)	(0.034)	(0.050)	(0.043)
Industry shareof TM using firms	0.906***	0.203	0.235	1.040***	0.618***	0.438***	0.764***	1.705***
	(0.216)	(0.230)	(0.219)	(0.275)	(0.152)	(0.055)	(0.169)	(0.173)
Size (log employment)	0.224***	–	0.223***	0.288***	0.168***	0.142**	0.084**	0.234***
	(0.071)		(0.022)	(0.081)	(0.045)	(0.019)	(0.029)	(0.030)
Group dummy	0.234	0.247**	0.214***	0.217	–0.179*	0.066	0.094	–0.086
	(0.166)	(0.096)	(0.043)	(0.145)	(0.107)	(0.043)	(0.063)	(0.060)
Foreign market	0.259*	–	0.107***	0.366	0.324***	0.356***	0.335***	0.544***
	(0.137)		(0.032)	(0.272)	(0.079)	(0.033)	(0.046)	(0.045)
Hampering factor: costs	–0.223***	0.229***	0.271***	0.811***	0.036	0.153***	0.222***	0.513***
	(0.081)	(0.046)	(0.027)	(0.137)	(0.048)	(0.013)	(0.032)	(0.039)
Hampering factor: knowledge	0.005	0.229***	0.443***	0.792***	0.233***	0.176***	0.056	0.253***
	(0.060)	(0.042)	(0.048)	(0.132)	(0.061)	(0.015)	(0.043)	(0.044)
Hampering factor: market	–	–0.009	0.140***	0.174**	0.137***	0.055***	–0.005	0.161***
		(0.038)	(0.022)	(0.073)	(0.051)	(0.011)	(0.040)	(0.039)
Other hampering factors	–0.166**	–1.367***	–	–0.037	–0.544***	–0.973***	–0.752***	–1.120***
	(0.079)	(0.207)		(0.073)	(0.081)	(0.053)	(0.062)	(0.097)
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ME of a 1% increase in the indus. share of patenting firms (in pp.)	0.274**	0.437**	0.352**	0.585**	0.017	0.077**	0.095	0.242***
	(0.077)	(0.172)	(0.163)	(0.211)	(0.018)	(0.033)	(0.052)	(0.062)
Sample mean of dependent var.	0.505	0.452	0.345	0.570	0.095	0.429	0.683	0.458
# Observations	576	1 846	10 624	1 150	1 918	9 196	2 470	3 096
Sargan test (DOF, p-value)	2.082	2.139	4.155	7.661	13.33	9.641	3.773	3.800
	(7, 0.955)	(9, 0.989)	(7, 0.762)	(9, 0.569)	(9, 0.148)	(9, 0.380)	(9, 0.926)	(9, 0.924)

Note: Industry dummies are at the one-digit level except for Germany (at the two-digit OECD STAN level). Industry-level variables are computed at the four-digit level, except for Austria and Norway where the aggregation level is three-digit.

* Significance at the 10% level.

** Significance at the 5% level.

*** Significance at the 1% level.

Source: Respective national innovation surveys, 2002-04 (except Austria, 1998-2000).

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Table 5.A4.2. **Estimation of the innovative input equation**

R&D expenditures, full sample

Coefficient (standard deviation)	Internal R&D expenditures (Equation type 1)							
	Austria (1)	Belgium (2)	Brazil (3)	Denmark (4)	Finland (5)	France (6)	Germany (7)	Norway (8)
Patents	0.432***	0.798***	0.354**	1.266***	0.287***	0.383***	0.215***	0.189***
	(0.109)	(0.197)	(0.108)	(0.298)	(0.047)	(0.037)	(0.062)	(0.043)
Industry shareof TM using firms	0.946***	0.499*	3.533***	0.799**	1.018***	0.412***	1.205***	1.520***
	(0.264)	(0.284)	(0.352)	(0.359)	(0.201)	(0.058)	(0.222)	(0.170)
Size (log employment)	0.159**	–	0.358***	0.336***	0.213***	0.136***	0.153***	0.197***
	(0.081)		(0.035)	(0.093)	(0.039)	(0.020)	(0.032)	(0.031)
Group dummy	0.117	0.263**	0.231***	0.352*	–0.089	0.043	0.053	–0.086
	(0.189)	(0.113)	(0.059)	(0.188)	(0.087)	(0.044)	(0.069)	(0.061)
Foreign market	0.398*	–	0.015	0.489	0.392***	0.389***	0.525***	0.569***
	(0.216)		(0.064)	(0.329)	(0.081)	(0.035)	(0.067)	(0.048)
Hampering factor: costs	0.020	0.204***	0.350***	0.802***	0.013	0.147***	0.269***	0.541***
	(0.108)	(0.058)	(0.046)	(0.164)	(0.041)	(0.013)	(0.039)	(0.043)
Hampering factor: knowledge	0.072	0.285***	0.458***	0.676***	0.278***	0.201***	0.150**	0.241***
	(0.092)	(0.054)	(0.077)	(0.151)	(0.053)	(0.016)	(0.053)	(0.044)
Hampering factor: market	–	–0.029	0.201***	0.209**	0.214***	0.079***	–0.018	0.171***
		(0.049)	(0.039)	(0.098)	(0.047)	(0.012)	(0.047)	(0.042)
Other hampering factors	–0.128	–1.410***	–	0.043	–0.854***	–0.988***	–0.900***	1.160**
	(0.163)	(0.238)		(0.101)	(0.095)	(0.053)	(0.072)	(0.112)
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ME of a 1% increase in the indus. share of patenting firms (in pp.)	0.210***	0.302*	0.079	0.427*	0.262***	0.088**	0.206**	0.264***
	(0.053)	(0.166)	(0.135)	(0.251)	(0.065)	(0.036)	(0.073)	(0.060)
Sample mean of dependent var.	0.403	0.360	0.165	0.443	0.382	0.413	0.568	0.413
# Observations	576	1 846	10 624	1 150	1 918	9 196	2 470	3 096
Sargan test (DOF, p-value)	4.036	2.992	28.6169	11.921	12.17	11.601	9.997	4.410
	(7, 0.776)	(9, 0.965)	(7, 0.000)	(9, 0.218)	(9, 0.204)	(9, 0.237)	(9, 0.351)	(9, 0.882)

Note: Industry dummies are at the one-digit level except for Germany (at the two-digit OECD STAN level). Industry-level variables are computed at the four-digit level, except for Austria and Norway where the aggregation level is three-digit.

* Significance at the 10% level.

** Significance at the 5% level.

*** Significance at the 1% level.

Source: Respective national innovation surveys, 2002-04 (except Austria, 1998-2000).

