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STI

REVIEW No. 27

SCIENCE TECHNOLOGY INDUSTRY

Special Issue on New Science and Technology Indicators

Introduction –
New Science and Technology Indicators for the Knowledge-based Economy: Opportunities and Challenges

Investment in Knowledge

Constructing Internationally Comparable Indicators on the Mobility of Highly Qualified Workers: A Feasibility Study

Innovation Surveys: Lessons from OECD Countries' Experience

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ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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FOREWORD

Prepared by the OECD Directorate for Science, Technology and Industry, the STI *Review*, published twice yearly, presents studies of interest to science, technology and industry policy makers and analysts, with particular emphasis on cross-country comparisons, quantitative descriptions of new trends and identification of recent and future policy problems. Because of the nature of OECD work, the STI *Review* explores structural and institutional change at global level as well as at regional, national and sub-national levels. Issues often focus on particular themes, such as surveys of firm-level innovation behaviour and technology-related employment problems.

As the goals and instruments of science and technology policies have evolved over the past decade, the need has arisen for new indicators in the field. The current issue of STI *Review* reports on the major advances achieved by a multi-year project conducted by OECD which aimed to select and design novel sources of data and new statistical methods able to broaden the range of science and technology indicators and respond to the enhanced demand. Major topics covered include: investment in knowledge, mobility of highly skilled workers, innovation surveys and innovation indicators, public support to industrial technology, and fiscal policies for R&D. The OECD wishes to acknowledge the financial support of DG Research of the European Commission for this project.

The views expressed in this publication do not necessarily reflect those of the OECD or of its Member countries. The STI *Review* is published on the responsibility of the Secretary-General of the OECD.

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INTRODUCTION
NEW SCIENCE AND TECHNOLOGY INDICATORS FOR THE KNOWLEDGE-BASED ECONOMY: OPPORTUNITIES AND CHALLENGES

An extended and high-quality set of quantitative indicators is necessary to the design and evaluation of science and technology (S&T) policy. Indicators allow the comparison of the relative situations of countries, the assessment of their areas of strength and weakness, and the identification of domains where policy intervention is required. They also provide feedback on the effects of policies. Above all, indicators have to be able to adapt to the changing conditions and the content of S&T policy.

At its meeting at Ministerial level held in 1995, the OECD Committee for Scientific and Technological Policy agreed in its conclusions that "there is a need for Member countries to collaborate to develop a new generation of indicators which can measure innovative performance and other related output of a knowledge-based economy". They also agreed that "trends and challenges to the science system need to be studied further by the OECD" and that "special attention should be given to the data required for assessment, monitoring and policy-making purposes".

Demand from policy makers was the rationale for past statistical endeavours that resulted, for instance, in the *Frascati Manual* (for research and experimental development, R&D) in the early 1960s and the *Oslo Manual* (for innovation) in the 1990s. As a result of such efforts, there exists today a rich set of S&T indicators, many of which are collected by countries and compiled by the OECD and other international organisations. These include R&D expenditure, head-counts of researchers, technology balance of payments, production and trade of high-technology goods and patents (these indicators are published twice yearly in the OECD's *Main Science and Technology Indicators*). However, as is argued in the above-quoted ministers' request, there is a clear need to extend the list of S&T indicators. The context, as well as the content, of technology policy have been changing, resulting in demand for new indicators, while at the same time new data sources and new methodologies are becoming available, providing opportunities for the supply of new indicators.

Changes in demand for indicators

The importance of research and development (R&D) for technological change and economic growth became clear after the Second World War. The *Frascati Manual* ("guidelines for the collection of R&D data", first published in 1963), resulted directly from demand by policy makers for measuring this newly identified factor of growth. Since then, this view has not been disputed, although it has been broadened and deepened. Part of this change in perspective is certainly due to new conditions in the real world as well as, notably, the emergence of the "knowledge-based economy". Major aspects can be summarised as follows.

Innovation: R&D is a central piece in the process of technological change, but it is not the only one. Technological innovations are new products or new processes actually commercialised or implemented by firms. In addition to R&D in the strict sense, there are other sources of new technology, such as design, new software, training. The "innovation surveys" developed through the 1990s, notably by Eurostat, aim to capture such activities. This applies especially to the expanding service industries, where little R&D is undertaken but where innovation is spreading.

Investment in knowledge: certain activities, in addition to R&D, lead to an increase in the stock of knowledge and information available to the economy, such as investment in software, in training or in education. It is therefore useful to integrate certain of these activities under the common label of "investment in knowledge", which gives a broader view of the advance towards knowledge-based economies. A better integration of R&D into the overall framework of economic statistics, the system of national accounts (SNA), goes into the same direction, as it links R&D to other productive activities. This is the purpose of ongoing efforts at OECD.

Human resources in S&T (HRST) are the major factor that enable a country to generate and master new technology. A large HRST base is a *sine qua non* condition for a country to continue to innovate, as it embodies the knowledge stock of the country. In addition to researchers, engineers and technicians allow an efficient application of technology. In particular, policies aimed at encouraging firms to spend more on R&D will fail if the supply of HRST is insufficient, as more spending would result only in higher costs. Counts of researchers, which have been available for a long time, reflect only one part of human resources. It is therefore necessary to measure other components of HRST (R&D managers, production engineers, technicians), and to investigate its structure and dynamics (such as structure by skills, S&T fields, its domestic and international mobility). The

"Canberra Manual" (OECD and Eurostat, 1995) was a first step in this direction. More work needs to be done on the methodological side (improved definitions) and on the identification and exploitation of the appropriate sources of data (*e.g.* labour force surveys, census and special surveys performed in many countries).

Services are becoming increasingly innovative, but this trend is not well captured by current statistics which were built on the "bricks and mortar" model. Much innovation in the services is not based on formal R&D, and R&D in these sectors differs in many respects from R&D in manufacturing – its focus is not on the natural sciences but more on the social sciences and humanities (SSH). In that sense, it is clear that the issue is not one of R&D in the service sectors, but rather service-type R&D in all sectors (as even manufacturing firms perform research in these fields). Efforts have been engaged for the past decade both to capture non-R&D innovation (through innovation surveys) and to improve the coverage of R&D surveys to service firms. The definition of R&D in the *Frascati Manual* was broadened in the 1993 edition in order to more clearly encompass SSH. Many countries have included service industries in their survey sample. It seems, however, that the notion of R&D in services has still to be clarified, and the fifth revision of the *Frascati Manual* is doing exactly that, by providing specific examples of R&D related to human behaviour (customers, workers) and to organisation.

Emerging technologies, notably information and communication technology (ICT), biotechnology, and, possibly in the future, others such as nanotechnology. These new technologies have in common a large leverage effect in that they can influence entire parts of the economy. They lead to the emergence of entirely new industries, they reshape many existing sectors and they change consumer demand. This is notably the case for ICT, which is recognised as being a "general purpose technology". For these technologies, it is important not only to measure their technological evolution (increase in performance) and the resources devoted to their improvement (R&D, patents), but also their diffusion throughout the economy, which determines their impact on performance. Indicators of use, such as the number of PCs or Internet connections tell us a great deal about the impact of ICT on the economy. Definition and measurement of ICT industries and ICT-related activities such as e-commerce have progressed. Statistical activity in this field has been expanding rapidly over the past years (see OECD, 2000, for ICT, and OECD, 2001*a*, for biotechnology).

Circulation of knowledge: as activities devoted to the creation of new knowledge have expanded, it has become increasingly important for the entities involved to maintain connections with one another. The increasing specialisation of knowledge producers, be they companies or individual scientists, and the acceleration of change makes it even more crucial that they remain connected, as they are all sources of new knowledge for their partners. Networks are being set up (between companies, between companies and universities, between scientists, across borders), based on various types of contractual arrangements (*e.g.* joint ventures, subcontracting, exchange of personnel). The mobility of people, as carriers of human capital and knowledge, between companies, universities, across borders, is becoming increasingly important. The overall performance of a national system of innovation depends critically on its ability to make knowledge available where it is needed in the economy. This is the role of a broad set of institutions, including various types of public and semi-public research organisations. Indicators should be developed that reflect the circulation of knowledge: its intensity, its patterns, the obstacles encountered. This raises a particular challenge for statisticians as it implies not looking at one entity at one point in time, but rather looking at several entities at once and at their relationships, and following them over time. When it comes to international networks or international circulation of knowledge, the challenge is more difficult as statistics are produced by national agencies, independent of each other and whose methods and concerns often differ, making it difficult to draw a consistent international picture.

Internationalisation is a major trend experienced by all technology-related activities. Multinational firms have research facilities in many different countries, R&D joint ventures are increasingly international, human resources and ideas circulate across borders (even more with the Internet), public research bodies, in the face of rising costs, co-ordinate for their research programmes and for establishing international research facilities (EC framework programmes, space station). For all countries, foreign technology is a major factor of economic growth. All these factors, again, raise special difficulties for national statistical agencies. Greater co-ordination is needed in order to put in place common definitions and procedures for the collection of data. The ongoing OECD work on a "globalisation manual" is a step in this direction, following on from the collection of data of R&D performed by affiliates of foreign multinationals which started in the mid-1990s (OECD, 2001*b*). Innovation surveys include questions regarding international linkages, such as sources of knowledge and alliances related to innovation.

Behaviour of firms: innovation is more market-driven than in the past; it is influenced by the strategy and special conditions faced by individual firms. Stronger competitive pressures push firms to become more innovative and to rapidly adopt recent technology. Businesses may face obstacles to innovation such as market access (due to incumbents or to regulation) or access to funds (lack of financing for innovative SMEs). However, these new trends are not clearly visible from aggregate (country or industry level) data. Longitudinal databases must be set up and accessed by researchers. This raises statistical difficulties (tracking a same firm from year to year is not easy, especially as firms often merge or split) and legal ones (confidentiality of firm-level data). A related challenge is to capture in the statistical net new, start-up firms, which play a key role in emerging technologies, and to improve coverage of activities related to venture capital.

Output indicators: much experience has been gained over the past decades in measuring the input to technological activities (R&D, personnel). It has long been felt, however, that output indicators are needed as well. They are needed by governments, to evaluate their programmes and researchers; they are needed by firms, who want to assess the contribution of R&D to their global achievement. Measuring output is far more difficult than measuring inputs: whereas the units in which inputs should be counted are clear (monetary units, number of people), this is not the case for outputs. What is the output of technological activities? In what units can they be counted? How can the contribution of technology to performance be isolated from other sources? What statistical sources might be used to capture outputs? For scientific activities, number of publications and citations of these are the preferred indicators, while for technology, counts of patents (and citations) are favoured. For both publications and patents, the drawbacks are well known, but much progress is being made in mitigating them. In addition, for technology, innovation surveys provide other indicators, such as the share of new products in total turnover.

Science and technology policies have changed radically over the past decade. With increasing R&D expenditure by business, the share of government, and hence its influence, has waned; the end of the Cold War has led governments to reduce their defence budget, formerly a major contributor to public R&D. In terms of innovation policy, new instruments are being experimented with, which are more market friendly than previous ones and usually involve less money but make use of more sophisticated incentive mechanisms (tax breaks, grants, soft loans, procurement). Public science is now expected to contribute more than before to social (such as the environment) and economic (transfer to industry) goals, and public research systems are being reformed accordingly – sometimes blurring the barriers between the public and private sectors. All these changes have increased the difficulty of mapping public policies: knowing the total amount of government R&D spending is no longer sufficient to obtain a clear picture of government policy. An effort in this direction was conducted at the OECD in the 1990s ("public support to industry").

The supply side

Growing and changing demand for information is a general trend in the knowledge-based economy, and the fact that this encompasses S&T indicators too is not surprising. To a large extent, progress on the supply side has permitted statisticians to adapt their products to these new conditions. On the supply side as well, statisticians are faced with the same trends as other knowledge producers.

Advances in methodology have been made in new areas, notably by the OECD and its Member countries. This has resulted in certain cases in new manuals or new statistical publications, even in new surveys. For HRST, the "Canberra Manual" (co-produced with Eurostat) was published in 1995. It gives a definition of HRST which aims to be compatible with existing classifications by occupations (ISCO) and by educational attainment (ISCED). Implementation has been partly successful to date, as internationally comparable estimates of HRST stocks and flows have been made for European countries (by Eurostat), although not yet for other countries. The basic issue is with the national classifications of occupations, which are in many cases incompatible with the international classification. Revision of the "Canberra Manual" was launched in 2001. Concerning globalisation, the "special session on globalisation" of the Statistical Working Party of the OECD Industry Committee (SWIC) has clarified conceptual aspects in the measurement of globalisation (a manual is in preparation). R&D expenditure of foreign affiliates is collected and published on a regular basis by the OECD (*e.g.* OECD, 2001*b*). On the R&D side, the *Frascati Manual* is increasingly taking into account the new demands detailed above. For ICT and biotechnology, definitions have been agreed upon by OECD Member countries, allowing collection of data to start on an internationally comparable basis. Methodological work on patents has been pursued, following the "Patent Manual" (OECD, 1994).

Innovation surveys were pioneered in the early 1980s notably in a few European countries, before spreading to other OECD countries throughout the 1990s. An enormous effort has been devoted to conceptualisation and implementation in the recent years. The *Oslo Manual* that sets international guidelines for innovation surveys, was first published by the OECD in 1992, and revised with Eurostat in 1997. Many countries, especially European ones (Community Innovation Surveys, co-ordinated by Eurostat), but also Canada, Australia and Korea, have carried out two or three rounds. Initially designed for manufacturing industries, such surveys now cover the services as well. The purpose of innovation surveys is to collect information on the innovation behaviour of firms: the type of innovation they have carried out (or not), their innovation intensity, the cost (beyond R&D), the objectives, the obstacles, the sources of technological knowledge (*e.g.* competitors, universities).

The increasing power of information technology has allowed the use of very large databases with a computer power that was previously undreamed of. This is the case especially for scientific publications, for patents and for firm-level data. Every year, more than three million patents are applied for worldwide, and the number continues to rise. Much valuable information is contained in each patent record. The same applies to scientific publications (the number of journals continues to grow) and to most firm-level studies (often based on panels of thousands of firms).

The cheaper computers and greater computing power available today mean that such data can be put to statistical use.

L*inking different data sources*: when it comes to mapping certain areas, such as the innovating behaviour of firms, S&T networks, the mobility of human resources or government S&T policies, more than one source of data is needed in order to obtain a complete picture. Each source of data gives specific information that makes more sense when matched with information from other sources. For instance, a good picture of innovating firms requires knowledge of their innovation activity, skill structure, product range, market shares and more; such information can be accessed only by resorting to several different data sources. Furthermore, in a globalising world, cross-country comparisons of firms are necessary, which implies matching business surveys from different countries. All of this raises few technical problems today, thanks to the advance of computing power, but it does raise legal problems due to concerns about confidentiality which drastically limit access to data. Further thinking about these issues is needed by both statisticians and law makers.

N*etworking statisticians*: the increasing diversity of data sources, methods and areas in S&T statistics means that division of labour is progressing in this field as well. It is not the same person, or the same administrative department, which is in charge of all these data in any country: specialisation is becoming the rule. Reaping the rewards from greater division of labour (in terms of more data produced and the higher competence of specialised experts), while keeping some unity (as it is important to keep consistency between the various indicators), is not straightforward. Statisticians in charge of the various aspects of S&T will have to think of new, more open and more flexible ways of co-ordinating with each other, within as well as between countries. Like their colleagues in other domains of knowledge production, they have to work increasingly in networks.

The "Blue Sky" activity

The "New S&T indicators" activity was launched in 1996 by the NESTI (National Experts on S&T Indicators) and the OECD Secretariat, following the request by ministers. It was clearly part of the broader endeavour by S&T policy makers and statisticians to adapt statistics to changes in demand and to new opportunities raised by new factors on the supply side. The activity did not aim to tackle all the issues mentioned above, but instead to give a clear signal that policy makers and statisticians were aware of the new conditions in S&T, and to make substantial progress in certain areas. Over the project life, active participation and regular supervision by statisticians from OECD Member countries (especially delegates to the NESTI) was key to the quality of the results. The project benefited from financial support from the European Commission. This special issue of the STI *Review* reports on the major achievements of this project. They are summarised as follows.

"Investment in Knowledge", by *Mosahid Khan*, proposes an instrument for measuring the advance towards knowledge-based economies. Investment in knowledge is calculated as the sum of expenditure on R&D, on higher education and on software (while clearing for the overlap). Ideally, one would like to take into account other components, such as expenditure on design, on training and on organisational change but, for the time-being, data availability imposes limits on what can be done. Certain types of intangibles are left aside in this exercise, notably expenditures related to marketing or branding, as their contribution to economic growth is not clear (although they are of course key to companies' competitiveness). The data reported in the article show that investment in knowledge is a sizeable part of GDP of OECD countries (around 5%-6% on average), and that it has been increasing more rapidly than GDP or physical investment over the 1990s.

"Constructing Internationally Comparable Indicators on the Mobility of Highly Qualified Workers: A Feasibility Study", by *Mikael Akerblom*, draws on in-depth work conducted in the Nordic countries. It sets a conceptual framework for measuring mobility; there are actually many different meanings to the word "mobility" (*e.g.* engaging in temporary training in another firm is not the same as changing employer, while changing establishment does not mean changing enterprise). Not distinguishing between the various types of mobility, with the proper criteria (what kind of change, for how long, …) might lead to misleading indicators. The article then assesses whether existing data sources are suitable for calculating such indicators. Particular emphasis is put on two "test countries", France and the United Kingdom. In addition, the article tackles certain aspects of international mobility (for further insights on this question, see OECD, 2002).