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Table 5.A4.3. **Parameters measuring the incentive effects of IPR obtained in the innovative input equation**

Broadest indicator of innovative expenditures, patents and TM, full sample

(Whole sample)		Innovative expenditures (Equation type 1)							
		Austria (1)	Belgium (2)	Brazil (3)	Denmark (4)	Finland (5)	France (6)	Germany (7)	Norway (8)
Patents	Coefficient (Std Dev.)	0.432^{***}	0.798^{***}	0.354^{**}	1.266^{***}	0.287^{***}	0.383^{***}	0.215^{***}	0.189^{***}
		(0.109)	(0.197)	(0.108)	(0.298)	(0.047)	(0.037)	(0.062)	(0.043)
	Marg. Eff. (Std Dev.)	0.210^{***}	0.302^{*}	0.079	0.427^{*}	0.262^{***}	0.088^{**}	0.206^{**}	0.264^{***}
		(0.053)	(0.166)	(0.135)	(0.251)	(0.065)	(0.036)	(0.073)	(0.060)
	Sargan Test (DOF, p-val)	4.036	2.992	28.6169	11.921	12.17	11.601	9.997	4.410
		(7, 0.776)	(9, 0.965)	(7, 0.000)	(9, 0.218)	(9, 0.204)	(9, 0.237)	(9, 0.351)	(9, 0.882)
Trademarks	Coefficient (Std Dev.)	0.275^{**}	0.029	0.622^{***}	0.162^{*}	0.143^{***}	0.100^{**}	0.179^{**}	0.414^{***}
		(0.118)	(0.064)	(0.089)	(0.087)	(0.052)	(0.037)	(0.064)	(0.081)
	Marg. Eff. (Std Dev.)	0.205^{**}	0.023	0.258^{***}	0.116	0.017	0.019	0.150^{*}	0.492^{***}
		(0.088)	(0.088)	(0.060)	(0.095)	0.023	(0.033)	(0.080)	(0.102)
	Sargan Test (DOF, p-val)	8.424	6.842	19.500	28.039	11.13	15.288	7.933	11.150
		(7, 0.297)	(9, 0.654)	(7, 0.007)	(9, 0.001)	(9, 0.267)	(9, 0.083)	(9, 0.541)	(9, 0.265)
Patents and trademarks	Coefficient (Std Dev.)	0.672^{**}	0.589^{***}	0.296^{***}	1.381^{***}	0.379^{***}	0.538^{***}	0.338^{***}	0.788^{**}
		(0.336)	(0.157)	(0.065)	(0.389)	(0.083)	(0.047)	(0.071)	(0.281)
	ME. TM (Std Dev.)	0.212^{*}	0.047^{**}	0.137^{**}	0.168^{*}	0.014	0.020^{**}	0.173^{**}	0.347^{**}
		(0.110)	(0.019)	(0.047)	(0.091)	0.012	(0.009)	(0.054)	(0.122)
	ME. PAT (Std Dev.)	0.137^{*}	0.219^{**}	0.170^{**}	0.418^{*}	n.a.	0.057^{**}	0.042^{**}	n.a.
		(0.071)	(0.091)	(0.058)	(0.228)		(0.024)	(0.013)	
	Sargan Test (DOF, p-val)	19.891	23.967	4 707.856	19.069	13.19	48.221	6.357	35.480
		(8, 0.011)	(10, 0.008)	(8, 0.000)	(10, 0.039)	(10, 0.213)	(10, 0.000)	(10, 0.784)	(10, 0.000)

Note: Industry dummies are at the one-digit level except for Germany (at the two-digit OECD STAN level). Industry-level variables are computed at the four-digit level, except for Austria and Norway where the aggregation level is three-digit.

* Significance at the 10% level.

** Significance at the 5% level.

*** Significance at the 1% level.

Source: Respective national innovation surveys, 2002/04 (except Austria, 1998/2000).

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Table 5.A4.4. **Parameters measuring the incentive effects of IPR obtained in the innovative input equation**

Broadest indicator of innovative expenditures, patents and TM, manufacturing *vs.* services

			Innovative expenditures (Equation type 1)							
			Austria (1)	Belgium (2)	Brazil (3)	Denmark (4)	Finland (5)	France (6)	Germany (7)	Norway (8)
Manufacturing industries	Patents	Coefficient	0.419[3]	0.575[3]	0.121[2]	1.088[3]	0.158[3]	0.351[3]	0.145[2]	0.403[3]
		(std dev.)	(0.105)	(0.129)	(0.046)	(0.388)	(0.061)	(0.043)	(0.054)	(0.081)
		Marg. eff.	0.304[2]	0.561[3]	0.330[2]	0.991[2]	0.035	0.202[3]	0.112[2]	0.408[3]
		(std dev.)	(0.105)	(0.131)	(0.114)	(0.505)	0.023	(0.035)	(0.052)	(0.099)
		Sargan test	1.589	1.857	2.434	8.995	12.95	7.011	4.004	4.930
		(DOF, p-val)	(7, 0.979)	(9, 0.994)	(7, 0.932)	(7, 0.253)	(9, 0.165)	(9, 0.640)	(9, 0.911)	(9, 0.840)
	Trademarks	Coefficient	–0.781	0.068	0.536[3]	0.129	0.046	0.027	0.113	0.088
		(std dev.)	(2.238)	(0.067)	(0.102)	(0.356)	(0.058)	(0.045)	(0.074)	(0.097)
		Marg. eff.	–0.401	0.086	0.380[3]	0.096	0.015	0.017	0.107	0.090
		(std dev.)	(1.599)	(0.088)	(0.066)	(0.256)	0.032	(0.040)	(0.087)	(0.121)
		Sargan test	32.247	2.979	14.121	32.048	9.34	10.328	9.107	9.500
		(DOF, p-val)	(7, 0.000)	(9, 0.965)	(7, 0.049)	(7, 0.000)	(9, 0.407)	(9, 0.325)	(9, 0.427)	(9, 0.392)
Service industries	Patents	Coefficient	n.a.	n.a.	n.a.	n.a.	0.666[2]	1.375[2]	0.408[3]	n.a.
		(std dev.)					(0.312)	(0.671)	(0.125)	
		Marg. eff.	n.a.	n.a.	n.a.	n.a.	0.230	0.669	3.029[2]	n.a.
		(std dev.)					0.148	(0.532)	(1.429)	
		Sargan test	n.a.	n.a.	n.a.	n.a.	125.97	0.828	6.150	n.a.
		(DOF, p-val)					(9, 0.000)	(5, 0.975)	(9, 0.725)	
	Trademarks	Coefficient	n.a.	–0.514	n.a.	n.a.	–0.739	–0.098	0.194	n.a.
		(std dev.)		(0.862)			(0.501)	(0.361)	(1.521)	
		Marg. eff.	n.a.	–0.974	n.a.	n.a.	–0.353	–0.061	0.221	n.a.
		(std dev.)		(1.613)			0.294	(0.370)	(2.642)	
		Sargan test	n.a.	4.175	n.a.	n.a.	14.01	4.176	844.390	n.a.
		(DOF, p-val)		(9, 0.524)			(9, 0.016)	(5, 0.524)	(9, 0.000)	

Note: Industry dummies are at the two-digit OECD STAN level except for services in Germany (industry dummies at the one-digit level). Industry level variables are computed at the four-digit level, except for Austria and Norway where the aggregation level is three-digit.

* Significance at the 10% level.

** Significance at the 5% level.

*** Significance at the 1% level.

Source: Respective national innovation surveys, 2002-04 (except Austria, 1998-2000).

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Table 5.A4.5. **Parameters measuring the incentive effects of IPRs obtained in the innovative input equation**

Broadest indicator of innovative expenditures, patents and TM, manufacturing industries

(Manufacturing industries)			Innovative expenditures (Equation type 1)							
			Austria (1)	Belgium (2)	Brazil (3)	Denmark (4)	Finland (5)	France (6)	Germany (7)	Norway (8)
All manufacturing firms	Patents	Coefficient (std dev.)	0.419*** (0.105)	0.575*** (0.129)	0.121** (0.046)	1.088*** (0.388)	0.158*** (0.061)	0.351*** (0.043)	0.145** (0.054)	0.403*** (0.081)
		Marg. eff. (std dev.)	0.304** (0.105)	0.561*** (0.131)	0.330** (0.114)	0.991** (0.505)	0.035 0.023	0.202*** (0.035)	0.112** (0.052)	0.408*** (0.099)
		Sargan test (DOF, p-val)	1.589 (7, 0.979)	1.857 (9, 0.994)	2.434 (7, 0.932)	8.995 (7, 0.253)	12.95 (9, 0.165)	7.011 (9, 0.640)	4.004 (9, 0.911)	4.930 (9, 0.840)
	Trademarks	Coefficient (std dev.)	–0.781 (2.238)	0.068 (0.067)	0.536*** (0.102)	0.129 (0.356)	0.046 (0.058)	0.027 (0.045)	0.113 (0.074)	0.088 (0.097)
		Marg. eff. (std dev.)	–0.401 (1.599)	0.086 (0.088)	0.380*** (0.066)	0.096 (0.256)	0.015 0.032	0.017 (0.040)	0.107 (0.087)	0.090 (0.121)
		Sargan test (DOF, p-val)	32.247 (7, 0.000)	2.979 (9, 0.965)	14.121 (7, 0.049)	32.048 (7, 0.000)	9.34 (9, 0.407)	10.328 (9, 0.325)	9.107 (9, 0.427)	9.500 (9, 0.392)
Manufacturing SMEs	Patents	Coefficient (std dev.)	1.114*** (0.370)	n.a.	0.123 (0.225)	n.a.	n.a.	0.362*** (0.082)	0.085 (0.065)	0.377*** (0.074)
		Marg. eff. (std dev.)	0.506* (0.304)	n.a.	0.101 (0.154)	n.a.	n.a.	0.383*** (0.057)	0.058 (0.061)	0.388*** (0.100)
		Sargan test (DOF, p-val)	20.450 (7, 0.005)	n.a.	0.396 (3, 0.941)	n.a.	n.a.	5.144 (9, 0.822)	3.448 (9, 0.944)	5.510 (9, 0.788)
	Trademarks	Coefficient (std dev.)	0.106 (0.102)	n.a.	0.497*** (0.107)	n.a.	n.a.	0.037 (0.048)	0.155* (0.080)	0.145 (0.092)
		Marg. eff. (std dev.)	0.064 (0.114)	n.a.	0.378*** (0.068)	n.a.	n.a.	0.035 (0.043)	0.145 (0.101)	0.145 (0.121)
		Sargan test (DOF, p-val)	5.461 (7, 0.604)	n.a.	1.846 (3, 0.605)	n.a.	n.a.	7.633 (9, 0.571)	8.507 (9, 0.484)	6.360 (9, 0.704)

Note: Industry dummies are at the two-digit OECD STAN level, except for Austria and Denmark (at the one-digit level). Industry-level variables are computed at the four-digit level, except in the case of Austria and Norway where the aggregation level is three-digit.

* Significance at the 10% level.
** Significance at the 5% level.
*** Significance at the 1% level.

Source: Respective national innovation surveys, 2002-04 (except Austria, 1998-2000).

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Innovation in Firms: A Microeconomic Perspective

ANNEX A

Methodology

This section includes methodological notes and metadata concerning the innovation surveys and the definitions used in this project. In particular, it was decided to use CIS 4 as the "benchmark" in terms of sectoral coverage and firm size classes in order to ensure a reasonable degree of cross-country comparability. Known deviations are noted in the country notes section.

The Fourth Community Innovation Survey (CIS 4)

Methodological recommendations [excerpts]

(In accordance with Section 7 of the Annex to the Commission Regulation on innovation statistics No. 1450/2004)

1. Target population

The target population of the CIS 4 shall be the total population of enterprises related to market activities (NACE activities C to K).

1.1. NACE

Core coverage

In accordance with Section 2 of the Annex of the Commission Regulation on innovation statistics, the following industries shall be included in the core target population of the CIS 4:

- mining and quarrying (NACE 10-14);
- manufacturing (NACE 15-37);
- electricity, gas and water supply (NACE 40-41);
- wholesale trade (NACE 51);
- transport, storage and communication (NACE 60-64);
- financial intermediation (NACE 65-67);

- computer and related activities (NACE 72);
- architectural and engineering activities (NACE 74.2);
- technical testing and analysis (NACE 74.3).

Additional coverage, in order of descending priority (to be done on a voluntary basis):

- research and development (NACE 73);
- construction (NACE 45);
- motor trade (NACE 50);
- retail trade (NACE 52);
- legal, accounting, market research, consultancy and management services (NACE 74.1);
- advertising (NACE 74.4);
- labour recruitment and provision of personnel (NACE 74.5);
- investigation and security activities (NACE 74.6);
- industrial cleaning services (NACE 74.7);
- miscellaneous business activities n.e.c. (NACE 74.8);
- real estate activities (NACE 70);
- hotels and restaurants (NACE 55);
- renting of machinery and equipment without an operator (NACE 71).

These economic activities should be regarded as "non-core" and do not necessarily have to meet the same quality requirements as for the core coverage, *e.g.* for item and unit non-response (*i.e.* a non-response survey does not have to be carried out in respect of these NACE industries) or the required level of precision.

1.2. Size-classes

It is recommended that **all** enterprises be included in the target population. However, the minimum coverage shall be all enterprises with **10 employees or more**.

1.3. Statistical units

The main statistical unit for CIS 4 shall be the enterprise, as defined in the Council Regulation 696/1993 on statistical units or as defined in the national statistical business register. EU Regulation 2186/1993 requires that member States set up and maintain a register of enterprises, as well as associated legal units and local units.

In the Council Regulation 696/1993.[1] the enterprise is defined as "the smallest combination of legal units that is an organisational unit producing goods or services, which benefits from a certain degree of autonomy in decision making, especially for the allocation of its current resources. It may carry out one or more activities at one or more locations and it may be a combination of legal units, one legal unit or part of a legal unit." In general, innovation activities and decisions usually take place at the enterprise level, which leads to the enterprise being used as the statistical unit. If the use of the enterprise as a statistical unit is not feasible, other units such as the division of the enterprise group, the kind of activity unit (KAU), the local kind of activity unit (LKAU) or the enterprise group may be used instead.

1.4. The observation period

The observation period to be covered by the survey shall be 2002-04 inclusive, *i.e.* the three-year period from the beginning of 2002 to the end of 2004. The reference period of the CIS 4 shall be the year 2004.

2. Survey methodology

2.1. Sampling frame

The **official, up-to-date, statistical business register**[2] **of the country** should be used.

2.2. Census or sample survey

Data should be collected through a census, sample survey or a combination of both.

2.3. Stratification

The target population shall be broken down into similar structured subgroups or strata (which should be as homogeneous as possible and form mutually exclusive groups). Appropriate stratification will normally give results with smaller sampling errors than a non-stratified sample of the same size and will make it possible to ensure that there are enough units in the respective domains[3] to produce results of acceptable quality.

The stratification variables to be used for the CIS 4, *i.e.* the characteristics used to break down the sample into similarly structured groups, should be:

- The economic activities (in accordance with NACE).[4]

In accordance with the requirements of Section 5, paragraph 2 of the Annex of the Commission Regulation on innovation statistics, stratification by NACE should be done at least at two-digit (division) level, except for NACE 74. Here the three-digit sections NACE 74.2 and 74.3 should be treated as separate

NACE categories while NACE 74.1 and 74.4 to 74.8 should be treated as a single NACE category:

- Enterprise size according to the number of employees.[5]

The size-classes used should at least be the following:

- 0-9 employees;
- 10-49 employees;
- 50-249 employees;
- 250+ employees.

More detailed breakdown by size classes may also be used, but, whatever size-classes are chosen, they should fit into the above size groups:

- Regional aspects: In accordance with Section 7, paragraph 2 of the Annex of the Commission Regulation on innovation statistics, the methodology will include regional aspects. Therefore, the regional allocation of the sample shall be taken into consideration when sampling.