"Innovation Surveys: Lessons from OECD Countries' Experience", by *Dominique Guellec and William Pattinson*, looks at what we can discover about various features of innovation from innovation surveys of the type conducted in the Community Innovation Survey (CIS) programme, and the issues that need to be addressed to ensure that future surveys provide even better indicators and are more helpful to policy makers. Innovation surveys have substantially improved our knowledge of innovation. They have enabled investigations of phenomena that were previously not possible and have enabled the confirmation of previously unsubstantiated ideas. For instance, innovation surveys have shown that a high proportion of firms innovate; that a great deal of innovation is taking place in the services as well as in manufacturing; that innovation affects the performance of firms in terms of profitability, productivity and employment generation; and that innovation policies are targeted to large firms more than to small ones. However, despite substantial progress, there are still drawbacks to innovation surveys. For instance, definitional issues (What is a technological innovation? What is an innovative firm?) have not all been solved and statistical methodologies are not identical across countries. Easier access to micro-level data by analysts will be necessary to allow the flourishing of studies that would facilitate an evaluation of the data and provide useful information to policy makers.

"To Be or Not to Be Innovative: An Exercise in Measurement", by *Jacques Mairesse and Pierre Mohnen*, proposes an econometric approach to innovation survey data, with a view to extracting as much information as possible from the basic data. They first check that the "micro-aggregation" procedure used for anonymising CIS data does not bias the characteristics of the population, coming to the reassuring conclusion that it does not. It is thus possible for statisticians and econometricians to use micro-aggregated data with little loss of information. They propose an econometric model for explaining the innovative performance of firms; they regress the share of new products in the sales of the firm on various factors such as size, industry, country, R&D performance, membership or not of a group. They propose an "indicator of innovativeness", which is the share of new products in sales which is not explained by the factors mentioned above. This indicator is similar to total factor productivity, in the sense that it is a residual from a model estimation, which captures the own performance of the concerned country or industry when certain known factors have been accounted for.

"Using Patent Counts for Cross-country Comparisons of Technology Ouput" by *Hélène Dernis, Dominique Guellec and Bruno van Pottelsberghe* examines the drawbacks associated with the traditional published patent-based indicators, and proposes solutions. Although patents have been used for calculating statistical indicators for decades, there is no broadly accepted methodology in this area. Indicators are usually weakly comparable across countries, and the years reported do not correspond to the year of invention (reflecting instead strategic or administrative delays in the submission, processing and publication of patent applications). The method proposed to solve these issues is to count only "patent families" (a set of patents taken out in various countries to protect a single invention), by "priority date" (first date of filing for protection worldwide). The use of such indicators would give a new picture of cross-country comparisons of technological performance.

"Improving Measures of Government Support to Industrial Technology", by *Alison Young*, reports a data collection exercise conducted by the OECD in 1993-98. The purpose was to collect more precise data on government programmes aimed at supporting industrial technology, and to classify such information in new ways that better reflect the type of relationship with the recipient. Three broad categories are proposed: grants and subsidies (including soft loans and tax reliefs), public procurement (mainly defence-related), and public infrastructure (direct and indirect contribution of public laboratories to industrial innovation). This goes far beyond the usually accessible data, which merely identify transfers of funds (from government to business), without identifying the type of underlying contract or transaction. The classification proposed in this article is clearly more appropriate to the analysis of innovation policies. Its drawbacks are that it requires large amounts of information, which is costly to collect, and which is sometimes viewed as confidential by governments.

"Measuring the Value of R&D Tax Treatment in OECD Countries", by *Jacek Warda*, develops the "B-index" methodology. Most OECD governments have introduced special fiscal measures for R&D, be it depreciation allowances or (increasingly often) R&D tax credits, notably for small and new firms. Their aim is to stimulate business R&D, as governments estimate that firms do not spend enough in this domain compared with other domains (such as physical investment). It is, however, difficult to compare such tax reliefs across countries as fiscal legislation is complex and multi-dimensional. The purpose of the B-index is to measure the after-tax cost of investment on R&D for a given pre-tax cost. The B-index takes into account both corporate income tax and tax reliefs related to R&D. It is based on a standard approach in the fiscal literature ("effective rate of taxation"). Comparisons of OECD countries along this scale point to large heterogeneity, and increasing generosity over the recent past.

What next?

What has been the contribution of the "New S&T indicators" project? Beyond the methodological results and indicators presented in this issue of the STI *Review*, two types of outcomes can be seen:

- *Regularly published indicators*: these include patents, investment in knowledge, the B-index, all of which are published in, for instance, the OECD's STI *Scoreboard* (OECD, 2001*c*).
- *Further methodological work in areas identified as especially important and difficult*: this includes HRST, R&D in national accounts, investment in knowledge, innovation indicators and patents. In all of these areas, the OECD has initiated special projects that should lead to new indicators in the future.

For HRST, co-operation of S&T statisticians with labour and education statisticians will allow to improve the methodology ("Canberra Manual"), broaden the range of countries which collect data, and refine the detail of these data. A review of statistical sources and problems in the field of international mobility is engaged.

For a better integration of R&D data and national accounts, a task force with experts in both fields is to be set up, which will examine how R&D data could accommodate the SNA framework, and how the SNA should be adapted to take into account the specificities of R&D.

For investment in knowledge, the methodology is still in its infancy. One avenue of future work is to broaden the scope of the concept so as to better capture expenditure on training or on design. This must be related also to national accountants' efforts to improve the measurement of expenditure on software, and that of R&D in the services so as to better capture this R&D which is not essentially on technology (which is a major component of the revision of the *Frascati Manual*).

For innovation, OECD is closely following the progress of innovation surveys in Europe and other countries. With an expanded range of countries conducting such surveys and improved comparability of the data, further work on indicators may become possible in the near future and will be reflected in a coming revision of the *Oslo Manual*.

For patents, ongoing work at OECD aims to design, calculate and test various types of indicators: indicators of output (at aggregate and industry levels), indicators of linkages (between firms, between the public and business sectors, between countries, between technology lines).

Dominique Guellec

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INVESTMENT IN KNOWLEDGE

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This article was prepared by Mosahid Khan of the Economic and Statistical Analysis Division of the OECD's Directorate for Science, Technology and Industry. It makes use of a report prepared on behalf of the OECD and the Dutch Ministry of Economic Affairs by M.M Croes (CBS, Statistics Netherlands), "Data for Intangibles in Selected OECD Countries", December 2000.

I. INTRODUCTION

Expenditure on R&D, education and software can be considered as investment in knowledge, which is a crucial factor in determining economic growth, job creation and improved living standards. R&D, higher education and software expenditures have in common that they produce new knowledge, be it technology, human capital or computer programs. This article provides an international comparable estimate of investment in knowledge for 24 OECD countries for the period 1990-98, using a narrow definition of investment in knowledge (*i.e.* including only expenditure on research and development, higher education, and software). Estimating total investment in knowledge is problematic because of the lack of an internationally agreed definition, insufficient information on the overlap between the categories and limited data coverage in such areas as spending on innovation, design, job-related training, vocational training, etc.

Notwithstanding these measurement difficulties, it is possible to estimate internationally comparable figures of total investment in knowledge for the OECD countries. Latest available data show that total investment in knowledge now accounts for 4.7% of OECD-wide GDP, and the share is increasing over time. Within the major economic zones (the United States, Japan and the European Union), the United States has the most knowledge-intensive economy: total investment in knowledge amounts to 6.0% of GDP, in contrast to 4.7% for Japan and 3.6% for Europe. Furthermore, the United States and the European Union are moving more rapidly than Japan towards a knowledge-based economy.

The OECD aggregated level of investment in knowledge enshrouds the differences across countries. In 1998, the investment in knowledge to GDP ratio varied from 1.5% to 6.5%, with the share being lowest in Mexico, Greece and Portugal, at less than 2% of GDP, and highest in Sweden and the United States, at more than 6% of GDP. Domestic research and development expenditure (GERD) is the largest component of the investment in knowledge in smaller OECD countries, such as Sweden, Finland and Ireland. In addition, countries where the majority of the R&D is financed by industry tend to have high investment in knowledge.

The software component of investment in knowledge has been expanding rapidly during the 1990s. In 1998, it accounted for more than 1% of GDP for 16 OECD countries (excluding the overlap between R&D and software).

For the majority of the OECD countries, the higher education component of investment in knowledge accounts for the smallest share of the investment in knowledge total. Expenditure on higher education (excluding the overlap between R&D and education) exceeded 1% of GDP in eight countries only. Korea is the only country where the higher education expenditure component accounts for more than 2% of GDP.

The data indicate that the amount of money spent on investment in knowledge has increased considerably during the 1990s, more than expenditures for physical investment (gross fixed capital formation). In addition, the figures indicate that for most countries the pace of growth of investment in knowledge is higher than that of fixed capital investment.

Results of work carried out previously within this domain were reported in the 1999 OECD *Science, Technology and Industry Scoreboard* (OECD, 1999); however, the figures for investment in knowledge differ from the figures reported in this article for the following reasons:

- In this article, a narrow definition of investment in knowledge is used, compared to previous work. The broader definition of investment in knowledge includes education expenditure for all levels, while the narrow definition used here includes only higher education expenditures.
- In the previous study, due to limited data availability, only direct public expenditure for educational institutions was taken into consideration. For recent years, private expenditure for educational institutions has now become available and is included in the calculation of the total investment in knowledge.
- The overlap between R&D and software expenditure was identified and excluded from total investment, while in the previous study, it was not possible to exclude the overlap due to lack of information.
- In the previous study, the capital expenditure of the R&D component was excluded; in this article, it is included.

Work in this area is relatively new and is being continuously developed; the methodology is not yet stabilised. There are a number of issues, both at the conceptual level and the data-collection level that provide challenges to estimating internationally comparable figures for total investment in knowledge. At a conceptual level, the lack of a commonly agreed definition hampers the measurement of knowledge investment. Data availability is also a problematic area which requires further effort. For example, at present, data relating to spending by enterprises on job-related training programmes are extremely scarce; hence, they are excluded from the calculation of investment in knowledge. For these reasons, the figures presented in this article should be viewed as presenting a partial and provisional picture of total knowledge investment.

II. WHAT SHOULD BE CONSIDERED AS INVESTMENT IN KNOWLEDGE?

While the definition of (physical) investment is well accepted (SNA93),[1] there is lack of international consensus on the definition of investment in knowledge. For this reason, little is known of the magnitude of investment in knowledge over time and across countries. Development of indicators for investment in knowledge is important as such indicators are closely related to knowledge-based economies and can provide a picture of the structural changes taking place in the OECD economies and the extent to which they are becoming knowledge-based economies.

Investment in knowledge is defined in this article as "expenditures directed towards activities with the aim of enhancing existing knowledge and/or acquiring new knowledge or diffusing knowledge". The output of those expenditures is the "creation or diffusion of knowledge", but the input could be tangible. R&D, education and software expenditures can be considered as directed towards quantitative change or extension or diffusion of existing knowledge, or acquisition of completely new knowledge. Along with R&D, education and software expenditures, training, innovation and industrial design expenditures should be additional components of the total investment in knowledge.

For the purpose of this article, total investment in knowledge is defined and calculated as the sum of expenditure on R&D, on total higher education from both public and private sources and software. Simple summation of the three components would lead to overestimation of the investment in knowledge owing to overlap between the three components (R&D and software, R&D and education, software and education). Therefore, before calculating total investment in knowledge, the data require various transformations in order to derive figures that meet the definition.

- The R&D component of higher education, which overlaps R&D expenditure, was estimated and subtracted from total higher education expenditure.
- All software expenditures cannot be considered as investment, because some are considered as consumption. Purchases of packaged software by households and operational services in firms were estimated (using data from private sources) and excluded.
- The software component of R&D, which overlaps with R&D expenditure, was estimated using information from national studies and excluded from software expenditure.
- Owing to lack of information, it was not possible to separate the overlap between education and software expenditure; however, limited available information indicates that the overlap is quite small.

A more complete picture of investment in knowledge would also include other components. Owing to lack of data availability, it was not possible to include them:

- Data relating to expenditure on the design of new goods are collected from innovation surveys, but are only available for the European countries, along with a few other OECD countries. Furthermore, the data for the European countries are available for the reference year 1996 only.
- Data on spending by enterprises on job-related training programmes are scarce.
- Other components, such as investment in organisation, are even more difficult to estimate at this stage.

In contrast to the previous study, this article adopts the narrow definition of investment in knowledge. This results in the inclusion of higher education expenditure only, whereas in previous work educational expenditure for all levels was included. Expenditure on higher education is included rather than all education expenditure as it is assumed that this expenditure results in creation and diffusion of more sophisticated and or advanced knowledge, and is similar to R&D and software expenditure.

In this article, internationally comparable figures are estimated for investments in knowledge for 24 OECD countries for the period 1990-98, with the aim of providing an indication of the extent in which countries are moving towards knowledge-based economies. This article is based on earlier work commissioned by the OECD to Statistics Netherlands (Croes, 2000).[2] Improvements are made in the following areas: improvement of definition, inclusion of private educational expenditure and identification and exclusion of various overlaps between the three investment-in-knowledge components. Finally, it also highlights areas which will require further work in order to improve the measurement of investment in knowledge.

III. DATA SELECTION

Data for investment in knowledge can be compiled from either demand-side or supply-side data. Demand-side data include total expenditure of purchased software or total business enterprise sector expenditure in research and development. Supply-side data, on the other hand, are those such as turnover and sales figures of the computer services sector. From a theoretical point of view, demand-side data are preferred over supply-side data for measuring investment in knowledge because they provide the possibility to take into account structural differences in an economy. Furthermore, if the data are measured correctly (definition, coverage, etc.), they improve the international comparability of investment in knowledge. Another reason for using demand-side data is that they normally include internal production, whereas supply-side data exclude internal production. Therefore, using supply-side data may lead to underestimation of the investment figures.

As stated earlier, investment in knowledge consists of three components: R&D and innovation expenditure, educational and training expenditure, and software expenditure. For all three components, demand-side data are used.

R&D and innovation

Research and experimental development is defined as "… creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications" (OECD, 1993). R&D can be decomposed into three activities, basic research, applied research and experimental development. Technological product and process (TPP) innovations, on the other hand, are defined as "… implemented technologically new products and processes and significant technological improvements in products and processes" (OECD and Eurostat, 1997). TPP innovating activities, along with marketing for new or improved products and training directly linked to the innovative process, are counted as innovation. Parts of innovation expenditure, such as training or industrial design, should be considered as investment in knowledge. However, due to limited data availability and timeliness,[3] the innovation component of investment in knowledge is not included in the calculation of the total investment in knowledge (only the R&D component is included).

Demand-side R&D data (gross domestic expenditure on R&D – GERD) are taken from OECD's *Main Science and Technology Indicators* database (MSTI). For the purpose of estimating missing data points, data relating to three R&D categories are used: business enterprise R&D (BERD), higher education R&D (HERD), government R&D (GOVERD), along with total domestic R&D expenditure (GERD).

Although innovation data are not taken into account when measuring the total investment in knowledge, some innovation expenditure data are presented below for selected countries to provide some insight into the magnitude of investment.

Education and training

Education and training comprises three main categories: *i*) public spending on formal education; *ii*) spending for education by private households; and *iii*) spending by enterprises on job-related training programmes.

For a correct measurement of total investment in knowledge, all of the above three categories should be taken into consideration in estimating total investment in knowledge. However, lack of data means that spending by enterprises on job-related training programmes is excluded from the calculation of the total investment in knowledge. Data on vocational training are available for countries that participated in the Vocational Training Survey of the European Union. However, these data are not fully comparable due to differences in the definitions, coverage and reference periods (OECD, 1998*a*).

Education expenditure can be separated by level of education (primary, secondary and tertiary). Although education expenditures are available for all levels, only tertiary level expenditure (International Standard Classification of Education – ISCED 5 and 6) is included in the calculation of investment in knowledge, since it could be assumed that this expenditure results in the creation of "sophisticated knowledge"; higher education (tertiary) expenditure is therefore more comparable to R&D and software expenditures. Although education expenditures for all levels are not taken into consideration, they are reported below to provide some insight into the education priorities of individual countries.

Education expenditure are taken from the OECD's Education database. The data used here refer to direct and indirect expenditure on educational institutions from both public and private sources.

Software

In the *Frascati Manual* (OECD, 1994), software is defined as "the mandatory set of instructions for digital instrument operations". This comprises system software, tools software and application software. Investment in software consists of software purchased from third parties and internally produced software. All software expenditures cannot be considered as investment in knowledge; those expenditures on software which are not considered to be investment in knowledge need to be identified and excluded from the total. For example, expenditure relating to software upgrades, minor modifications, maintenance and support, etc., are not considered to be investment in knowledge and are therefore excluded from the total figure.

A few countries[4] have recently published official national estimates on software investment. These estimates are in the framework of the United Nations System of National Accounts (SNA). It would have been preferable to use official national estimates, but these are available for only seven countries; hence, data from a private source are used for complete coverage. Software expenditure data used here are taken from the International Data Corporation (IDC/WITSA, 1999). The demand-side data for software expenditures used in the IDC/WITSA report include packaged software, purchased IT services and internal IT services.

IV. ISSUES RELATED TO COMPARABILITY

The available R&D data for the OECD Member countries are of high quality as most of the OECD countries have a long tradition of collecting R&D data according to the guidelines outlined in the *Frascati Manual*. However, cross-country comparability may be hindered in some cases due to national specificities (*e.g.* due to differences in methods for selecting the statistical unit to be covered), although the magnitude of the differences is extremely small (hence the data do not require adjustment).

Similarly, education data are also of high quality and are compiled by the OECD according to standard guidelines. International comparability of the data may be hampered in some cases due to national peculiarities. However, these are assumed to have little impact on the overall investment in knowledge totals (hence no adjustment is performed on the data).

As the most recent IDC software data set only includes annual figures for the period 1992-99, estimates were made for 1990 and 1991. The estimates for both packaged software and purchased professional IT services are partly based on earlier published material that was brought into line with the latest figures. Internally produced professional IT services data for 1990 and 1991 were calculated by using information derived from the 1992-98 series and the US and Italian estimates on software investments produced on own account. As software investment produced on own account is only a small proportion of total investment in knowledge, it has little or no impact on the total.

As most of the figures presented here are expressed as percentages of GDP, it should be noted that, in compliance with the revised System of National Accounts (SNA93), several countries have revised their GDP figures. The effect of the revised GDP figure differs according to country. For example, in the case of the Netherlands, the revision raised GDP by 4%, while the average change for the Member States of the European Union is only 2%. Hence, the figures published here may be different from those published in earlier publications.

V. ISSUES RELATED TO OVERLAP

As mentioned above, there are three main areas of overlap between the different components of the investment in knowledge considered here: R&D with software, R&D with education, and education with software.

Software is not only a tool included in total R&D expenditure, it also may be the subject of R&D (software R&D). Furthermore, expenditure on software R&D

may be quite high; therefore, it should be excluded when estimating the software investment component of the total investment in knowledge.

Unfortunately, software R&D is not measured separately in R&D surveys, making it difficult to separate the overlap between R&D and software. However, to calculate a more "accurate" estimate of the total investment in knowledge, the overlap between R&D and software has to be excluded. Available R&D data for the computer services sector indicate that software R&D varies between 1% and 9% of BERD. Other national studies, which include all sectors, indicate that this percentage may be much higher, between 25% and 40%.[5]

Based on the available information from national studies, it was decided to separate the overlap by making an assumption that the overlap between R&D and software represents 25%. The assumption of a 25% overlap between R&D and software is on the high side; consequently, the total investments in knowledge reported here are conservative estimates. One criticism of this assumption would be that the size of the overlap varies across countries. While acknowledging this point, applying this assumption to exclude the overlap will represent a more "accurate" estimate of the total investment in knowledge than by including the overlap.

Another significant overlap is that between expenditures on education and R&D. Educational expenditure includes a part of R&D expenditure already included in gross domestic expenditure on R&D (GERD), namely R&D in the higher education sector (HERD). In principle, it should be relatively straightforward to estimate the overlap between R&D and education because of the availability of data in the OECD databases: one containing R&D expenditure in the higher education sector (the DSTI database); the other comprising overall expenditure in the higher education sector (Education database, DEELSA). However, for the result to be valid, two conditions have to be satisfied. The coverage of the national education database and the R&D database has to be identical and the coverage of the national education database and the R&D database has to be identical across countries. At present, the coverage of the two databases are not identical for all countries.

An earlier OECD study (OECD, 1998*b*) showed that the Education database and the R&D database are consistent for Germany and Sweden; however, for France, the Netherlands and the United Kingdom, subtracting HERD from total education expenditure results in a considerable underestimation of total public educational expenditure. Recent work in this area showed that for Australia, Denmark and the United States, the two databases are consistent, while for Canada, slight inconsistency exists between the databases, and for Finland, the coverage of the R&D database collection differs from that of the Education database. Unfortunately, no corrections can be made for those countries where the coverage of the data collections differs. Although subtracting could lead to an underestimation of investments in education for some countries, this method was chosen to exclude the overlap because an estimation excluding the overlap would be more "accurate" than one including it.

Finally, data on packaged software include purchases by educational institutes, thus creating an overlap between education and software. Data availability on the overlap is extremely limited; however, the available data indicate that the overlap is likely to be marginal.[6] Therefore, no correction is made for this overlap in the estimation of the total investment in knowledge. Moreover, when expenditure on vocational training is taken into account, expenditure on training as a result of, for example, the introduction of new software might lead to an overestimation of educational expenditures. As the expenditure on vocational training is not taken into account, there is no need for data correction.

VI. ESTIMATION OF INVESTMENT IN KNOWLEDGE

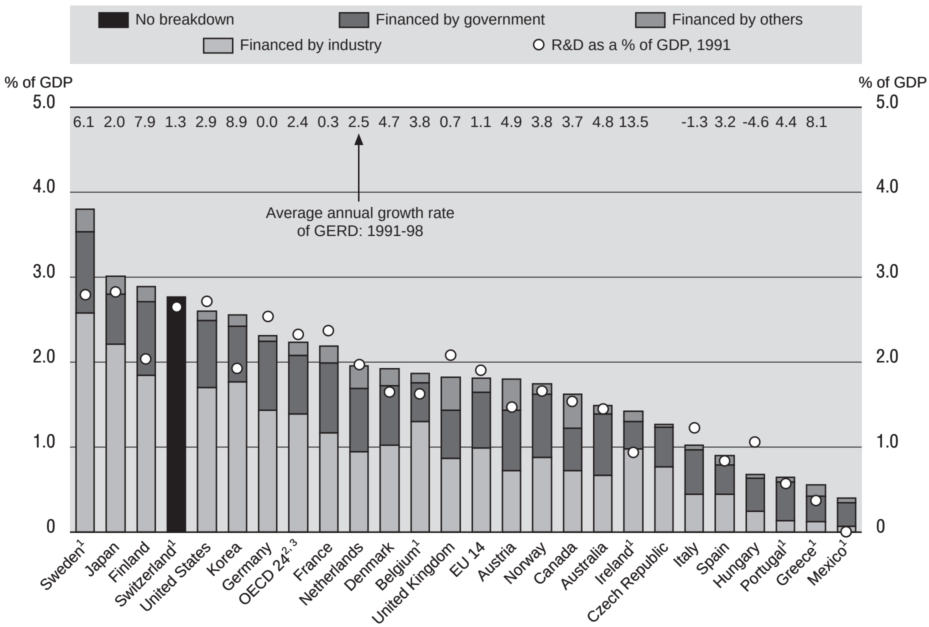
The R&D component of investment in knowledge

The R&D component of investment in knowledge should include both R&D expenditure and innovation expenditure. However, in this article, for the reasons outlined above, only total domestic R&D expenditure (gross domestic expenditure on R&D – GERD) is included for the investment in knowledge estimate, including both current and capital R&D expenditures.

In 1998, total R&D expenditure of the 24 OECD countries ranged from 3.8% to 0.4% of GDP, with the OECD-24 average being 2.2% (Figure 1). For major OECD regions, R&D expenditure relative to GDP trended downwards in the early 1990s. Since the mid-1990s, R&D intensity has increased continuously in Japan and the United States. In Japan, it was mainly due to the stagnation of GDP growth since 1997, rather than to a significant increase in R&D expenditure. In the United States, the increase is mainly due to an increase in R&D expenditure, as GDP grew rapidly. The share of GDP allocated to R&D is by far the highest in Sweden (3.8%), followed by Japan (3.0%) and Finland (2.9%), well above the OECD-24 average (2.2%). Both Sweden and Finland, along with Korea, increased the allocation of resources towards R&D relative to GDP between 1991 and 1998. This is in sharp contrast to the four large European countries, Germany, France, the United Kingdom and Italy, where the R&D expenditure to GDP ratio decreased over the same period. The general trend is that countries in which the majority of R&D expenditure is financed by industry tend to have high R&D intensities. However, there are two exceptions, Ireland and the Czech Republic, where the R&D intensities

Figure 1. **R&D component of investment in knowledge**

R&D expenditure as a percentage of GDP and sources of R&D financing, 1991 and 1998



1. OECD estimates.
2. Growth rate and 1991 value exclude Mexico.
3. Breakdowns by source of finance refer to total OECD as reported in MSTI, but the R&D as a percentage of GDP refer to OECD 24.

Source: OECD, MSTI database, March 2001.

are at the lower end of the spectrum although the share of R&D financed by industry is relatively high.

R&D data availability for the reported countries is fairly comprehensive for the period 1990-98. However, for a few countries, some data points were missing, and these were estimated using either the simple adjacent years method or a linear trend extrapolation.

The innovation component of investment in knowledge

For reasons mentioned earlier, part of the innovation expenditure that is considered to be investment in knowledge is not taken into account; however, some data are presented in Table 1 to provide an indication of the magnitude of innovation expenditure. Innovation comprises a range of activities, including R&D. When both manufacturing and services are considered, Second Community Innovation Survey (CIS-2) data show that between 2% and 8% of GDP are spent on innovation (Table 1). For other separate innovation items, such as training and marketing, the expenditures are less than 1% of GDP.

Table 1. **Innovation expenditure as a percentage of GDP, 1996**

	A1	A2	B	C	D	E	F	G	H	I
	GERD[1]	BERD[2]	Innovation[1]	Non-machines (sum of D-H)	Industrial design	Training	Marketing	External technology	Other	Total machines and equipment
Austria	1.6	0.8	2.3	1.5	0.1	0.1	0.2	0.2	1.0	0.7
Belgium	1.8	1.3	1.7	1.1	0.2	0.0	0.1	0.1	0.7	0.5
Denmark	1.9	1.1	3.0	1.9	0.2	0.1	0.3	0.2	1.0	1.1
Finland	2.5	1.7	3.4	2.5	0.1	0.0	0.4	0.1	1.8	0.9
France	2.3	1.4	2.1	1.9	0.1	0.0	0.1	0.1	1.6	0.2
Germany	2.3	1.5	6.7	5.8	0.3	0.1	0.2	0.4	4.8	0.9
Netherlands	2.0	1.1	2.5	1.6	0.1	0.2	0.1	0.1	1.1	0.9
Norway[3]	1.7	0.9	1.7	1.1	0.1	0.1	0.1	0.1	0.7	0.6
Sweden	3.6	2.7	7.7	6.5	0.6	0.2	1.0	0.8	4.0	1.2
United Kingdom	1.9	1.2	3.1	2.0	0.4	0.2	0.2	0.4	0.8	1.1

1. Total economy.
2. Enterprise only.
3. 1997.

Source: OECD for R&D data; Eurostat for innovation data.

The education and training component of investment in knowledge

Education data are collected by the OECD's Directorate for Education, Employment, Labour and Social Affairs (DEELSA). For the calculation of the education component of investment in knowledge, both public and private expenditure are taken into account. Total educational expenditure is defined as the sum of direct public expenditure for educational institutions, public subsidies to households and other private entities (excluding public subsidies for student living costs) and private payments to educational institutions (excluding public subsidies to households and other private entities).

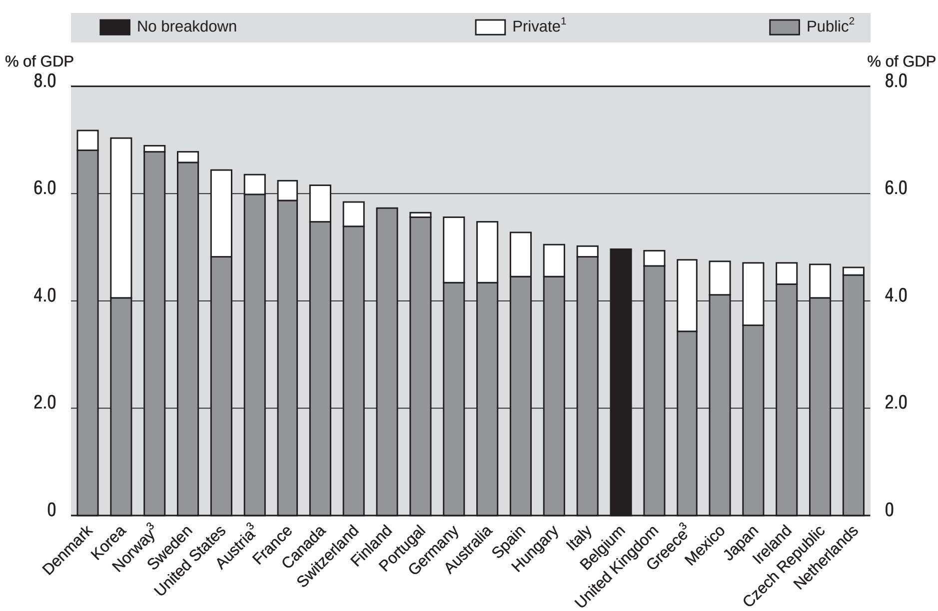
Public spending for education data often refers to total payment for the whole of the educational sector – it includes investments in "teaching and education" as well as expenditures for other tasks that cannot be considered to be investment in knowledge. Some support service and maintenance is a good example of education expenditure which cannot be considered as investment in knowledge. However, at present, it is not possible to exclude such expenditures from total education expenditure, due to lack of information.

Availability of direct public expenditure for educational institutions for the sample countries between 1990-98 is quite comprehensive for all the countries except Mexico. The missing data points were estimated using either the simple adjacent years method or a linear trend extrapolation.

Public subsidies to households and other private entities (excluding public subsidies for students' living costs) data are available from 1993-98 for the majority of the countries; however, data for a few countries (Belgium, Japan and Korea) are missing for all the years. The missing data for 1990-92 were estimated using the available information on transfers and payments to private entities and linear trend extrapolations.

Figure 2. **Education component of investment in knowledge**

Expenditure on educational institutions as a percentage of GDP by source of fund, 1998
All levels of education

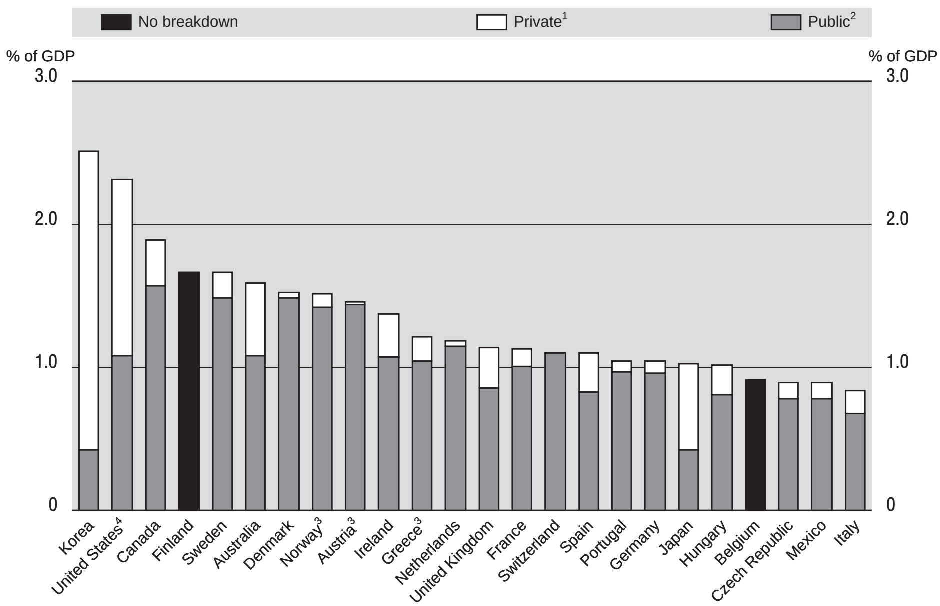


1. Net of public subsidies attributable to educational institutions.
2. Including public subsidies to households attributable for educational institutions. Including direct expenditure on educational institutions from international sources.
3. Public subsidies to households not included in public expenditure, but in private expenditure.

Source: OECD, Education database, March 2001.

Figure 3. **Education component of investment in knowledge: higher education (ISCED 5 and 6)**

Expenditure on higher educational institutions as a percentage of GDP by source of fund, 1998



1. Net of public subsidies attributable to educational institutions.
2. Including public subsidies to households attributable for educational institutions. Including direct expenditure on educational institutions from international sources.
3. Public subsidies to households not included in public expenditure, but in private expenditure.
4. Includes post-secondary non-tertiary.

Source: OECD, Education database, March 2001.

Data availability on private payments to educational institutions is similar to that of public subsidy data. With the exception of Belgium, Greece and Norway, educational expenditures from private sources are available for all the countries for the 1993-98 period. Similar to other components of educational expenditure, the missing data points were estimated using the available information and linear trend extrapolation.

Data relating to educational expenditure are available by level of education: primary, secondary and higher education. For the calculation of the total investment in knowledge, only the higher education (ISCED 5 and 6) expenditure is taken into consideration. However, some data relating to all levels of educational expenditure are presented below to provide some insight into the resources allocated to each level of education.

Educational expenditure for all levels is quite large across the OECD countries. The majority of the countries allocated more than 5% of GDP in 1998 (Figure 2). Denmark and Korea are the only countries where educational expenditure amounted to slightly more than 7% of GDP, far above the ratio of the Netherlands (4.6%), the Czech Republic (4.7%) and Ireland (4.7%). Although these percentages provide an indication of investments in education, they do not present the whole picture. Low or high percentages can be a reflection of differences in the various countries' educational systems as well as socio-economic factors.