2.4. Sample size

There is no minimum sample size needed, as long as the sample size chosen will meet the precision levels required (see Section 4.6). However, if a particular stratum has less than 6 enterprises, then all the enterprises in this stratum should be selected for the survey.

The expected response rate should be borne in mind, *i.e.* the sample size should take into account the non-response rates experienced in CIS 3 and compensate accordingly. Finally, there should be no replacement of deleted or not-relevant units. The sample size should be large enough to compensate for any of these types of units.

2.5. Sample selection and allocation

The selection of the sample should be based on random sampling techniques, with known selection probabilities, applied to strata. It is recommended to use simple random sampling without replacement within each stratum.

Different allocation schemes can be used, depending on the structure of the population. It is recommended to use optimum allocation, taking into account the need to "compromise" the allocation, in order to obtain the required levels of precision for all indicators and domains.

The variance in each stratum to be used for sample selection can be based on previous CIS 3 results, if there is reliable information available. If not, one can either use the CIS 3 national average or assume that a problem stratum will be close to a stratum for which reliable results are available. If new sectors of the economy are added for the CIS 4, one can either use the national average for the CIS 3 or assume that the new sector will be close to a sector that has been sampled previously.

Member States are free to use whatever sampling methods they prefer, as long as the quality thresholds for the results are achieved. However, in accordance with Section 7, paragraph 4 of the Annex of the Commission Regulation on innovation statistics, Eurostat should be informed in advance of the method of sampling and allocation scheme being used.

3. Collecting and processing of data

3.1. SAS programs for processing the data

The SAS programs which were used for CIS 3 will be updated for use for the CIS 4 and provided free (along with good user documentation) to those member States that want them.[6] There will be some user support for these programs once the CIS 4 starts. The program rules will also be provided.

3.2. Survey questionnaire

In accordance with Section 7, paragraph 1 of the Annex of the Commission Regulation on innovation statistics, the CIS 4 will be based on a harmonised survey questionnaire for all NACE sectors. The questionnaire shall cover the main themes listed in the *Oslo Manual*. This harmonised questionnaire shall be used in all national innovation surveys.

3.3. Data collection

The CIS 4, like the previous innovation surveys, shall be mainly based on mail surveys. These provide a relatively inexpensive means of gathering information from a widely dispersed sample. Other data collection methods, such as internet surveying or personal interviews may also be used, as long as data quality is assured.

Member States may combine the CIS 4 questionnaire with other surveys, as long as this does **not negatively affect the quality of the output of the CIS 4.**

3.4. Data editing

Throughout the processing cycle, there should be a systematic and sustained follow-up with the responding enterprises to make sure that the data provided is of good quality and passes all edit checks. Data quality checks have to be done at micro- and macro-level by member States before the results are finally processed and sent to Eurostat. The checking routines of the SAS programs will be delivered to the member States.

Of course, the SAS edits can be adapted for other computer systems and member States can also develop their own checks and edits, *i.e.* the CIS 4 data could be linked with other national data or be compared with R&D survey data.

4. Data quality

4.1. Response rates

The units that do not respond to the CIS 4 survey questionnaire may have different characteristics than those that do respond. Therefore, all efforts shall be made to minimise unit (and item) non-response.

The recommended technique to elicit response is to send at least two reminder letters to the sampled enterprise. These should be sent out within an acceptable period after the sending of the original questionnaire. In some cases, timely telephone reminders may also prove useful.

4.2. Unit non-response and non-response survey

If non-respondents, as an unweighted percentage of all relevant enterprises in the sampling frame, exceed 30%, then a simple random sample of **at least** 10% of the non-respondents (excluding non-relevant enterprises) should be selected. The form to be used for this non-response survey is to be specified. It shall include some of the questions of the standard CIS 4 questionnaire, in order to determine if the non-respondent is an innovator or not. If non-response is not equally distributed across strata, member States may use a stratified non-response sample.

The non-response survey should have a very high response rate. This non-response survey should be carried out for at least the core target NACE population.

If the results from the non-response analysis indicate that there is a difference between respondents and non-respondents for a certain type of enterprise, this information should be used when calculating the weighting factors (see Section 4.5). Member States shall describe how the information from the non-response survey has been used to reduce eventual bias in the estimates.

4.3. Item non-response

Item non-response should be kept at a minimum by asking the enterprises for the additional information needed. Item non-response for general variables on the enterprises should not exist, as this information should be available in the business register or from other sources. Some respondents may return questionnaires that have some items filled in, but these cases should only be counted as respondents if they are usable in the processing stage.

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Before carrying out automatic imputation, member States should, as far as possible, make use of administrative, historical (*e.g.* the CIS 3 survey) or other available data sources such as R&D surveys.

4.4. *Imputation*

To correct for item non-response (after every attempt is made to get the information from the enterprises concerned) imputations shall be done. Imputed values should be flagged as this enables proper non-response analysis to be done.

The SAS software package (see Section 3.1) will impute metric (or measurement) variables separately from ordinal (or ranking) variables, as was done for the CIS 3.

- Metric variables: A weighted mean of each metric variable, by NACE and size class, is calculated and applied as a ratio to the enterprises with the missing values, within the stratum concerned.
- Ordinal, nominal and percentage variables.

This imputation shall be done after the metric estimation. The technique used is nearest neighbour hot decking using entropy.[7] This technique will use data from clean records (a donor with a record not violating any error check), in order to copy the missing data. The donors are chosen in such a way that the distance between the donor and recipient be minimised.[8]

Member States may also use other reliable methods of imputation, as long as the quality of results is at least identical.

4.5. *Weighting and calibration*

The survey results should be weighted in order to adjust for the sampling design and for unit non-response to produce valid results for the target population. Additional auxiliary information should also be incorporated, if it is considered that this will enhance the accuracy of the estimates.

The basic method for adjusting for different probabilities of selection used in the sampling process is to use the inverse of the sampling fraction. *i.e.* using the number of enterprises or employees. This would be based on the figure Nh/nh where Nh is the total number of enterprises/employees in stratum h of the population and nh is the number of enterprises/employees in the **realised** sample in stratum h of the population, assuming that each unit in the stratum had the same inclusion probability. This will automatically adjust the sample weights of the respondents to compensate for unit non-response.

However, if a non-response analysis is carried out (and the results indicate that there is a difference between respondents and non-respondents), then the results of the non-response analysis should also be used when calculating the final weighting factors. One approach is to divide each stratum into a number of response homogeneity groups with (assumed) equal response probabilities within groups. A second approach could be to use auxiliary information at the estimation stage for reducing the non-response bias.

If the frame contains auxiliary information about the sampling units, *i.e.* variables that are correlated with at least some of the measurement variables of interest, this information should be used to improve the estimation further.[9] In general, the variables to use for calibration are turnover and the number of enterprises, both by NACE and size classes but others can also be used.

Various software packages are available to do the calculations needed to derive calibrated weights. These include:

- CLAN. This was developed by Statistics Sweden and it is a suite of SAS-macro commands.
- CALMAR (Calibration on Margins). This is another SAS macro developed by INSEE in France.
- CALJACK. This is also a SAS macro developed by Statistics Canada.

Several different sets of weights may be produced, depending on the variables of interest. In practice however, there will probably be only up to three different weights produced.

Member States are free to use whatever calibration technique they prefer but, in accordance with Section 7, paragraph 4 of the Annex to the Commission Regulation on innovation statistics, they should provide information about the calibration methods used.