Although for all the countries, the majority of educational expenditure is financed by the public sector, a significant proportion of total expenditure on education is financed by the private sector. Of the 24 countries reported here, funds from the private sector account for more than one-fifth of total educational expenditure in Korea (42%), Greece (28%), the United States (25%), Japan (25%), Germany (22%) and Australia (21%).

Similar to educational expenditure for all levels, educational expenditure for higher education (as a percentage of GDP) varies across countries (Figure 3). Korea and the United States are the only countries where higher educational expenditure amounts to more than 2% of GDP (more than twice the ratio of Italy, Mexico, the Czech Republic and Belgium). However, data for the United States should be interpreted with a degree of caution as they include post-secondary and non-university educational expenditure (ISCED 4). It is not possible to separate and exclude the ISCED 4 expenditure from total higher educational expenditure, although available information suggests that this proportion is relatively small.

Comparing the ranking of educational expenditure for all levels with those for higher education provides some indication of national specificity. Denmark ranks first when education expenditure for all levels is taken into calculation; however, when countries are ranked according to higher educational expenditure, it goes down to seventh place. The rankings of the Netherlands and Ireland improve when only higher educational expenditures are taken into account.

The share of expenditure from private sources for higher educational is double the share of expenditure from private sources for all levels of educational expenditure. Higher educational expenditure from private sources accounts for the largest share of total higher educational expenditure in Korea (83%), Japan (59%) and the United States (53%). Private sources account for about one-third of total higher educational expenditure in Australia, and around one-quarter in Spain and the United Kingdom.

Other expenditures on education and training

As we have shown, public expenditures on education are high. However, investments in education and training are underestimated as they should also include training efforts undertaken by firms (vocational training). The resources allocated for vocational training by enterprises are of a similar level to private payments to educational institutes. Unfortunately, data on firm-based training are scarce, although the available data suggest that firms spend about 2% of total labour costs on vocational training (*i.e.* about 1% of GDP). However, when these figures are compared with those for training expenses for innovation (Second Community Innovation Survey of the European Commission), the picture becomes less clear. Training expenditures incurred for innovation make up around 30% of total expenses on vocational training in the Netherlands, while the corresponding figure for Belgium is no more than 6% (Table 2). The large differences between countries indicate a certain amount of bias in the measurements for training expenses incurred for innovation.

Table 2. **Expenditure for training for selected OECD countries**

	Vocational training[1]	Training for innovation[2]
Belgium	0.5	0.03
Denmark	1.2	0.13
France	n.a.	0.02
Germany (new *Länder*)	0.8	0.09
Netherlands	0.6	0.17
United Kingdom	1.3	0.18
United States	1.0	n.a.

Note: Figures are not comparable to other data due to changes in GDP.
Sources: 1. *Scholing van werkenden: enn vergelijking tussen laden*, Max Groote Rapport, 1997.
2. Eurostat.

The software component of investment in knowledge

Data relating to software expenditure are not available at the OECD; however, they are available from various private sources. The software data reported here are taken from ICD/WITSA (1999).

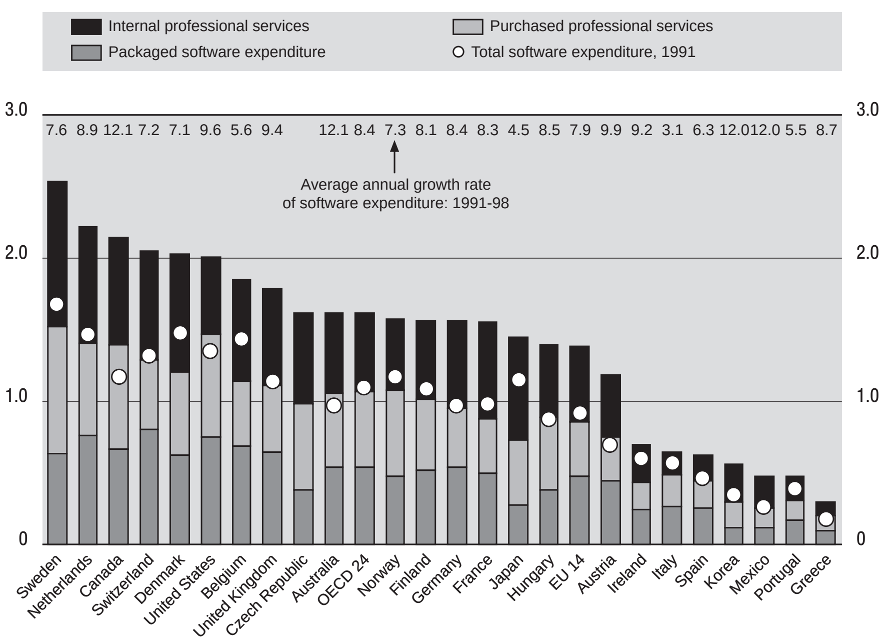
As mentioned above, software data include expenditure figures on packaged software, purchased IT services and expenditure for internal IT services. Not all expenditures on packaged software should be taken into account for the calculation of total investment in knowledge. Purchases for software upgrades with minor modification and maintenance related to package software should not be considered as investment in knowledge; they are operational expenditure. Due to limited information, it was not possible to exclude such purchases from the total; hence, the software component is somewhat overestimated.

IT services include both purchased and internal services. However, some IT services are clearly operational expenditure rather than investment in knowledge and they should thus be excluded. Separate figures for purchases of investments in professional IT services (defined as consulting and implementation)[7] and purchases of operational IT services (*e.g.* hardware support services) are available. Data for 1994-99 on the shares of IT professional services indicate that, in general, the share of professional services ranges between 30% and 60% of total services.[8] Shares for 1990-93 are estimated by a linear regression on the available shares. Unfortunately, the data series do not include similar itemised information for "professional internal services". Therefore, it is assumed that the annual shares of "professional internal services" are similar to those of the annual estimated shares on "purchased professional services".

The software expenditure presented in Figure 4 includes only the amount considered to be investment in knowledge, hence the data reported does not represent the total software expenditure of individual countries.

Figure 4. **Software component of investment in knowledge**

Software expenditure as a percentage of GDP, 1991 and 1998



Source: OECD based on data from International Data Corporation, March 2001.

The software component of investment in knowledge of the 24 OECD countries can be clustered into three groups. The high software expenditure group includes Sweden, the Netherlands, Canada, Switzerland, Denmark and the United States, where software expenditure in 1998 amounted to more than 2% of GDP. The medium software expenditure group includes the Czech Republic, Australia, Norway, Finland, Germany and France, where software expenditure in 1998 amounted to about 1.6% of GDP. Countries in the low software expenditure group allocated less than 1% of GDP for software expenditure.

During 1990, the ratio of software expenditure to GDP increased for all the reported countries; however, the rate of increase varied across countries. The software expenditure to GDP ratio increased by more than 0.7 percentage points in Canada, Sweden, the Netherlands and Switzerland, whereas in the Southern European countries, plus Ireland, the increase in the ratio was low.

Comparing software estimates and data from national statistics

At least seven countries have published estimates on total software investment. Only three other countries (Italy, the Netherlands and the United States) are able to provide separate data on purchased software and software produced on own account. Table 3 provides a comparison between private and national

Table 3. **Comparison between estimates based on IDC data and estimates from National Accounts**

Billions of national currency, except Italy – in trillion

	1990		1995		1997	
	Estimates (IDC)	National Accounts	Estimate (IDC)	National Accounts	Estimates (IDC)	National Accounts
Total software						
Australia	3.8	5.7	5.9	6.7	7.5	7.6
Belgium	82.5	:	110.3	59.1	133	64.6
Finland	4.4	5.7	6.1	6.7	7.4	7.6
France	57.2	27.9	91.1	35.7	113.9	52.5
Italy	7.0	8.0	10.7	10.3	11.8	12.3
Netherlands	6.8	4.6	10.2	5.3	12.4	6.9
United States	74.1	66.3	117.1	108	144.3	137.4
Purchased software						
Italy	4.9	5.5	7.9	7.5	8.7	9.3
Netherlands	3.2	3.6	5.7	3.9	6.6	4.4
United States	40.1	37.2	73.4	65	98.5	90
Own account software						
Italy	2.0	2.5	2.8	2.8	3.1	2.9
Netherlands	3.6	1.0	4.5	1.4	5.8	2.5
United States	33.9	29.1	43.6	43.0	45.8	47.4

sources. For four countries (Australia, Finland, Italy and the United States), the absolute level of total software investment in 1997, as estimated here, is about the same as that shown in National Accounts estimates. For the other countries, the estimates presented in this article are almost twice as high. Itemised figures for the Netherlands and the United States indicate that these increases may be caused by an overestimation of purchased software. However, the difference between the 1990-97 growth of the software figures as estimated here and those from the National Accounts is small for the countries that have a good match between the absolute figures of IDC and National Accounts (Australia, Finland, Italy and the United States).

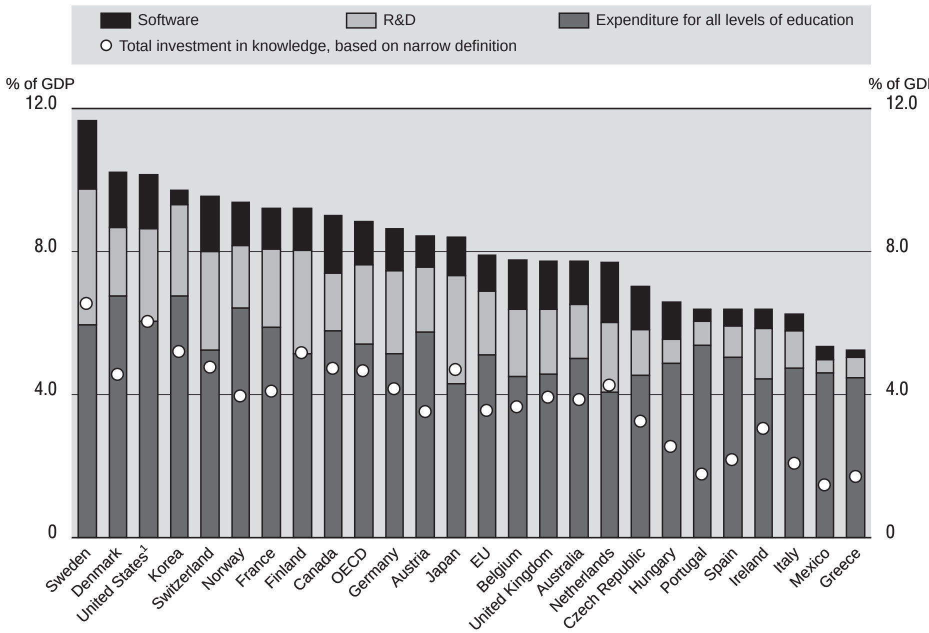
VII. TOWARDS A KNOWLEDGE-BASED ECONOMY?

To what extent are the OECD countries becoming "knowledge-based" economies? To obtain an indication of the extent to which countries are moving towards a knowledge-based economy, total investment in knowledge is calculated for 24 OECD countries for the period 1990-98. The three components of investment in knowledge (R&D expenditure, higher educational expenditure and software expenditure) are combined after adjusting the data to exclude overlaps and to exclude certain software expenditures which are not considered to be investment in knowledge. Furthermore, the education component of the investment in knowledge *only* includes the higher educational expenditure (ISCED 5 and 6).

Figure 5 provides data for total investment in knowledge as a percentage of GDP for 24 OECD countries for 1998, using both a narrow and a broader definition of investment in knowledge. If investment in knowledge is defined in a broader sense (which includes educational expenditure for all levels along with R&D and software expenditure), total investment in knowledge for the OECD-24 would amount to 8.8% of GDP. The investment in knowledge to GDP ratio for Sweden, Denmark and the United States would exceed 10%, almost twice the ratio of Greece and Mexico.

However, for the reasons mentioned above, investment in knowledge is defined here in a narrow sense, which includes R&D, software and higher educational expenditure. Figure 6 shows total investment in knowledge using a narrow definition broken down by components. In 1998, total investment in knowledge for the OECD-24 area amounted to about 4.7% of GDP (Figure 6). Of the major economic zones, the United States is the most knowledge-based economy, with an investment in knowledge to GDP ratio of 6.0%, compared to 4.7% and 3.6% for Japan and the European Union, respectively. Along with the United States, Sweden, Korea and Finland also have high investment in knowledge to GDP

Figure 5. **Investment in knowledge based on broad definition (including all levels of education) as a percentage of GDP, 1998**



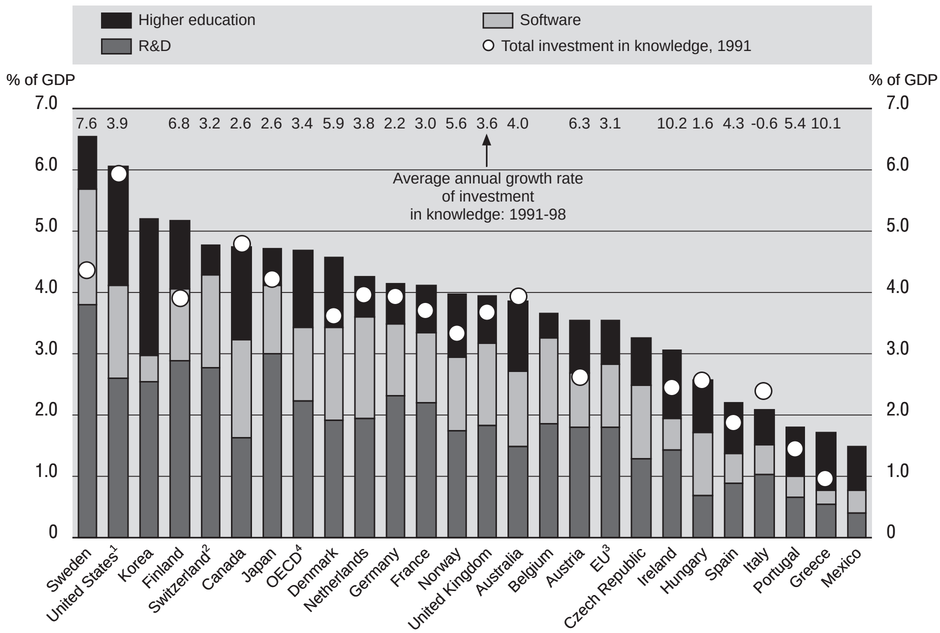
1. Investment in knowledge based on narrow definition, includes post secondary non-tertiary education (ISCED 4).
Source: OECD, MSTI database and Education database; International Data Corporation, March 2001.

ratios, whereas the southern European countries plus Mexico have some of the lowest investment to GDP ratios.

Analysis of overall investment in knowledge by components provides additional details of the structure of the investment in the countries studied. In Sweden, Finland, Switzerland, Japan, Germany, France, Belgium and Austria, R&D expenditure is the major component of total investment in knowledge, accounting for more than 50% of the total. For both Mexico and Greece, total investment in knowledge depends mainly on high educational expenditure, accounting for around half of the total. Total investment in knowledge in Hungary, on the other hand, primarily depends on software expenditure, which accounts for about two-fifths of the total.

During the 1990s, the investment in knowledge to GDP ratio increased significantly in three Nordic countries (Sweden, Finland and Denmark) and Austria,

Figure 6. **Investment in knowledge based on narrow definition (including higher education only) as a percentage of GDP, 1991 and 1998**



1. Includes post secondary non-tertiary education (ISCED 4).
2. Growth rate refers to 1992-98.
3. Growth rate excludes Belgium.
4. Growth rate excludes Belgium, the Czech Republic, Korea, Mexico and Switzerland.

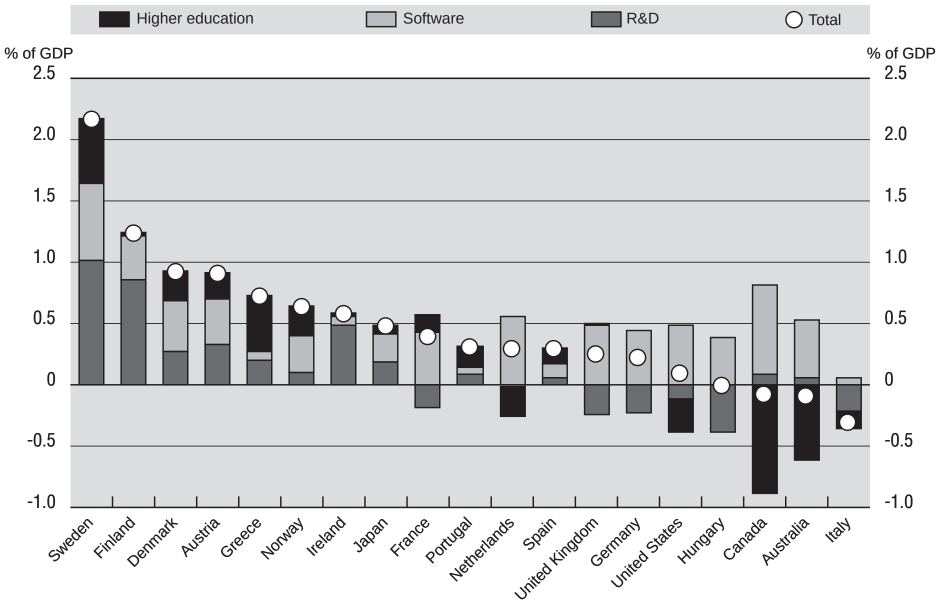
Source: OECD, MSTI database and Education database; International Data Corporation, March 2001.

while decreasing slightly in Canada, Australia and Italy. However, it should be noted that this decrease in the investment in knowledge to GDP ratio is due to higher growth in GDP rather than to a decrease in investment in knowledge (total investment in knowledge in Canada and Australia increased by 2.6% and 4.0% annually between 1991-98).

For most of the countries, the source of increase in investment in knowledge during the 1990s is the software component; this is most notably the case in the Netherlands, the United Kingdom and the United States (Figure 7). In both Canada and Australia, software expenditure relative to GDP increased significantly, although the increase in the software component was outweighed by the decrease in higher education expenditure, resulting in an overall decrease in investment in knowledge. The source of the total increase in investment in

Figure 7. **Source of change in investment in knowledge between 1991-98 as a percentage of GDP**

Difference between 1991 and 1998 ratios

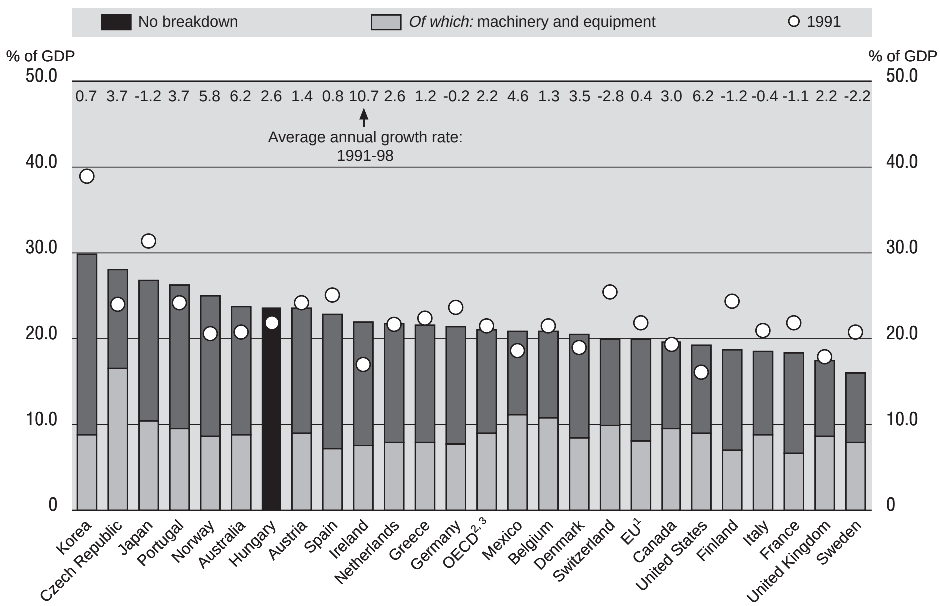


Source: OECD, MSTI database and Education database; International Data Corporation, March 2001.

Ireland, Finland and Sweden is the R&D component. Growing R&D expenditure accounted for almost all of the increase in investment in knowledge in Ireland, around two-thirds in Finland, and little under half in Sweden. An increase in higher education expenditure was the main source of the rise in investment in knowledge in Greece.

Comparing the evolution of investment in knowledge with that of gross fixed capital formation (GFCF) over the 1990-98 period shows that the majority of the OECD countries have been moving towards a knowledge-based economy. The average annual growth rate of investment in knowledge was higher than that of fixed capital for all countries, except Australia, Canada, Hungary, Ireland, Italy, Norway and the United States, where the rate of growth of GFCF was similar to or higher than that of investment in knowledge. This could be partly due to the inclusion of some components of investment in knowledge, such as software expenditure, in the calculation of fixed capital investment. GFCF also includes investment in facilities used for R&D, education and software. The share of gross fixed capital formation relative to GDP in Korea, Finland, Switzerland, Sweden and Japan decreased by more than 4.5 percentage points between 1991 and 1998 (Figure 8).

Figure 8. **Gross fixed capital formation as a percentage of GDP, 1991-98**



1. Growth rate excludes Belgium.
2. Growth rate excludes Belgium, the Czech Republic, Korea, Mexico and Switzerland.
3. Machinery component share of the OECD excludes Hungary.

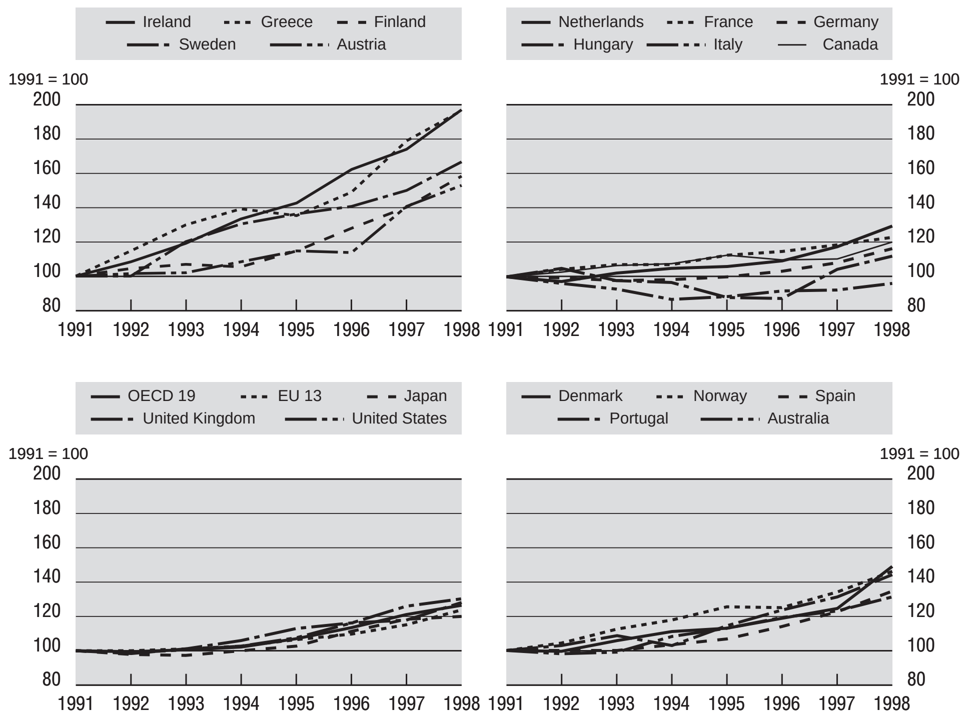
Source: OECD, National Accounts database, March 2001.

The evolution of investment in knowledge in the smaller OECD countries (Ireland, Greece, Sweden, Finland and Austria), has been extremely dynamic, whereas in large OECD countries (the United States, Japan, Germany, France and the United Kingdom), the significant increase in investment in knowledge occurred from the mid-1990s onwards (Figure 9 and Table 4).

During the 1990s, for most countries, the rate of increase of the index of investment in knowledge was higher than that of gross fixed capital formation. The notable exceptions to the general trend are Australia, Italy and the United States.

Figure 9. **Evolution of investment in knowledge, 1991-98**

1991 = 100



Source: OECD, MSTI database and Education database; International Data Corporation, March 2001.

However, as mentioned earlier, the fact that the index of gross fixed capital is higher than that of investment in knowledge in Australia, Italy and the United States may be due to the inclusion of some high-growth component of investment in knowledge (such as software) in the calculation of gross fixed capital formation.

Table 5 provides another indicator to track the evolution of investment in knowledge and gross fixed capital formation. A high ratio would indicate that relatively more money is spent on investment in knowledge as compared to gross fixed capital formation. The ratio varied across countries, ranging from 0.07 (Portugal) to 0.41 (Sweden) in 1998. The Nordic countries (Sweden, Finland and Denmark), Canada, the United States, France and the United Kingdom have a relatively high investment in knowledge to fixed capital investment ratio. For the majority of the

Table 4. **Evolution of investment in knowledge and gross fixed capital formation**
Constant prices, 1991 = 100

	Investment in knowledge				Gross fixed capital formation				Difference			
	1992	1994	1996	1998	1992	1994	1996	1998	1992	1994	1996	1998
Australia	98	108	119	131	107	126	133	153	–9	–18	–14	–21
Austria	102	109	114	153	99	102	105	110	2	7	9	43
Canada	102	108	110	120	96	103	102	123	6	5	8	–3
Denmark	100	111	119	149	94	96	109	127	5	15	10	22
Finland	105	106	128	158	79	63	75	92	26	42	53	66
France	104	107	115	123	97	89	89	93	7	18	26	30
Germany	99	98	103	116	103	101	97	99	–4	–3	6	18
Greece	115	139	149	196	95	83	91	108	20	56	58	88
Hungary	105	96	87	112	92	95	99	120	13	1	–12	–8
Ireland	108	134	162	197	102	108	145	204	7	25	17	–7
Italy	96	87	91	96	98	87	93	97	–2	–1	–1	–1
Japan	98	100	112	120	98	93	102	92	0	7	10	28
Netherlands	97	104	109	130	100	98	108	120	–3	7	1	9
Norway	105	118	125	146	97	107	123	148	8	11	2	–2
Portugal	103	103	123	144	98	93	105	129	5	10	19	16
Spain	100	103	114	135	92	85	92	106	8	19	22	29
Sweden	100	130	141	167	86	73	79	85	14	58	61	81
United Kingdom	98	106	116	128	92	95	105	116	6	11	12	12
United States	99	102	116	130	103	118	132	152	–4	–15	–15	–22
OECD-19	99	102	113	126	99	101	109	117	0	1	5	10
EU-13	100	102	110	124	97	92	96	103	2	10	14	21

Source: OECD, MSTI database and Education database, National Accounts database; International Data Corporation, March 2001.

countries, the ratio followed an upward trend during the 1990s, most notably in. Sweden and Finland (Figure 10).

VIII. CONCLUSION

The data reported in this article provide some insight into the magnitude of knowledge investment in the OECD countries and the structure of investment in knowledge and fixed capital formation and the dynamics over time.

As mentioned, various issues relating to the calculation of the total knowledge investment indicators require further efforts in order to estimate figures according to the definition adopted here. The availability of data relating to training expenditure by firms is at present scarce. Available information shows the expenditure in this area to be quite substantial; therefore, efforts should be made

Table 5. **Ratio of knowledge investment over physical investment, 1991-98**
Based on constant prices

	1991	1992	1993	1994	1995	1996	1997	1998
Australia	0.19	0.17	0.16	0.16	0.17	0.17	0.16	0.16
Austria	0.11	0.11	0.11	0.12	0.12	0.12	0.14	0.15
Canada	0.25	0.26	0.28	0.26	0.28	0.27	0.23	0.24
Denmark	0.19	0.20	0.22	0.22	0.20	0.21	0.20	0.22
Finland	0.16	0.21	0.27	0.27	0.27	0.27	0.27	0.28
France	0.17	0.18	0.20	0.20	0.21	0.22	0.23	0.22
Germany	0.17	0.16	0.16	0.16	0.17	0.17	0.18	0.19
Greece	0.04	0.05	0.06	0.07	0.07	0.07	0.08	0.08
Hungary	0.12	0.13	0.13	0.12	0.11	0.10	0.11	0.11
Ireland	0.14	0.15	0.18	0.18	0.17	0.16	0.14	0.14
Italy	0.11	0.11	0.12	0.11	0.11	0.11	0.11	0.11
Japan	0.13	0.13	0.14	0.14	0.15	0.15	0.16	0.18
Netherlands	0.18	0.18	0.19	0.19	0.19	0.18	0.19	0.20
Norway	0.16	0.17	0.18	0.18	0.18	0.16	0.16	0.16
Portugal	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07
Spain	0.07	0.08	0.09	0.09	0.09	0.09	0.09	0.10
Sweden	0.21	0.24	0.36	0.38	0.37	0.37	0.40	0.41
United Kingdom	0.21	0.22	0.23	0.23	0.23	0.23	0.22	0.23
United States	0.37	0.35	0.34	0.32	0.32	0.32	0.33	0.31
OECD-19	0.21	0.21	0.22	0.22	0.22	0.22	0.23	0.23
EU-13	0.15	0.15	0.17	0.17	0.17	0.17	0.18	0.18

Source: OECD, MSTI database, Education database, National Accounts database; International Data Corporation, March 2001.

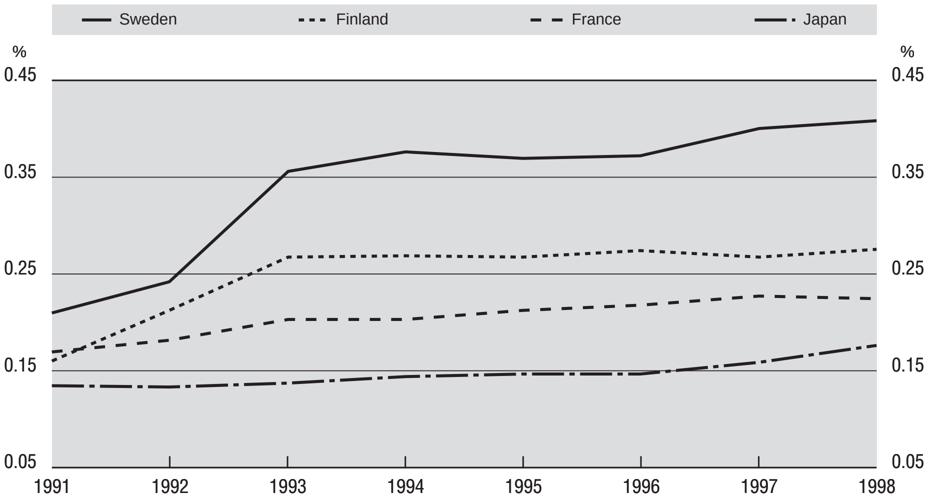
to include those data in the total knowledge investment calculation. The availability of innovation data is also extremely limited; for example, innovation data are available for the countries of the European Union; however, the latest available data refer to 1996 reference year.

The overlap between higher education and R&D was corrected for by subtracting the higher education R&D from education expenditure. However, studies in this domain have shown that this approach may result in underestimation of education expenditure for some countries as the education and R&D databases do not have same coverage. In this area, further work is required to make the databases compatible.

Furthermore, data relating to the overlap between education and software need to be excluded from the calculation of the total knowledge investment; however, due to lack of information, it has not been possible to exclude this overlap. It is hoped that in the future this will be remedied.

The overlap between R&D and software was estimated and excluded based on limited available information. In this area, too, further work is required, specifi-

Figure 10. **Ratio of knowledge investment over physical investment, 1991-98**



Source: OECD, MSTI database, Education database, National Accounts database; International Data Corporation, March 2001.

cally with regard to the collection of information on the magnitude of overlap between the two components.

The availability of software expenditure data within the SNA framework is limited. Further efforts are required in this area to compile an internationally comparable data set; this would considerably improve the measurement of investment in knowledge indicators.

NOTES

1. Total investment figures refers to gross fixed capital formation which is defined in the SNA93 (System of National Accounts, 1993) as: "measured by the total value of a producer's acquisitions, less disposals, of fixed assets during the accounting period plus certain additions to the value of non-produced assets realised by the productive activity of institutional units. Fixed assets are tangible or intangible assets produced as outputs from processes of production that are themselves used repeatedly or continuously in other processes of production for more than one year."
2. This article makes use of a report prepared on behalf of the OECD and the Dutch Ministry of Economic Affairs (Croes, 2000).
3. Of the 24 countries for which investment in knowledge is calculated, innovation data are available for both services and manufacturing in only half of the countries; latest available data for the European countries refer to reference year 1996.
4. Those countries that have published estimates for software investments are Australia, Belgium, Finland, France, Italy, the Netherlands and the United States.
5. A Dutch study found that almost 25% of R&D by firms (BERD) can be labelled as software R&D (CBS/Statistics Netherlands, 2000). Canadian R&D survey data indicate that this percentage may rise as high as 36% of BERD [Software Research and Development (R&D) in Canadian Industry 1995, Service Bulletin Science Statistics, Vol. 21, No. 6, July 1997].
6. According to the EITO 1997 report, 2% (data for 1995) of the software market is accounted for by consumer applications. This small share is confirmed in data from the US Bureau of Economic Analysis, indicating that 3% (data for 1992) of custom and prepackaged software is purchased by private households. IDC country data on the number of installed PCs suggests that between 40% and 60% of installations are by private households. Less than 10% of total installations are in the education market.
7. These items include business process reengineering, process improvement, external customisation of software and IT training and education.
8. In this report the estimates for professional services are calculated by using the shares found in the EITO publication. Unweighted average shares were used for countries (Australia, Canada, Japan, United States) for which no specific information is included in the EITO publication.

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CONSTRUCTING INTERNATIONALLY COMPARABLE INDICATORS ON THE MOBILITY OF HIGHLY QUALIFIED WORKERS: A FEASIBILITY STUDY

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I. SUMMARY

The starting point for this analysis was OECD work on the need for mobility indicators and the inventory of various available sources and special studies (Rosengren, 1998). The objective was to examine in detail a selection of the data sources and studies listed in Rosengren and to identify additional national and international sources, with the aim of evaluating their potential usefulness in the construction of internationally comparable indicators on the mobility of the highly qualified. Australia, Belgium, Finland, France, Germany, Korea, Italy, Spain, the United Kingdom and the United States participated in the study. This article describes a first attempt to construct indicators from international sources and from national sources in three countries (the United States, France and the United Kingdom) and provides conclusions and recommendations for future work.