4.6. Precision of results

The CIS 4 should be carried out in order to achieve a certain level of precision concerning the following indicators:

1. Percentage of innovation-active enterprises.
2. Percentage of innovators that introduced new or improved products to the market.
3. New or improved products, as a percentage of total turnover.
4. Percentage of innovation active enterprises involved in innovation co-operation.

These variables are listed in Section 1 of the Annex of the Commission Regulation on innovation statistics. In addition, the CIS 4 should also achieve a certain level of precision with regard to the following indicator:

1. Total turnover per employee.

Article 6 of the Commission Regulation on innovation statistics states that quality evaluation shall be carried out by member States. Therefore, after processing the data, the 95% confidence intervals[10] for the first three indicators should be $\theta^\wedge \pm 0.05$, for indicator 4 the 95% confidence interval should be $\theta^\wedge \pm 0.10$, and for indicator 5 the confidence interval should be $\pm$ 10% of the estimate $\theta^\wedge$.

In accordance with Section 7, paragraph 4 of the Annex of the Regulation on innovation statistics, member States shall transmit these quality results to Eurostat.

Country notes

This section includes country-specific notes on survey methodology, focusing in particular on differences between national surveys and the CIS 4 model questionnaire (and associated methodological recommendations).

Australia

Data are sourced from the 2005 Innovation Survey. The reference period is 2004-05 and this may affect the cross-country comparability of some results.

ISIC 7421 is included in manufacturing rather than services.

The 2005 Innovation Survey includes enterprises with five or more employees. Hence, many of the indicators compiled for this project include enterprises with fewer than ten employees.

Goods and services were not distinguished in Innovation Survey 2005.

Enterprise sells goods and services to foreign markets. This question was not asked in Innovation Survey 2005.

Canada

Unit of observation

The unit of observation for the Survey of Innovation 2005 is the *establishment*. It is defined as follows, along with the other units of observation that are possible at Statistics Canada.

The *Enterprise* (the top of the hierarchy) is associated with a complete set of financial statements. The enterprise, as a statistical unit, is defined as the organisational unit of a business that directs and controls the allocation of resources relating to its domestic operations, and for which consolidated financial and balance sheet accounts are maintained from which international transactions, an international investment position and a consolidated financial position for the unit can be derived. It corresponds to the institutional unit as defined for the System of National Accounts.

The *Company* is the level at which operating profit can be measured. The company, as a statistical unit, is defined as the organisational unit for which income and expenditure accounts and balance sheets are maintained from which operating profit and the rate of return on capital can be derived.

The *Establishment* is the level at which the accounting data required to measure production is available (principal inputs, revenues, salaries and wages). The establishment, as a statistical unit, is defined as the most homogeneous unit of production for which the business maintains accounting records and from which it is possible to assemble all the data elements required to compile the full structure of the gross value of production (total sales or shipments, and inventories), the cost of materials and services, and labour and capital used in production.

The *Location* (the bottom of the hierarchy) requires only the number of employees for delineation. The location, as a statistical unit, is defined as a producing unit at a single geographical location at which or from which economic activity is conducted and for which, at a minimum, employment data are available.

Firm size

The Survey of Innovation 2005 did not survey establishments between 10 and 19 employees.

Industry classification

There are some differences between the NAICS and the NACE classification of manufacturing. The most important being whether or not printing is included.

Reference period

The reference period for the Survey of Innovation 2005 for some questions is 2002 to 2004 and for other questions it is for 2004.

Question design

Canada adopted the CIS questions for key questions in its survey in order to be comparable. There should not be major discrepancies with the CIS questions.

Respondent to the questionnaire

The target respondent was the CEO of the company for single establishment (establishments with only one location) and the plant manager for establishments that were part of a multi-establishment enterprise.

Definition of higher education

The estimates for indicator S.18 (firms that collaborated (in innovation) with higher education or government institutions) include both universities and colleges.

Finland

Non-technological innovation

For marketing and organisational innovations, Finland did not apply the questions from the model questionnaire. Instead national questions were used covering changes in business strategy, organisation structure and external relations for organisational changes and changes in marketing methods or strategy and aesthetic changes of products to measure the changes made for marketing.

Japan

Data come from the Japanese National Innovation Survey 2003 (J-NIS 2003) carried out by the National Institute of Science and Technology Policy (NISTEP). The reference period of the survey is 1999-2001.

New Zealand

Data collection

The Business Operations Survey 2005 was a postal survey. Initial contact was made to key and/or complex businesses in the survey by telephone, before the mailing, to determine the appropriate person(s) within the business to whom the survey questions could be directed. For all other businesses, the survey form was addressed to the managing director. The survey was posted between August and October 2005 and collected information for the last financial year for which the business had data available at that point.

Target population

The target population for the Business Operations Survey 2005 was live enterprise units on Statistics NZ's Business Frame which at the population selection date:

- Were economically significant enterprises (those that have an annual GST turnover figure of greater than NZD 30 000).
- Had six or more employees.
- Had been operating for one year or more.
- Were classified to Australian and New Zealand Standard Industrial Classification – New Zealand Version 1996 (ANZSIC96) codes listed as "in scope" in List 1 below.
- Were private enterprises as defined by New Zealand Institutional Sector 1996 Classification (NZISC96) listed in List 2 below.

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List 1. **ANZSIC96 Codes in scope**

In scope for survey	Scope for these indicators
ANZSIC96 code – description	
A – Agriculture, forestry and fishing	Out of scope for these indicators
B – Mining and quarrying	B151 (Exploration) in scope for services, all others in scope for total economy
C – Manufacturing	In scope for manufacturing
D – Electricity, gas and water supply	D3702 (Sewerage and Drainage Services) out of scope, all others in scope for total economy
E – Construction	E4251 (Landscaping services) in scope for services, all others out of scope
F – Wholesale trade	F462 (Motor vehicle wholesaling) out of scope, all others in scope for services
G – Retail trade	Out of scope
H – Accommodation, cafes and restaurants	Out of scope
I – Transport and storage	In scope for services
J – Communication services	In scope for services
K – Finance and insurance	In scope for services
L – Property and business services	L782 (Technical services) and L783 (Computer services) in scope for services, all others out of scope
N – Education	Out of scope
O – Health and community services	Out of scope
P91 – Motion picture, radio and television services	Out of scope
P93 – Sport and recreation	Out of scope
Out of scope	
M – Government administration and defence	
P92 – Libraries, museums and the arts	
Q – Personal and other services	

List 2. **NZISC96 Codes in scope for survey**

NZISC96 code – description
1111 – Private corporate producer enterprises
1121 – Private non-corporate producer enterprises
1211 – Producer boards
2211 – Private registered banks
2221 – Private other broad money (M3) depository organisations
2291 – Private other depository organisations n.e.c.
2311 – Private other financial organisations excluding insurance and pension funds
2411 – Private insurance and pension funds

An enterprise is defined as a business or service entity operating in New Zealand, such as a company, partnership, trust, government department or agency, university or self-employed individual.

The final estimated population size for the survey was 34 760 enterprises.

For these indicators the final estimated populations size was 7 806 enterprises (see target industries and firm sizes below).

Sample design

The sample design was a two-level stratification according to ANZSIC industry and employment size groups. This information was obtained using enterprise ANZSIC industry and employment information from Statistics NZ's Business Frame.

The first level of stratification was 33 ANZSIC industry groupings. Within each of the ANZSIC groups there is a further stratification by employment size group. The four employment size groups used in the sample design are:

- 6-19 employees (small);
- 20-29 employees (medium 1);
- 30-49 employees (medium 2);
- 50 or more employees (large).

For these indicators: the small group has been split into two groups and the 6-9 employees group has been excluded, the large group has been split into two with 250+ employees representing the large firm size. The remaining groups have been amalgamated to form the SMEs group (10-249 employees).

To produce these indicators, new weights have been applied to the data to account for the changes to the smallest size stratum. However, imputation was carried out on the full sample using the original survey stratification.

Measurement errors

The Business Operations Survey 2005 results are subject to measurement errors, including both non-sample and sample errors. These errors should be considered when analysing the results from the survey.

Non-sample errors

Non-sample errors include mistakes by respondents when completing questionnaires, variation in the respondents' interpretation of the questions asked, and errors made during the processing of the data. In addition, the survey applied imputation methodologies to cope with non-respondents. Statistics NZ adopts procedures to minimise these types of error, but they may still occur and are not quantifiable.

Given the nature of the data collected, there are limitations on the level of accuracy that can be expected from the survey. Many respondents do not keep separate accounts of their innovation expenditure, or records may not be kept in the form required for the survey, and estimation may be required. Even though detailed descriptions of what should and should not be included as innovation

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were provided in the questionnaire, there may still be differences in interpretation of what constitutes innovation and the nature of any co-operative arrangements with other businesses involved in the innovation process.

Sample errors

Total revenue was used as the numeric design variable for the survey. The sampling error on the total revenue figure has been measured at 5.9% at the 95% confidence level.

Response rate

The Business Operations Survey 2005 targeted an 80% response rate. The survey achieved an actual response rate of 80.1%, which represented 5 595 businesses.

Non-response and imputation

Unit non-responses

Unit (or complete) non-response occurs when units in the sample do not return the questionnaire. The initial selection weight of the remaining units in the stratum was adjusted to account for the unit non-response (no item non-response imputation would occur for the units that did not return the questionnaire

Item non-responses

Item (or partial) non-response is when the questionnaire is returned but some questions are not answered. No item non-response imputation was carried out for units that did not answer 60% or more of the questions they were required to answer (based on questionnaire routing rules). The respondents who did not meet this criterion were classified as unit non-responses and the weights were adjusted accordingly.

Imputation cells and merging. Units were assigned to imputation cells for the calculation and assignment of imputation factors. Imputation cells were based on industry and rolling mean employment.

For each variable a minimum number and percentage of linked units was required within the imputation cell for the imputation method to run. This was to ensure the robustness of the imputation factor calculations. The minimum number of linked units was ten and the minimum percentage was 60%. If an imputation cell did not fulfil these criteria it was merged before imputation, following a list of merging preferences until sufficient responses were achieved. The imputation factor was then calculated from all of the linked units in the merged cell but applied to non-respondents in the original (unmerged) imputation cell only. If there was still insufficient response once all the specified cells were merged in order, the imputation factor was calculated across all linked units in the final merged cell (*i.e.* using the "best available" imputation factor) and applied to non-respondents in the original (unmerged) imputation cell only.

Imputation of numeric variables. The imputation methods used were weighted mean imputation and donor imputation. Using the weighted mean method, a weighted mean was calculated from linked responding units for each numeric line code within each imputation cell. Non-responding units were then imputed with the weighted mean for their imputation cell. Weighted mean imputation was used to impute totals.

Donor imputation randomly selected a donor from within each imputation cell. The non-respondent was then imputed with the value(s) from the donor. Donor imputation was used to impute components and percentages so that the distribution was maintained.

Imputation of categoric questions. For categoric imputation the method used was nearest neighbour imputation, which involved finding a donor with the most similar responses. The donor supplied responses for all categoric variables requiring imputation. If the donor unit did not respond to any of the variables requiring a response, the next best donor was chosen to supply this information. This was continued until all the variables had a response.

Unlinking. Influential responses were excluded from the imputation factor calculations for numeric variables. There were three kinds of unlinking:

- Automatic exclusion – due to logic, *i.e.* unit was non-response (unit or item), specially treated or not required to answer that question.
- Automatic unlinking – due to influence, *i.e.* units with undesirable influence on imputation factor calculations for a variable were automatically detected and unlinked for that variable (with the ability to manually decline this). The checks were carried out at the imputation cell level or merged imputation cell level and were done separately for each variable.
- Manual unlinking – due to influence, *i.e.* additional units with undesirable influence on imputation factor calculations that were not automatically detected could be unlinked.

Special treatment. Special treatment candidates were identified as outliers using an interquartile check. The checks were carried out separately by variable. However, if a unit was accepted for special treatment for one variable then it was specially treated for all variables. If a unit was specially treated then its final weight was set to 1 and it was unlinked for all imputation factor calculations. If a unit was not specially treated then its final weight was its adjusted weight.

Definitions

General definitions

The Business Operations Survey was designed to collect data in accordance with the following definitions and terminology:

ANZSIC: Australian and New Zealand Standard Industrial Classification System – New Zealand Version 1996.

Business frame: a register of all businesses operating in New Zealand.

Employees: the number of employees is defined by an enterprise's rolling mean employment (RME) count. RME is a 12-month moving average of the monthly employment count (EC) figure. The EC is obtained from taxation data.

Enterprise: a business or service entity operating in New Zealand. It can be a company, partnership, trust, estate, incorporated society, producer board, local or central government organisation, voluntary organisation or self-employed individual.

Goods and services tax (GST): respondents are asked to exclude GST if possible in the financial figures provided in the questionnaire. If they did not, Statistics NZ takes out GST to make all enterprises comparable.

Last financial year: For the purpose of this survey, this refers to the last financial year for which the business had results available, as at August 2005, as entered on the questionnaire.

Innovation definitions

The Innovation module of the survey is designed to collect innovation data in accordance with the definitions contained in the OECD/Eurostat *Oslo Manual* (2005). The *Oslo Manual* is available from *www.oecd.org*. The following definitions relate specifically to the innovation module.

Innovation: for the purpose of this survey, innovation is broadly defined. It includes the development or introduction of any new or significantly improved activity for the business. This includes products, processes and methods that the business was the first to develop and those that have been adopted from other organisations.

For the Business Operations Survey 2005, an innovation is defined as the development or introduction of new or significantly improved:

- Goods or services – this does not include the selling of new goods or services wholly produced and developed by other businesses.
- Operational processes – *i.e.* methods of producing or distributing goods or services.
- Organisational/managerial processes – *i.e.* significant changes in the business’s strategies, structures or routines.

- Marketing methods – this includes sales and marketing methods intended to increase the appeal of goods or services for specific market segments, or to gain entry to new markets.

Co-operative arrangement: active participation with another organisation or individual in activities for the purposes of innovation:

- This includes collaborative arrangements for the purposes of innovation.
- Each party should bring exclusive knowledge or expertise to the co-operation.
- Partners do not necessarily gain immediate commercial benefit from the co-operation.

This does not include contracting-out work for which there is no active co-operation.