Three types of mobility indicators were examined:

- Between firms and other organisations.
- Between research-producing sectors and research-using sectors.
- International mobility.

Four different data sources permit the calculation of mobility indicators:

- Labour force or related surveys (all countries in theory, CLFS).
- Total registers (the Nordic countries, Belgium on the basis of a special project).
- Special longitudinal panels (at least the United Kingdom, Italy, Germany).
- Special surveys (the United States, in particular the SESTAT system).

The study found that extractions from the Community Labour Force Survey (CLFS) and national labour force surveys (or surveys closely related to labour force surveys) provide a good – if highly aggregated – picture of mobility in most countries. However, although these data may permit an analysis of trends in overall mobility and in mobility between various broad industries, they are not sufficiently detailed to monitor interactions between the research-producing sector and the research-using sectors. Sampling errors set limitations to the data. For detailed analyses, registers or censuses appear to be the only reliable source of data, although longitudinal panels can provide additional detail on specific aspects of mobility and enable analysis over longer periods of time.

A preliminary analysis of CLFS data and national labour force survey data provides a number of interesting results; these should be seen as examples of the types of information which could be derived using labour force survey data to analyse mobility:

- Mobility rates have risen to around 9% at the EU level.
- Significant variations exist between countries, ranging from 15% in Finland to 4% in Italy.
- Mobility has increased rapidly in the ICT sector.
- Mobility flows are concentrated in own sectors or close sectors

Until qualifications and occupations are better recorded in the general information collected on emigrants and immigrants, the possibilities for constructing indicators on international mobility do not look very promising. Information which is partially based on survey results may be available in various countries, although the international comparability of this information is limited. Shares of foreigners in total stocks of highly qualified workers are available from labour force surveys.

II. INTRODUCTION

The availability of appropriate human resources is one of the most important prerequisites for the development of science and technology. In 1994, the OECD and Eurostat adopted a methodological manual for the measurement of human resources for science and technology, the "Canberra Manual". Eurostat has further developed the concepts and definitions contained in the "Canberra Manual" into a system of indicators of stocks and flows of human resources for science and technology (HRST). These indicators mainly include flows into and out of the stock of HRST. Issues related to flows within HRST have not been the subject of very much attention until now.

During the last few years, the OECD, in co-operation with the EU member states, has conducted a programme relating to the development of new indicators for a knowledge-based economy. One of the ten projects involves the development of indicators on the mobility of human resources for science and technology. Another OECD research programme concerns the description of national innovation systems. Within this programme, Finland, Sweden and Norway participated in a substantial pilot study of the possibilities for utilising the Nordic countries' register-based statistical systems to develop mobility indicators (Nås *et al.*, 1998). The study highlighted the rich opportunities available in the Nordic countries for the development of various indicators related to human resource mobility.

Mikael Rosengren of Statistics Sweden undertook a study for the OECD on the need for mobility indicators, interviewing experts in the field in all OECD

Member and some non-member countries. At the same time, he made an inventory of available data sources and special studies from which useful information related to HRST mobility could be derived (Rosengren, 1998). The study did not provide an answer to the question of whether it was possible to develop internationally comparable indicators on the mobility of highly qualified personnel. However, it did provide sufficient information to encourage continued efforts to construct at least some rough mobility indicators which could be applied outside the Nordic area.

The aim of the study was to examine in detail some of the data sources and special studies identified in the Rosengren study and, if possible, to identify additional sources, and to evaluate their usefulness in the construction of internationally comparable indicators on mobility of highly qualified manpower. The study looked at international sources, such as the Community Labour Force Survey (CLFS) and the European Community Household Panel (ECHP), and at national sources for a set of countries: Australia, Belgium, Finland, France, Germany, Korea, Italy, Spain, the United Kingdom, the United States. A first attempt was made to construct indicators from the international sources and national sources for three countries (the United States, France, the United Kingdom).

This article first discusses the types of mobility indicators investigated in the study. The data sources identified as being relevant for the construction of indicators are then evaluated. A presentation of the findings follows, based on international sources and the results for the three countries. This is followed by conclusions and recommendations for future work.

III. TYPES OF MOBILITY INDICATORS

This section illustrates why mobility indicators are needed by policy makers. As a second phase, it presents the framework that could be used to produce the kinds of mobility indicators that could be envisaged for the future.

One of the policy objectives of a knowledge-based economy is to strengthen the effects of research-based knowledge. Tacit knowledge and the skills embodied in highly qualified personnel are essential for interpreting, evaluating and transforming codified knowledge into forms and contexts facilitating its use (Hauknes, 1994). Mobility of highly qualified personnel measures the flows of tacit knowledge within the innovation system. It is assumed that this circulation of knowledge is a major factor in the ability of national economies to generate and adopt new technologies in efficient ways (Nås *et al.*, 1998). A certain degree of mobility in the economy is assumed to be desirable, especially between the sectors producing research-based knowledge, such as universities and research institutes, and the sectors using this knowledge (various manufacturing and service sectors) – but also within the knowledge-using sector.

Mobility always represents a trade-off between the benefits for the recipient of the tacit knowledge embodied in a highly qualified person and the losses for the donor institution. Therefore, a rate of mobility which is too high could have a negative effect.

Knowledge flows in and out of a country are of particular interest for policy makers. Their attention is increasingly focused on issues related to "brain circulation", encouraging people to spend time abroad and to come back with greater tacit knowledge – to the benefit of the home economy.

Today, the statistical information available for policy makers to base policy decisions on is limited. This study attempts to investigate possibilities for improvement. Three types of indicators regarding the mobility of highly qualified manpower are addressed:

- Indicators on mobility between firms and other organisations.
- Indicators on mobility between the research-producing and research-using sectors.
- Indicators on internatinal mobility.

It does not look at some of the other types of mobility, such as the flows of university graduates into employment and international flows of university students.

For the three types of indicators described above, the focus is on institutional mobility, *i.e.* change of employer or employment status. Various units allow identification of the employer. Change of employer can be defined as change of establishment (local kind of activity unit). In many cases, a somewhat larger unit is preferable, for example, the local unit. It is also possible to define mobility in terms of change of organisation (enterprise). One possibility is to require both change in enterprise and establishment as the criteria for mobility. In some studies, mobility has been defined as change of industry, which of course is the most restricted definition. The data sources available in different countries will affect the definition used. In order to achieve comparability across countries, it would be useful to be able to apply uniform definitions as far as possible.

Mobility can be defined in a narrow sense to only include movements between employers, or in a wide sense to also include movements to and from unemployment or to and from the labour force. This study is limited to mobility of highly qualified manpower. This is a narrower concept than HRST according to the "Canberra Manual". It could be defined as:

- A combination of educational and occupational criteria, as used in the "Canberra Manual" or in the US definition of scientists and engineers.
- According to purely educational criteria.
- According to purely occupational criteria.

If educational criteria are used, a natural definition of the borderline is ISCED 6 and ISCED 7 according to ISCED (1976 version) or ISCED 5A and 6 of the 1998 version. In practice, people with at least a bachelors degree or equivalent are included. For international purposes, the occupations to be included have to be defined according to ISCO. Relevant categories include at least professionals (ISCO 2). A certain part of managers (ISCO 1) might also be relevant, but in practice has to be left out as there are difficulties in defining the appropriate categories according to ISCO, and difficulties in translating national categories into the appropriate categories.

The actual limitation is dependent on the data sources available and on the possibilities of translating national classifications into international standards. Differences in the definition of highly qualified manpower across countries will probably not significantly affect the comparability of mobility measures, so there is room for a certain amount of flexibility.

Other classifications used in the analysis of mobility are gender, nationality and age of personnel.

Indicators on mobility between firms and other organisations

For indicators on mobility between firms and other organisations, the basic idea is for a particular industry (for example, machinery NACE 29) to determine the share of employees changing employer or employment status from year t – 1 to year t. The change could be to another employer or to unemployment, other changes in labour force status or exit from the labour force (including migration abroad). The results may take the form of a mobility matrix, with delivering and receiving sectors. Table 1 illustrates a possible schema for such a matrix, taken from the Nordic mobility study (Nås *et al.*, 1998).

Table 1 shows that, in 1994, the total number of highly qualified employees (by qualification) in manufacturing was 24 395. Of these, 5 944 (or 24.4%) changed establishments between 1994 and 1995. In 56.8% of cases, mobility was within manufacturing; in 0.9% of cases, a former manufacturing employee left to attend a university.

Most of the sectors shown in the table represent clear aggregations of NACE categories for the enterprise sector, and the figures shown are indicators on mobility between firms (establishments or local units). The details of the industrial classification which could be used for this kind of analysis are dependent on the data source. Specific sectors of interest could be identified, as for example the ICT sector, defined according to NACE codes 30, 32, 642 and 72. If total registers are used, as in the Nordic countries, very detailed categories can be used. On the other hand, these are difficult to analyse and more aggregated categories are preferred.

Table 1. **Finland: Mobility of employees with a university degree**

Delivering sectors (1994)	Primary sectors, mining oil	Manu-facturing	Utilities and construc-tion	Trade, hotels, restaurants	Transport, storage, com.	Financial services, real estate	Business services	R&D institutes	Higher education institutions	Public adm. and defence, health and social work	Other non-public services	From outside active workforce	N persons moving	N persons employed	Mobility rate in
Receiving sectors (1995)															
Primary sectors, mining, oil	17.0	0.3	0.4	0.5	0.2	0.1	0.5	1.5	0.1	0.1	0.6	1.0	377	2 211	17.1
Manufacturing	5.8	56.8	11.4	11.7	5.4	2.3	10.7	9.9	5.3	1.2	5.4	14.7	8 061	23 576	34.2
Utilities and construction	0.3	1.5	34.5	0.7	1.5	0.2	1.9	0.5	0.1	0.1	0.3	2.0	888	2 924	30.4
Trade, hotels, restaurants	3.5	5.9	2.8	37.6	3.7	1.6	4.1	1.4	0.9	0.5	2.6	7.0	3 357	11 992	28.0
Transport, storage, communications	1.0	1.4	1.0	2.2	47.7	0.7	1.9	0.4	0.2	0.2	0.7	2.3	1 244	4 588	27.1
Financial services, real estate	0.0	0.5	0.4	0.7	0.2	65.2	2.2	0.3	0.2	0.3	0.7	1.2	2 087	6 599	31.6
Business services	4.5	5.9	10.1	7.2	5.7	7.6	38.3	4.8	3.3	1.5	4.5	12.2	5 777	20 812	27.8
R&D institutes	0.6	0.4	0.1	0.2	0.1	0.2	0.5	39.2	1.6	0.3	0.3	1.3	794	3 625	21.9
Higher education institutions	1.3	0.9	1.0	1.5	0.3	0.5	1.3	8.5	34.5	2.9	4.1	10.8	4 787	11 508	41.6
Public administration, health, social	6.7	5.1	5.5	6.5	4.1	2.9	7.5	7.3	11.4	67.2	14.9	38.0	28 582	100 638	28.4
Other non-public services	2.9	1.1	0.6	1.2	1.6	1.0	1.7	1.0	0.0	0.0	0.0	4.9	1 184	11 687	10.1
Out of active workforce	56.1	19.8	30.7	28.7	28.1	17.5	28.3	24.7	26.3	17.2	55.4	0.0	12 229	19 300	63.4
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**			
N persons moving	312	5 944	690	2 813	955	2 416	4 643	778	4 327	27 251	2 447	19 300			
N persons employed	2 374	24 395	3 073	12 838	4 556	7 012	21 931	3 830	13 098	106 511	12 957	19 300			
Mobility rate out	13.1	24.4	22.5	21.9	21.0	34.5	21.2	20.3	33.0	25.6	18.9	100.0			

If the data used for the analysis are based on sample surveys, the industrial breakdowns have in any case to be fairly aggregated.

If data sources provide data for several years, more complex mobility indicators can be constructed to derive mobility paths for highly qualified personnel. For example, if information is available for years t – 1, t and t + 1, the following types of employment category could be distinguished:

- Same employer t – 1 and t, new employer t + 1.
- Same employer t – 1 and t, not employed t + 1.
- Same employer all three years.
- Not employed t – 1, employed t, new employer t + 1.
- Not employed t – 1, employed t, not employed t + 1.
- Not employed t – 1, same employer t and t + 1.
- Not employed all three years.
- Employed t – 1, new employer t, same employer t + 1.
- Employed t – 1, new employer t, not employed t + 1.
- Employed t – 1, new employer t, again new employer t + 1.

This type of calculation can be made for various populations in terms of education and/or qualification, age, etc. Employment may be further broken down by industry. If data are available for more than three years, indicators, such as the share of stable workers (workers not changing employment), and characteristics of frequent movers can be computed.

Indicators on mobility between the research-producing sector and the research-using sector

The research-producing sector includes universities, other institutions of higher education, research institutes and other major research units belonging to the public sector. These indicators are in principle rather similar to those on mobility between firms, the main difference being that in most cases, they cannot be directly computed using the NACE/ISIC classification to classify the employer. This indicator is used to investigate the relationship between the public research or knowledge infrastructure and the business sector. The institutions involved have often to be identified from several NACE/ISIC codes. As the number of institutions is limited, it is possible in theory to do this by using a special coding for the institutions.

In the first round, it would be useful to identify the universities. This has been attempted in the experimental calculations shown in Section V for the United States, France and the United Kingdom. It would appear to be possible through the use of detailed national codes or by extracting them according to organisation numbers. For the CLFS, the broader category education (NACE 80) has been used in Section V. In the future, it might be possible to include NACE category 73 (research units) in the same group. A classification of the types of institutions to be included in the analysis will need to be developed in the long run.

Indicators on international mobility

International mobility of highly qualified personnel is ideally defined as: people employed in year t who go abroad either temporarily or permanently for employment purposes; and people employed in year t coming from abroad. The information should be broken down by qualification (field and study) and/or occupation and country of origin/destination. In order to address issues of brain drain, brain gain and brain circulation (people going abroad and returning to their home country), indicators of flows are necessary. It would be especially interesting to follow the case of temporary migrants returning to the home country in order to monitor the phenomenon of brain circulation.

A recent Japanese study (Japan External Trade Organisation, 1998) identified the following indicators for the United States, Korea and Australia:

- Foreign-born scientists and engineers (United States).
- Permanent visas issued to immigrant scientists and engineers (United States).
- Foreign recipients of US PhD degrees (United States).
- Visas issued to foreigners for the purpose of research and teaching, and visas issued to national citizens for the purpose of research and teaching abroad, by country (Korea).
- Arrivals and departures (no distinction according to whether these are long-term or short-term) for scientists, engineers, university teachers, by country group (Australia).

In countries which make broad use of visas, some information on international mobility is available although these statistics reflect national specificities and are not comparable. The Nordic countries, for example, collect fairly full data sets on outflows, but maintain only partial data on inflows due to incomplete information on immigrants' qualifications.

Partial surveys based on information from various subgroups also exist; these include factors such as participation in exchange programmes and are limited to certain institutes or universities only.

In general migration statistics, it is very difficult to identify the qualifications and occupations of migrants. This refers in particular to inflows and there seem to be no plans for improving the situation. It therefore appears unlikely that it will be possible to construct internationally comparable flow indicators in the near future.

However, it is possible to obtain a picture of international mobility from an analysis of changes in the share of foreign citizens in stocks of highly qualified personnel.

IV. EVALUATION OF DATA SOURCES

Achieving internationally comparable indicators calls for fairly homogeneous sources of information. In this section, two uniform sources for data on mobility are described; namely, the labour force surveys carried out in a number of countries and the integrated European Community Household Panel. This is followed by a general description and evaluation of various national sources.

Labour force surveys

Labour force surveys are usually sample surveys, with sample sizes of about 0.5-1.0% of the total population. The sampling unit is often the household or dwelling; in some cases, the person. Many surveys ask for information on industry of employment in year $t - 1$ as well as in year t. Most labour force surveys use rotating samples in the sense that the same households are surveyed several times and usually included in the sample for at least one year (before being replaced by other households).

It is therefore possible to follow the employment characteristics of one person over two years. This can be done using the information on employment for the preceding year. For mobility analysis, important labour force survey variables include: employment status, detailed industry of primary and secondary employment, other details concerning employers, occupation, formal qualification (broadly described), nationality, demographic characteristics, earnings.

Since the labour force surveys also contain data on nationality and the period of employment in the country, it is possible to analyse the share of foreign citizens in various stocks of employees as an indication of brain gain from abroad.

As the labour force survey is a sample survey, there is the problem of sampling error which will affect the accuracy of results for smaller aggregates; these errors are more crucial for smaller countries. Sampling errors are discussed in Section V in connection with the presentation of UK data.

Within the European Union, labour force surveys are in principle harmonised through an EU regulation. As part of the Community Labour Force Survey (CLFS), Eurostat collects micro data on the individual level from its member states. It is possible to carry out extractions on the basis of employment in the previous year. It is, however, not possible to link the micro data at the European level in order to conduct mobility analysis.