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Table A.1. Selected metadata from national innovation surveys

	Australia	Austria
Survey name	2005 Innovation Survey.	4. Europaeische Innovationserhebung – CIS 4
Reference period	2004-05.	2002-04.
Statistical unit	Australian Business Number (ABN) unit for businesses with simple structures and Type of Activity (TAU) unit for businesses with complex structures.	Enterprise.
Minimum size cut-off point for firms to be included (# of employees)	Businesses with 5 or more employees.	10.
Treatment of missing item responses	Imputation undertaken for missing financial items using historical and live respondent mean techniques. Other items imputed through weight adjustment during estimation.	Due to intensive follow-up activities with the respondents after they sent in the questionnaire for clarification of the reported data, item-non-responses could be kept at a minimum. For all variables in the CIS 4, item-non-response rates were less than 4%. Imputations for CIS 4 survey were carried out according to the Eurostat requirements.
Weighting and calibration	Imputation using weight adjustment, Estimation using live respondent mean.	Basic weights were first calculated by Nh/nh using the inverse of the sampling fraction. Then re-adjusted according to the results of the non-response analysis.
Industry coverage at Division level	All industries except the following ANZSIC (1993) divisions: Agriculture, forestry and fishing; Government administration and Defence; Education; Health and Community services; and Personal and other services.	NACE 10-14, 15-37, 40-41, 51, 60-64, 65-67, 72, 74.2 and 74.3.
Type of survey	A random sample of businesses stratified by industry, state/territory and number of employees	Mixed approach: all enterprises with 250+ employees, 33% of those with 50-249 and 23% of those with 10-49 employees. Industry, size class and region used as stratification variables.
Minimum size cut-off point for census survey	All businesses with 200 or more employees were included.	250.
Target population/ Sample size		
Manufacturing		7 420/2 204.
Services		8 352/2 222.
Total	141 000/6 800.	16 034/4 513.
Unit response rates		
Manufacturing		58.9%.
Services		58.3%.
Total	93%.	58.9%.
Type of survey	Mandatory.	Voluntary.
Joint survey	No.	No.
Known deviations from the *Oslo Manual*	The 2005 ABS survey also measured non-technological innovation; abandoned innovative activity and innovative activity not yet complete.	No known deviations. However, according to Eurostat requirements the CIS 4 still relied mainly on the *Oslo Manual 1997* and not on the *Oslo Manual 2005*.
Additional modules	Special modules covering more detailed information about business linkages, sources of ideas and acquisition of knowledge.	None.

Table A.1. **Selected metadata from national innovation surveys** *(cont.)*

	Belgium	Canada
Survey name	Community Innovation Survey (CIS 4)	Survey of Innovation 2005 (manufacturing)
Reference period	2002-04 (reference year 2004).	2002-04.
Statistical unit	Enterprise.	Statistical establishment ("plant").
Minimum size cut-off point for firms to be included (# of employees)	10.	20 employees and CAD 250 000 in revenues.
Treatment of missing item responses	First, manual control and cross-checking with anwers available in other surveys and registers (*e.g.* Bel-First for accounting data and R&D surveys for R&D data); second, imputation using the SAS program provided by Eurostat.	Donor imputation.
Weighting and calibration	Weights = inverse of sampling fraction	Weights adjusted for non-response.
Industry coverage at Division level	NACE 10,14, 15 to 37, 40, 41, 45, 50, 51, 52, 60 to 67, 72, 73, 74.	NAICS 1133 (logging). NAICS 31-33 to varying levels of detail.
Type of survey	Mixed.	Stratified random sample.
Minimum size cut-off point for census survey		
Target population/ Sample size		
Manufacturing	6 878/3 121	17 4726/8 902.
Services	14 116/4 762	n.a.
Total	24 729/8 562	18 488/9 059 (incl. logging).
Unit response rates		
Manufacturing	44%.	71.8%.
Services	37%.	n.a.
Total	39%.	71.9%.
Type of survey	Voluntary.	Mandatory.
Joint survey	No.	No.
Known deviations from the *Oslo Manual*	None.	Conforms to guidelines in *Oslo Manual* 1997.
Additional modules	None.	Market and supply chain, Commercialisation, Success factors, Skill level of firm, Intellectual property, External funding and support.

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Table A.1. **Selected metadata from national innovation surveys** *(cont.)*

	Switzerland	Germany
Survey name	Swiss Innovation Survey.	Mannheim Innovation Panel (MIP).
Reference period	2003-05.	
Statistical unit		Enterprise.
Minimum size cut-off point for firms to be included (# of employees)	5 employees.	5 employees.
Treatment of missing item responses	Multiple imputation is used.	Longitudinal imputation, if not available: cross-section imputation.
Weighting and calibration	Weights based on the inverse of the number of enterprises by stratum to adjust for sampling design deviations. Further, in order to adjust for unit non-response calibration on margins is also used. An individual sales weight is used in case of quantitative variables that refer to sales.	Bounded weighting used for quantitative variables (*e.g.* innovation expenditure), unbounded weighting used for qualitative variables (*e.g.* share of innovators); correction for unit-non response based on results from non-response survey.
Industry coverage at Division level	NACE 15-41, 45, 50-52, 55, 60-67, 70-74, 93.	NACE 10-41, 51, 60-67, 72-74, 90, 92.1, 92.2.
Type of survey	Stratified random sample.	Stratified random sample using 7-8 size classes (depending on the sector), 25 sectors, 2 regions (West and East Germany).
Minimum size cut-off point for census survey		1 000 employess in manufacturing; 500 employees in services.
Target population/ Sample size		
Manufacturing	11 601/3 035.	63 200/15 100.
Services	34 935/2 923.	200 300/11 900.
Total	56 723/6 609 (also incl. Construction).	233 500/27 000.
Unit response rates		
Manufacturing	41.6%.	19.4% (36.6% incl. non-response surv.).
Services	35.3%.	18.4% (31.1% incl. non-response surv.).
Total	38.7%.	18.9% (34.2% incl. non-response surv.).
Type of survey	Voluntary.	Voluntary.
Joint survey	2005 survey was combined with an ICT survey, previous ones were innovation only.	No.
Known deviations from the *Oslo Manual*	Specific deviations for items mentioned above (*e.g.* population coverage, reference period, etc.) as well as more general ones (*e.g.* types of innovations), questionnaire definitions.	None.
Additional modules	Special modules covering additional topics: additional questions with respect to motives and results of R&D co-operation ; R&D activities of Swiss firms in other countries.	Since the start of the MIP in 1993, a large number of special questions were used, including on IPR, sources of innovation, public support, innovation management, market structure and competition, financing, internationalisation, skill demand, type of technologies used, co-operation with public research, etc.

Table A.1. **Selected metadata from national innovation surveys** *(cont.)*

	Denmark	Italy
Survey name	CIS 4.	CIS 4.
Reference period	2002-04.	2002-04.
Statistical unit	Enterprise (in some cases consisting of more legal units).	Enterprise.
Minimum size cut-off point for firms to be included (# of employees)	10 employees, with some exceptions for certain industries (ranging from 2 to 50).	10 employees.
Treatment of missing item responses		Imputation. In particular, deductive imputation was used for some item non-response based on the answers provided in related questions: imputation by ratio means for metric variables and nearest-neighbour imputation by hot deck is applied for estimating nominal and ordinal variables.
Weighting and calibration	CALMAR used for deriving calibrated weights.	Calibration estimators methodology used. Estimates are constrained to two auxiliary variables: known totals in the population (number of enterprises and persons employed).
Industry coverage at Division level	In addition to core industries, Nace 01-05, 45, 52, 73, 74.11-74.14, 74.4-74.8, 75. 25, 90 and Nace 92.2 are included. Enterprises in Nace 73 have been allocated to other relevant Nace-groups.	NACE Divisions 10-74. NACE groups for 24.4, 35.3, 74.2 and 74.3.
Type of survey	Mixed: census/sample.	Mixed: census/sample.
Minimum size cut-off point for census survey	250 employees (100 for Knowledge Intensive Services).	250 employees.
Target population/ Sample size		
Manufacturing	/1 240.	85 762/16 479.
Services	/1 179.	78 838/16 498.
Total	/2 419.	193 312/44 571.
Unit response rates		
Manufacturing	83%.	46%.
Services	89%.	50%.
Total	86%.	49%.
Type of survey		Mandatory.
Joint survey	Yes, combined R&D/Innovation survey.	No.
Known deviations from the *Oslo Manual*	None.	None.
Additional modules	None.	No special module covering additional topics, only further information concerning inter-regional and intra-regional linkages (*e.g.* concerning cooperation or information sources).