Since labour force surveys exist in almost all countries and are fairly harmonised, they could be a good source for future indicators of mobility of highly qualified manpower. The use of the labour force surveys has been tested using both the Community Labour Force Survey and national surveys in two countries, the United Kingdom and France. The results of this test are presented in Section V.

The European Community Household Panel (ECHP)

The objective of the Panel is to collect very detailed data on households and the people living in households in Europe. Almost all EU countries participate in the survey, which is more harmonised in terms of content and survey methodology than the CLFS, although the sample size is considerably smaller (around 60 000 households) and the relative sample size varies across member states. Micro data from member states are gathered by Eurostat and released under certain conditions for use by researchers; they are also made available to the institutions collecting the basic data. Eurostat also carries out tabulations on request from researchers.

The Panel allows records from various years to be linked. The most significant variables for the construction of mobility indicators are the following:

- Employment status.
- Occupation (ISCO 2-digit) and industry of employment (NACE 2-digit).
- Information on previous employment and unemployment.
- Basic information on probable second job.
- Demographic information.

The advantage of the ECHP is that the information is uniform and available in one place. The main disadvantage is the considerably smaller samples compared with the CLFS, especially for some of the larger countries, such as Germany. Nevertheless, it was tested and the results showed that the ECHP does not provide an appropriate source of data for mobility indicators.

National sources

Registers represent the best source for studying mobility in the Nordic countries. In these countries, individuals and organisations (enterprise, establishment) have a unique identification number which is used in a variety of administrative and statistical registers. For research and statistical purposes, it is possible to combine information from these registers. The main administrative registers used are: population registers, taxation registers, pension registers, student registers, registers of buildings and dwellings. Information from these registers is combined with information from statistical registers, such as business registers and registers of degrees.

These operations result in annual information for each individual in the Nordic countries on demographic variables, formal education, occupational status, actual occupation (no longer available in Finland as of 1995), enterprise and establishment of employment, salaries, etc. These registers are a very valuable and up-to-now rather under-utilised resource for the construction of mobility indicators.

Register information is also available on people leaving the country for a period of at least one year, or entering the country for at least one year. For people entering the country, information relating to education levels is unfortunately lacking in around 80% of the cases; however, information on country of destination and country of origin is collected. For a more extensive description, see (Nås *et al.*, 1998).

The registers provide very detailed and accurate data. Errors are minor compared to sampling errors from surveys. Certain variables, such as occupation, are difficult to register accurately. In Finland, the occupation variable was deleted after 1995 due to difficulties in obtaining accurate information from administrative registers. The disadvantage with person registers stems from slow processing: the registers are not ready for use before late year t + 2.

Several countries have panels for longer periods. The Italian panel is based on social security archives and covers roughly 1% of employees in the private sector. In the United Kingdom, a panel based on the New Earnings Survey covers, in principle, the entire workforce. Neither of these panels provide information on formal qualifications. Both panels are described in Annex 1, together with some published results.

In the United States, the SESTAT system has been developed to monitor scientists and engineers. SESTAT is considered better than the national labour force survey for mobility analysis. The SESTAT database is developed and maintained by the National Science Foundation, and comprises three surveys:

- The National Survey of College Graduates (NSCG).
- The National Survey of Recent College Graduates (NSRCG).
- The Survey of Doctorate Recipients (SDR).

The surveys have been undertaken for 1993 and 1995 and will be repeated every other year. The target population for SESTAT is non-institutionalised US residents aged 75 years or less with at least a bachelor's degree in a S&E field on 30 June of the previous year, or with a bachelor's degree in a non-S&E field but working in an S&E occupation in the survey week 15 April.

The NSRCG and SDR surveys are at least partly longitudinal, thus facilitating employment comparisons between years. The sample sizes for the two surveys were around 60 000 and 50 000. After non-response follow-up, the number of completed interviews were 53 000 and 35 000.

Using SESTAT, it seems to be possible to analyse mobility between the following sectors:

- Private for-profit (company, business or individual, working for wages, salary or commissions).
- Private not-for-profit (tax exempt or charitable organisation).
- Self-employed in own not-incorporated business, professional practice or farm.
- Self-employed in own incorporated business, professional practice or farm.
- Local government.
- State government.
- US military service.
- US government (civilian employee).

A separate question was asked about employment in various educational institutions.

Sample size permitting, sub-division by the following types of qualifications might be possible:

- Bachelor.
- Post-baccalaureate certificate.
- Masters degree.
- Post-masters certificate.
- Doctorate.

Section V presents some results on the basis of extractions from the SESTAT system.

V. RESULTS

To test the possibilities for constructing indicators, Eurostat was asked to make a number of extractions from CLFS and ECHP, the United States to calculate indicators for 1993-95 on the basis of the SESTAT system, and France and the United Kingdom were asked to calculate indicators on the basis of their national labour force surveys for 1995-98.

Table 2. **Total mobility rates for highly qualified personnel in EU member states by sector, 1995-98**

Percentages

		ICT	Other manufacturing	Other private services	Education	Other community services	Agriculture, construction	Total mobility
Austria	1995	x	x	8	5	5	x	5.6
	1998	..	..	..	..	..	..	..
Belgium	1995	(11)	(6)	7	6	5	x	6.0
	1998	18	14	11	7	7	(14)	9.2
Denmark	1995	(15)	(10)	9	9	16	x	12.1
	1998	(15)	x	13	9	13	x	11.0
Finland	1995	x	x	(9)	9	9	x	8.6
	1998	20	(9)	15	11	17	x	14.7
France	1995	7	6	8	7	7	9	7.0
	1998	8	8	11	8	7	(7)	8.4
Germany	1995	5	6	8	5	7	9	6.6
	1998	11	7	10	5	7	10	7.3
Greece	1995	x	x	4	5	(3)	x	4.1
	1998	x	(7)	4	7	4	x	5.1
Ireland	1995	x	x	11	(7)	10	x	9.5
	1998	..	..	..	..	..	..	..
Italy	1995	x	(3)	4	4	2	(5)	3.5
	1998	(7)	5	4	4	3	(4)	4.1
Luxembourg	1995	x	x	x	x	x	x	(4.9)
	1998	x	x	x	x	x	x	(5.1)
Netherlands	1995	(8)	(6)	8	4	5	x	8.5
	1998	9	10	14	3	10	x	11.4
Portugal	1995	x	x	10	5	(3)	x	5.9
	1998	x	x	11	11	7	x	9.4
Spain	1995	(7)	13	15	12	10	16	12.1
	1998	23	14	15	13	11	11	13.0
Sweden	1995	..	..	..	..	..	..	..
	1998	(11)	(12)	17	5	8	x	9.6
United Kingdom	1995	11	11	13	8	9	9	10.2
	1998	18	14	16	9	10	14	12.0
Total	1995	8	7	9	6	7	9	7.7
	1998	13	9	11	7	8	10	9.0

x = Figure not reliable due to large sampling error or other reasons.
() = Figure uncertain due to considerable sampling error.
.. = Not available.
ICT sector (NACE 30, 32, 64, 72).
Other manufacturing (NACE 15-37, except 30, 32).
Other private services (NACE 50-74, except 64, 72).
Education (NACE 80).
Other community services (NACE 75-99, except NACE 80).
Agriculture, forestry, mining, utilities, construction (NACE 01-14, 40-45).

Results from CLFS extractions

Total mobility rates

Table 2 presents the basic results of the extractions. The mobility rates refer to numbers of highly qualified personnel [defined on the basis of qualification (ISCED 6+7) or occupation being occupied as professionals (ISCO 2)] changing jobs as a share of the total stock of employees. For Germany, Luxembourg, Ireland, the United Kingdom and the Netherlands, ISCO 2 was the only criterion used. These differences may influence the mobility rates, but are not crucial for the analysis. Only movements between employers are recorded; movements into and out of the labour force or from unemployment are excluded.

Table 3 presents mobility rates by gender for 1995 and 1998.

Table 3. **Mobility rates by gender, 1995 and 1998**
Percentages

	Men 1995	Women 1995	Men 1998	Women 1998
Austria	5.8	5.4	(1996) 6.0	(1996) 7.4
Belgium	5.4	6.5	9.2	9.3
Denmark	10.8	13.9	10.7	11.5
Finland	7.0	10.8	14.5	14.8
France	6.9	7.1	7.5	9,7
Germany	6.1	7.4	7.3	7.1
Greece	3.3	5.2	4.4	6.0
Ireland	8.3	10.8	(1997) 10.7	(1997) 12.7
Italy	2.8	4.3	3.2	5.1
Luxembourg	(4.6)	x	(4.8)	x
Netherlands	7.6	10.1	10.8	12.3
Portugal	5.5	6.4	7.4	11.1
Spain	9.9	14.9	9.7	17.0
Sweden	8.8	8.5	8.8	10.3
United Kingdom	9.7	10.9	13.3	10.4
EU total	**7.1**	**8.6**	**8.5**	**9.7**

x = Figure not reliable due to large sampling error or other reasons.
() = Figure uncertain due to considerable sampling error.
.. = Not available.

The following conclusions can be drawn from the above table. For the EU as a whole, the mobility rate has risen from below 8% in 1995 to 9% in 1998. It increased in all countries, with the exception of Denmark.

Mobility rates vary considerably across sectors. Again for the EU as a whole, they were highest in the ICT sector (13%), which was also the sector in which they rose most rapidly. The second highest mobility rate (11%) was recorded in other private services. Here, too, the increase was larger than in education and other community services, which recorded the lowest mobility rates (7% and 8%).

There are surprisingly significant differences in mobility rates across countries. In 1998, the mobility rate was highest in Finland (15%), followed by Spain (13%) and the United Kingdom (12%). The lowest mobility rates were recorded in Italy (4%) and Greece (5%). One could ask if these variations reflect real differences or if there exist differences in the national labour force surveys in terms of the interpretation of the "employer" concept. In countries with higher mobility rates, the rates seem to be comparatively higher in the other community services and education sectors. In Spain, mobility in the education sector appears to be particularly high (13%).

At the EU level, the mobility rate for women was 1.2 percentage units higher than that for men in 1998. Female mobility is higher in ten countries, at more or less the same level in three countries, and considerably lower in one country, the United Kingdom (no reliable information was available for Luxembourg).

One indicator which could be of particular importance for describing knowledge flows in the innovation system is the share of overall mobility attributed to flows between education institutions and other sectors. This refers to the second type of mobility indicator described above. Education institutions cover the knowledge-producing and -dissemination sectors together with all the other sectors assumed to be knowledge users. Due to the small numbers involved, this indicator can only be calculated for the EU as a whole and for the larger countries. For the EU as a whole, the indicator seems to suffer a slight drop from 6.1% in 1995 to 5.7% in 1998. At the individual country level, there is no clear trend – except for Italy where the share is declining.

Share of foreign citizens in the total stock of highly qualified employees

In most countries, the share of foreign citizens in the total stock of highly qualified employees represents between 3% and 4% of total stocks. For the EU as a whole, the decrease in the share is at least partly explained by the decline in the share for Germany (a whole percentage point). This may be due to technical differences in the German labour force survey. On the contrary, there appears to have been an increase in the share of some of the smaller EU member states.

Problems with using CLFS

In addition to the general problem of sampling error, there are problems in identifying the highest level of education attained in the CLFS. In 1998, the CLFS adopted the new ISCED classification and for many countries there will be breaks in the series of total stocks of highly qualified personnel (defined according to

Table 4. **Share of foreign citizens in the stock of highly qualified employees in EU member states**
Percentages

	1996	1998
Austria	7	..
Belgium	4	5
Denmark	3	4
Finland	x	(1.0)
France	4	4
Germany	5	3
Greece	2	3
Ireland	6	..
Italy	(0.5)	(1.1)
Luxembourg	41	41
Netherlands	3	3
Portugal	(0.9)	(1.4)
Spain	(0.8)	(1.1)
Sweden	4	4
United Kingdom	4	4
EU total	**3.4**	**3.1**

x = Figure not reliable due to sampling error or other reasons.
() = Figure uncertain due to considerable sampling error.
.. = Not available.

ISCED 6+7 of the old version or 5A+6 of the new version). Some countries present problems of comparability of stocks even before that date and it is well known that the comparability of international data from ISCED is far from perfect. It is not certain how far the introduction of the new ISCED classification will improve the situation. In some countries, this has led to the identification of highly qualified workers simply on the basis of occupation. The use of the classification of occupations is also very problematic. These issues of comparability across years within a country and/or comparability across countries may somewhat affect the mobility rates but are unlikely to dramatically modify the results.

The mobility rates calculated from labour force surveys are generally lower than those recorded in the Nordic studies based on comprehensive registers (Nås *et al.*, 1998; Graversen, 1999). Calculated according to the same principles, mobility rates were 16% in Sweden, 18% in Denmark and 19% in Finland for 1995-96, compared with around 10% using CLFS data. This variation is certainly due to methodological differences. Asking people about their employment one year ago (self-assessment) may lead to different results than those obtained by following the employment of people according to registers: errors may have occurred in the information collected on employment one year ago in the labour force surveys; the registers may produce overly high figures for mobility due to unnecessary changes in organisation numbers; and it might also be that changing from one establishment to another within an enterprise is not regarded as mobility in the LFS while it is so considered in the Nordic system of calculating mobility indicators from registers. These differences will need to be analysed in more detail at a later date.

In theory, labour force surveys contain data from which it should be possible to identify foreigners who have been in the country for less than one year (foreign immigrants). In practice, it was not possible to obtain reliable data for this in the current extraction from CLFS. This is probably due to missing information on qualifications/occupations for these categories in CLFS.

Extractions from national labour force surveys in France and the United Kingdom

Since the data available from the United Kingdom and France were fairly uniform and detailed, these have been more systematically analysed. First, an analysis of total mobility rates in the two countries was carried out. The analysis was then extended to various sectors. Finally, the shares of foreign born highly qualified employees in total employees in both countries were calculated. The illustrative data below are indicative of the types of indicators that could be produced from the labour force survey.

Before proceeding with an analysis of mobility, some data on total stocks are presented. The two countries were asked to provide data for people belonging to ISCED 6 and 7 or ISCO 2. As only in the United Kingdom were data separately available for ISCED 6+7 and ISCO 2, the population in the following tables has been defined according to ISCED (unless otherwise stated).

Table 5. **Total stock of highly qualified employees (ISCED 6 and 7), United Kingdom and France**

Millions

	United Kingdom	France
1995	3.07	2.23
1998	3.55	2.48

Table 6 provides additional information for stocks with reference to 1998. As indicated above, the ultimate aim is to have information according to a combined qualification/occupation criteria.

The stock of highly qualified employees seems to be slightly larger in the United Kingdom compared with France. In both countries, stocks are increasing steadily, which should be regarded as normal. In all categories, the numbers are

Table 6. **Stock of highly qualified employees in the United Kingdom and France, 1998, broken down by qualification and occupation criteria**

Millions

	United Kingdom	France
ISCED 6 + 7, not ISCO 2	1.99	1.24
Both ISCED 6 + 7 and ISCO 2	1.56	1.24
ISCO 2, not ISCED 6 + 7	0.83	0.57

higher in the United Kingdom, indicating a consistent structural pattern of employees across different categories. The table illustrates that if only qualification is used as a criterion, the population of highly qualified workers will be considerably smaller.

Total mobility rates

In Table 7, mobility is defined in a narrow sense as the share of employees in year t having a different employer in year t – 1. The concept of "employer" is defined according to enterprise in the questionnaire. The United Kingdom supplied information on sampling errors and this has been taken into account in the analysis. It is assumed that the French sampling errors do not significantly differ from those experienced in the United Kingdom.

Table 7. **Overall mobility rates in the United Kingdom and France 1995-98**

Highly qualified personnel (employees with ISCED 6 or 7 degrees), shares of persons with different employer one year ago, percentages

	United Kingdom	France
1995	9.1	7.5
1998	11.3	9.0

The sampling error for mobility rates (using the narrow definition) in this table is around 0.3-0.4%. This allows some tentative conclusions to be drawn: *i*) mobility rates seem to be higher in the United Kingdom than in France; *ii*) they appear to be increasing in both countries; and *iii*) they are slightly different compared to thus obtained from the CLFS due to differences in extraction methods.

Mobility rates can be calculated by age as shown in Table 8.

The rates are clearly higher, and appear to grow more rapidly for younger people. In the United Kingdom, a degree of growth in the mobility rate for older people is apparent, although this does not seem to be the case for France.

Table 8. **Mobility rates by age**
Percentages

	United Kingdom		France	
	20-39	40-64	20-39	40-64
1995	11.5	5.4	11.4	3.2
1998	14.4	6.5	13.6	3.3

Mobility in various sectors

In the following table, mobility rates are broken down by broad industry as follows:

- ICT sector (NACE 30, 32, 642, 72).
- Other manufacturing/manufacturing, excluding ITC (NACE 15-37, except 30, 32).
- Agriculture, forestry, mining, utilities, construction (NACE 01-14, 40-45).
- Other private services (NACE 50-74, except 642, 72).
- Universities or higher education (national subgroup of NACE 80).
- Other community services (NACE 75-99, except national subgroup of NACE 80).

The sectors chosen were deliberately broad to facilitate the analysis. The ICT sector was treated separately as there was evidence from other sources of a higher mobility rate in that sector. As the detailed tables on flows between sectors are generally based on rather small numbers (in some cases too small to be published), the numbers should be regarded as orders of magnitudes only. They are, nevertheless, presented here to provide a general picture of the mobility pattern.