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Table A.1. **Selected metadata from national innovation surveys** *(cont.)*

	Japan	Luxembourg
Survey name	Japanese National Innovation Survey 2003 (J-NIS 2003).	CIS 4
Reference period	1999-2001.	2002-04.
Statistical unit	Enterprise	Enterprise.
Minimum size cut-off point for firms to be included (# of employees)	10 "persons engaged" (includes employers).	10 employees.
Treatment of missing item responses	None.	Imputation.
Weighting and calibration	The weighting factor was based on the ratio between the number of enterprises and the total number of enterprises in each stratum of the frame population, except for strata where no sample was realised.	Weighting and calibration are used.
Industry coverage at Division level	The following ISIC Rev. 3 economic activities were included: 01-02, 05, 10-11, 13-14, 15-37, 40-41, 51, 60-64, 65-67, 72, 73, 742.	All CIS 4 core industries.
Type of survey	Mixed: census/sample.	Mixed: census/sample.
Minimum size cut-off point for census survey	250 persons engaged.	250 employees.
Target population/ Sample size		
Manufacturing	112 554/29 797.	314/194.
Services	100 035/11 684.	1 052/361.
Total	216 585/43 174 (incl. agric, forestry/fisheries and mining).	1 366/555.
Unit response rates		
Manufacturing	21.2%.	
Services	21.0%.	
Total	21.4%.	92%.
Type of survey	Voluntary.	Mandatory.
Joint survey	No.	Combined R&D / innovation survey.
Known deviations from the *Oslo Manual*	Some differences in terms of industrial coverage.	None.
Additional modules	IPRs for the most important product and process innovations.	Some additional questions (but not separate modules).

Table A.1. **Selected metadata from national innovation surveys** *(cont.)*

	New Zealand	Sweden
Survey name	Business Operations Survey.	CIS 4.
Reference period	Questions are a mix of last two financial years (*e.g.* headline innovation rates) and last one financial year (*e.g.* financial questions). Actual period depends on the balance date of each business, 76% of respondents had a balance date within 3 months of 31/03/2005.	CIS 4.
Statistical unit	Enterprise.	Enterprise.
Minimum size cut-off point for firms to be included (# of employees)	6 RME (rolling mean employment – a 12 month average of employee numbers).	10 employees.
Treatment of missing item responses	Respondents that answer less than 60% of required questions are treated as unit non-responses. Imputation is used for item non-response if the respondent has answered 60% or more of required questions. However, imputation is not used for the key innovation questions, which determine whether a unit is an innovator or not. Financials are imputed by stratum means, all other variables are donor imputed (predominately nearest neighbour).	Imputation (Eurostat recommendations – SAS programs).
Weighting and calibration	Weighting cells are based on enterprise size (4 categories) and industry (33 categories). Selection weight of cell = population of cell/number sampled from cell. Adjusted weight of cell = population of cell/(number of respondents in cell + number of enterprises in cell that ceased operating before selection date). Final weight = adjusted weight unless the unit is specially treated. Specially treated units have a final weight = 1 and are unlinked from imputation.	Weighting.
Industry coverage at Division level	ANZIC96 codes A-L, N, O, P91, P93.	NACE 10-41, 51, 60-67, 72-74.
Type of survey	The sample design was a two-level stratification according to ANZSIC industry and employment size groups (RME of 6-19, 20-29, 30-49, 50+). Total operating revenue is the numeric design variable used to select the sample.	Mixed: census/sample.
Minimum size cut-off point for census survey		250 employees.
Target population/ Sample size		
Manufacturing	5 683/1 554.	7 580/2 965 (incl. mining/quarrying and electricity, gas and water).
Services	23 269/4 390.	10 807/2 118.
Total	35 746/7 069 (incl.ANZIC96 A, B, D, E).	18 387/5 083.
Unit response rates		
Manufacturing	81%.	65%.
Services	81%.	69%.
Total	80%.	67%.
Type of survey	Mandatory.	Voluntary.
Joint survey	Yes. Each innovation section of the Business Operations Survey is run with a business operations section (financial performance and business environment measures) and one other contestable section (in 2005 it was business practices).	No.
Known deviations from the *Oslo Manual*	None, conforms to *2005 Oslo Manual*.	None.
Additional modules	2 additional modules. In 2005: Business Operations and Business Practices.	No.

Table A.1. **Selected metadata from national innovation surveys** *(cont.)*

	United Kingdom
Survey name	UK Innovation Survey (CIS 4).
Reference period	CIS 4.
Statistical unit	Enterprise.
Minimum size cut-off point for firms to be included (# of employees)	10 employees.
Treatment of missing item responses	No imputation.
Weighting and calibration	Weighted up to the number of enterprises in the population. Employment weights sometimes used.
Industry coverage at Division level	NACE sections C, D, E, F, G, H, I, J and K.
Type of survey	Mixed: census/sample.
Minimum size cut-off point for census survey	250 employees.
Target population/ Sample size	
Manufacturing	56 154/11 991 (incl. construction).
Services	121 900/16 539.
Total	178 054/28 530.
Unit response rates	
Manufacturing	56%.
Services	58%.
Total	58%.
Type of survey	Voluntary.
Joint survey	No.
Known deviations from the *Oslo Manual*	None. The UK Survey asks all questions of all respondents – *i.e.* unllike the CIS 4 core questionnaire it does not filter out non-innovators form the innovation activities and expenditure questions for example. This provides a much richer data set for analysis and modelling purposes.
Additional modules	No.

Notes

1. Council Regulation (EEC) N° 696/1993 of 15 March 1993, OJ No. L76 of the 3 March on the statistical units for the observation and analysis of the production system in the Community.
2. Council Regulation (EEC) No. 2186/1993 of 22 July 1993.
3. Domains are defined as strata or combinations or strata, for which results will be published.
4. The NACE code to use for stratification should be that of the enterprise at the end of the reference period 2004.
5. The enterprise size to use for stratification should be the number of employees at the end of the reference period 2004.
6. There are also now procedures available in SAS such as PROC SURVEYSELECT, PROC SURVEYMEANS and PROC SURVEYREG that can perform statistical procedures for complex sample surveys.
7. Cold deck imputation, on the other hand, makes use of a fixed set of values, which covers all of the data items. These values can be constructed with the use of historical data, subject-matter expertise, etc. A "perfect" questionnaire is created in order to answer complete or partial imputation requirements.
8. Nearest neighbour imputation: In this case a criteria is developed to determine which responding unit is "most like" the unit with the missing value in accordance with the predetermined characteristics. The closest unit to the missing value is then used as the donor.
9. It can be done for balancing purposes (in the sense that after calibration, "the sample looks like the population") or for improved consistency of estimates (in production systems, each sampled unit is given a unique final weight as part of the calibration process; as a result, estimates are consistent in the sense that the parts add up to the totals).
10. The confidence interval for the parameter,θ^, with approximate confidence level of 95%, is given by: θ^ ± 1.96 • *Variance* (θ^).

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Innovation in Firms

A MICROECONOMIC PERSPECTIVE

Innovation has become a key factor for economic growth, but how does the process take place at the level of individual firms? This book presents the main results of the OECD Innovation Microdata Project – the first large-scale effort to exploit firm-level data from innovation surveys across 20 countries in an internationally harmonised way, with a view to addressing common analytical questions. These include:

- Which characteristics of companies affect their propensity to innovate?
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These are important issues for policy makers who seek to promote innovation.

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