A number of conclusions could be drawn from Table 9. In 1995, 10.8% of the employees in the UK ICT sector had a different employer in 1994. Of these, over half were employed by another employer in the ICT sector. Other people changing jobs came from other sectors.

Based on information from the United Kingdom, the standard errors for the total mobility rate in the ICT sector are around 1.3%. This leads to several possible conclusions.

The mobility rates in the United Kingdom for the ICT sector are considerably higher than the average. In France, the difference seems to be small. Mobility rates in the ICT sector are rising in the United Kingdom, whereas there is no evidence of such a trend in France. In addition to recruiting from the own-sector, the ITC sector recruits from other private services. In the United Kingdom, people are also coming to ITC from other manufacturing industries; this is not the case in France.

Table 9. **Mobility rates for highly qualified personnel**

Employees with ISCED 6 or 7 degrees, shares of employees with different employer by industry of employer one year before, 1995-98, percentages

	Total mobility rate	ICT sector	Manufacturing, excluding ICT	Agriculture, construction, etc.	Other private services	Universities	Other community services
ICT sector							
United Kingdom							
1995	10.8	5.6	1.2	0.0	2.7	0.6	0.7
1998	18.3	8.9	1.9	0.5	4.2	0.8	2.1
France							
1995	8.1	5.3	0.6	0.0	1.9	0.0	0.3
1998	9.7	6.4	0.3	0.0	2.7	0.0	0.3
Other manufacturing							
United Kingdom							
1995	9.4	0.5	4.1	0.2	3.1	0.2	1.2
1998	12.2	0.6	5.5	0.3	4.2	0.3	1.3
France							
1995	5.5	0.1	2.8	0.1	1.0	0.9	0.6
1998	7.7	0.6	4.8	0.0	1.8	0.3	0.3
Agriculture, construction, utilities							
United Kingdom							
1995	7.1	0.5	1.0	3.1	2.2	0.0	0.3
1998	9.8	0.6	0.8	4.3	2.2	0.4	1.2
France							
1995	6.1	1.4	0.0	2.4	1.1	0.5	0.7
1998	8.3	0.0	0.5	5.6	0.6	0.4	1.2
Other private services							
United Kingdom							
1995	11.1	0.4	1.1	0.2	8.0	0.2	1.3
1998	13.7	0.9	1.3	0.7	8.5	0.1	2.2
France							
1995	6.8	0.5	0.6	0.3	4.4	0.4	0.7
1998	9.6	0.8	1.1	0.2	6.7	0.3	0.6
Universities							
United Kingdom							
1995	8.4	0.2	0.8	0.2	1.2	2.9	3.1
1998	7.0	0.0	0.4	0.0	1.2	3.1	2.3
France							
1995	7.8	0.0	0.1	0.0	0.4	6.6	0.7
1998	8.1	0.1	0.1	0.0	0.6	6.9	0.5
Other community services							
United Kingdom							
1995	7.8	0.0	0.3	0.1	1.2	0.2	5.8
1998	9.0	0.1	0.3	0.2	1.6	0.5	6.3
France							
1995	6.8	0.1	0.3	0.2	0.9	0.9	4.5
1998	7.3	0.3	0.0	0.1	0.9	1.4	4.6

The standard errors for mobility rates in the United Kingdom are around 0.8% for other manufacturing, leading to rather similar conclusions as for the ICT sector. The mobility rates are higher in the United Kingdom than in France and seem to be rising slightly. Recruitment is mainly from the own-sector and from private services.

The sampling error for the mobility rates for other private services is 0.6% for the United Kingdom. This leads to the clear conclusion that mobility rates are higher in the United Kingdom than in France, and rising in both countries. The recruitment pattern in private services seems to be more evenly spread than for other private sectors.

The university sector includes at least part of the units producing research results. The interaction between this sector and the private research-using sectors is therefore a particularly interesting area of study from the perspective of analysing knowledge flows in the innovation system. Part of the relevant units are included in other community services, but these are difficult to distinguish using labour force survey data.

As the university sector is rather small, the sampling error is again bigger at around 1%. A comparison of mobility rates in the United Kingdom and France shows no difference in the overall rates. There is no evidence of a trend in either of the two countries. However, an interesting feature is stronger recruitment from other community services in the United Kingdom compared with France. The reason for this could be the fact that there are proportionally more research units in this sector in the United Kingdom. The flows between universities and the private sector are so small that they are seriously affected by the LFS sampling errors.

The sampling error for the mobility rate in the United Kingdom for other community services is 0.3%, which leads to the conclusion that the mobility rates are on largely the same level in the United Kingdom as in France.

Foreign-born highly qualified employees

Table 10 presents the shares of foreign-born highly qualified employees. For France, the figures relate to the total population of highly qualified personnel (ISCED 6 and 7, or professionals ISCO 2). For the United Kingdom, the figures relate to ISCED 6 and 7 only. This might make the French share appear more significant.

Table 10. **Shares of foreign-born highly qualified employees**
Percentages

	United Kingdom	France
1995	3.4	12.7
1998	4.3	12.6

The table shows a surprisingly large difference between the United Kingdom and France, perhaps due to differences in defining and identifying foreign-born citizens in labour force surveys. The French share is also much higher than the share of foreign citizens in the stock of highly qualified employees calculated from the CLFS. For the United Kingdom, the proportions are of the same magnitude. The share of foreign citizens seems to be a better indicator than the share of foreign nationals. This should be further investigated if this indicator is to be used. Once sampling errors are taken into account, it is difficult to perceive any trend in these figures.

Extractions from the US SESTAT system

Using the SESTAT system, it is possible to compare employment for scientists and engineers (according to the US definition) in 1995 with employment in 1993 in order to calculate some basic mobility rates. The mobility rate has been defined as the shares of employees who were employed in both years having shifted jobs in the interim.

Table 11. **Basic mobility rates for scientists and engineers in the United States, 1993-95**

Percentages

	Scientists and engineers with a PhD	Scientists and engineers without a PhD	Total	Total (foreign born)
Total	14.9	19.3	19.0	20.2
Males	13.7	18.2		
Females	19.9	21.8		
Age: 40-75	10.2	14.6		
Age: below 40	26.9	24.2		

The general mobility rate for the United States (19%) could be a little bit higher than that for the EU if calculated on an annual basis; this is because it has to be divided by less than two in order to take into account people moving in both years.

The following other observations can be drawn from the table:

- Mobility rates are lower for PhDs than for other scientists and engineers.
- Mobility rates are higher for females.
- Mobility rates are higher for younger people.

From the more detailed material made available, it would appear that mobility rates seem to be slightly higher for scientists and engineers with a background in mathematics and computer sciences.

Most of the mobility takes place within the same broad sector. An indicator which is relevant for describing knowledge flows in the innovation system is the share of mobility attributed to flows from universities to other sectors and from these sectors to universities. This share is around 8% according to SESTAT data, higher than the corresponding figure for the EU (6%).

The main problems which arise from using SESTAT data are the very different concepts and classifications compared with the labour force surveys. The classification of employers in SESTAT is very broad and is not comparable with European data for broad industry groups based on NACE/ISIC. The advantage of the SESTAT for mobility analysis is: its specific targeting on scientists and engineers; its ability to tackle doctorates separately; and the fact that it enables analysis of mobility in various fields of science.

VI. CONCLUSIONS

The Community Labour Force and national labour force surveys permit the construction of aggregate indicators of mobility for the whole population of highly qualified personnel, and especially for the larger countries, for broad industry groups like those presented in this study. Compared to the broad industrial classification used in this report, research institutes could probably be added to the education sector and deducted from other community services, while agriculture and construction, etc., could be grouped together with other manufacturing sectors. The data could be further broken down into broad age groups and by gender. It would also be possible to construct the corresponding indicators from CLFS material for other non-EU EEA and Eastern European countries (the Czech Republic, Estonia, Hungary, Poland, Romania, the Slovak Republic, Slovenia) for at least one year.

The CLFS has the advantage of being a harmonised source of information on mobility, even if there are comparability problems with single variables, such as the education variable. For future work, it would be fairly cost-effective to collect data from a single source instead of having to approach the 25 national offices. Therefore, the use of CLFS is recommended for future work for these countries.

Nevertheless, the experience gained from this pilot project has shown that national labour force surveys may be able to produce more detailed breakdowns. In addition, the quality problems associated with qualifications data did not seem to be so severe as in the CLFS; at least, the series of stocks were more consistent than in the CLFS. Quality problems may be more easy to tackle on the national level. The extractions could be made on the basis of more detailed national classifications.

For most other OECD countries, national labour force surveys or related surveys may produce the same data, although this has not been tested in the present study. In future work, the use of a combination of CLFS data to the extent possible, and national labour force survey data for countries not included in the CLFS or to obtain complementary information, is one of the recommendations of this study.

The other EU source, the ECHP, does not seem to provide such a good source as it does not allow employment changes from one sector of employment to another to be followed. The sample size is also rather limited, leading to fairly substantial sampling errors.

Finland and other Nordic countries are able to construct almost any mobility indicator on the basis of their register-based statistical systems. The problem is more one of choosing the most appropriate indicators. Errors in the registers or weaknesses in registration routines may also cause problems for the analysis. In addition, the register-based approach is rather slow. Belgium may be able to obtain similar possibilities as a result of a special research project.

The United States is able to provide aggregated information from the SESTAT system. Due to the different timing, classifications and coverage of the US data, there are very limited possibilities for comparison with European data. On the other hand, separate information on mobility for doctorates can be produced in the United States but not on the European level using the CLFS. US data show clear differences in mobility between doctorates and other scientists and engineers. It would be interesting to test this more broadly on European data, but this does not seem to be possible for the moment using CLFS. Some national labour force surveys are able to produce this data (for example, the United Kingdom). The United Kingdom and Italy are able to provide complementary information, especially on long-term mobility on the basis of the panels described above.

Register-based data seem to produce higher mobility rates than do LFS data. The reasons for this may arise from different statistical units and ways of asking the question on employment in labour force surveys. The Nordic project will review this problem.

The possibilities for constructing indicators on international mobility do not look very promising for the time-being. The registration of qualifications and occupations of immigrants and emigrants has to be improved before it is possible to obtain better data. The indicator on the share of foreign citizens in total stocks of highly qualified employees, which can be obtained from labour force surveys, is a possible, but poor, substitute. The sampling errors in the LFS make increases in stocks difficult to analyse. Due to missing data, even greater difficulties may arise with the qualification variable for these employees in labour force surveys.

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INNOVATION SURVEYS: LESSONS FROM OECD COUNTRIES' EXPERIENCE

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I. INTRODUCTION

This article of the STI *Review* considers various characteristics of innovation using innovation surveys of the type conducted in the Community Innovation Survey (CIS) programme, and the issues that need to be addressed to ensure that future surveys provide even better indicators and are more helpful to policy makers.

Innovation surveys have substantially improved the existing knowledge on innovation. They have enabled investigations of phenomena that were previously impossible to study and have allow previously unsubstantiated ideas to be confirmed. For instance, innovation surveys have shown that a high proportion of firms innovate; that a great deal of innovation takes place in the services as well as in manufacturing; that innovation affects the performance of firms in terms of profitability, productivity and employment generation; and that innovation policies are concerned with large firms more than small ones.

Despite substantial progress, drawbacks remain. For instance, definitional issues (What is a technological innovation? What is an innovative firm?) have not all been settled, and statistical methodologies are not identical across countries. Easier access by analysts to micro-level data will be necessary in order for studies to be undertaken that would facilitate an evaluation of the data and provide useful information to policy makers.

Some of these issues have been addressed in the course of the preparation of the third round of CIS (CIS 3). The purpose of this article is to highlight some of the achievements and drawbacks of innovation surveys as a measurement tool; we do not intend to be exhaustive in our coverage of the issues or of the literature.

II. INNOVATION SURVEYS: GENESIS AND PURPOSE

The goal of innovation surveys is to improve our understanding of technological innovation in countries, industries and firms. CIS 1 was initially aimed at the measurement of technological innovation within the manufacturing sector; data were collected on enterprises, allowing statisticians and users to draw conclusions about innovation in firms and industries for those countries that took part in the CIS programme. These included most of the European Union member states, as well as a small number of other OECD countries, particularly Australia and Canada.

The original CIS 1 survey round was undertaken in 1993, with firms being asked about innovative activities over the three-year period 1990-92. The surveys were based on the concepts and definitions contained in the interim version of the "Oslo Manual", released in 1992 (OECD, 1992), and a standard questionnaire prepared mainly by Eurostat based on those concepts.

The CIS 1 programme was followed by a second round of surveys undertaken in 1997 and covering innovative activities undertaken in 1994-96 (CIS 2). An important extension of the survey scope in this round was the inclusion of selected industries from the service sector; in this context, it should be noted that some countries had already experimented with adding this sector prior to CIS 2. Further, the number of countries taking part in the survey programme increased. The surveys were again based on (the revised version of) the *Oslo Manual* which had been reviewed, revised and reissued by OECD, in conjunction with Eurostat and Member country delegates of the Group of National Experts on Science and Technology Indicators (OECD and Eurostat, 1997). As previously, the survey questionnaires were based on a standard developed mainly by Eurostat.

The third round of the CIS programme (CIS 3), covering the years 1998-2000, was launched in 2001.

The purpose of innovation surveys

Broadly speaking, innovation surveys aim to respond to three major concerns:

- Innovation goes *beyond* R&D: much technological innovation does not result from research and development, although it has large effects on the economy. This is the case especially in the service industries. In addition, non-technological innovation might result in improved economic performance, notably (but not only) in the service industries. In the past, these aspects escaped statistical measurement.

- There is a need for indicators of the *output* of inventive activities, in addition to the existing high-quality indicators of input (R&D). Indicators of output, especially patents, although highly informative, do not cover all innovations. Smaller innovations, in particular, are not patented. In addition, patents say nothing about the impact of inventions, whether on productivity or on market performance.

- There is a need to improve knowledge of the conditions of *innovative activities at the firm level*: R&D surveys provide mainly aggregate data and lack information on firms – their motives, strategies, links with performance, obstacles to innovation, what makes a firm innovative or not.

In accordance with these concerns, innovation surveys aim to gather the major categories of information (see *Oslo Manual*) shown below. Not all of these issues are covered in the subsequent discussion:

- Types on innovation: product; process; invented/adopted by the firm.
- Size of innovative output: share of output in new goods.
- Costs of innovation.
- Goals of innovation.
- Factors hampering innovation.
- Patenting activity.
- Sources of information.
- Co-operation for innovation (with competitors, customers, universities, government).
- Basic information on the firm: turnover, employment, whether or not it belongs to a group.

III. MEASURING INNOVATION AND MAPPING INNOVATORS

A first use of the results from innovation surveys was the calculation of aggregate indicators of innovation, or "innovation rates". The objective of such indicators is to reflect the innovativeness of a country compared to other countries, at an aggregate level, in certain industries or in certain size classes of firms. These indicators are basically the sum of firms' responses to the surveys. Their significance involves two separate types of issue: What do these responses actually capture? How can the responses be aggregated, *i.e.* how to obtain quantitative indicators based on qualitative data?

Industry

The CIS 1 Innovation Survey programme concentrated almost solely on measuring innovation in the manufacturing sector, while the CIS 2 programme was extended to include some service sector industries. Aggregate results on the extent of innovative activity are shown in Table 1. They are calculated as a simple average: the percentage of firms that consider themselves as innovative among the total population of firms.

As can be seen from the table, the CIS 2 results for the European Union show that for the manufacturing sector, technological innovation took place in 51% of enterprises (employing 20 workers or more). For service sector enterprises with ten or more employees, the innovation rate was 40%.

Table 1. **Share of innovative firms, European Union countries, 1994-96**
Percentages

Industry	Share of innovators
Manufacturing	
Food, beverages, tobacco	50
Textiles, leather	35
Wood, pulp, paper, publishing	45
Coke, chemicals	70
Rubber, plastic, etc.	51
Basic metals and fabricated products	48
Machinery and equipment, nec	68
Electrical and optical equipment	69
Transport equipment	56
Manufacturing, nec	48
Total manufacturing	**51**
Services	
Wholesale trade and commission trade	34
Transport	24
Telecommunications	65
Financial intermediation	54
Computer and related activities	68
Engineering services	55
Water, gas and electricity	35
Total services	**40**

Source: Eurostat.

Moreover, innovative activity is not evenly distributed across industries within these two broad sectors. In the manufacturing sector, the textiles and leather industries achieved an innovation rate of only about 35%, with the highest innovation rates being achieved in the coke and chemicals industry, the machinery and equipment industry and the electrical and optical equipment industries – at about 70% each. Similarly, in the service sector, the transport industries had a low innovation rate at around 25%, while the telecommunications and computer and related activities industries had innovation rates of around 65-70%.

These results are not dissimilar from those obtained in surveys other than CIS 2. For example, surveys conducted in Australia for the manufacturing sector have shown similar degrees of industry deviations round the mean, although the overall levels of innovation measured are different, probably because of the different size cut-off used in that survey. The Australian surveys carried out in 1994 also showed significant differences in rates of innovation within service sector industries (there were no service sector industries covered in 1997). That survey also measured a lower level of activity, again probably primarily due to the different cut-off used.

Size

The CIS 2 surveys used different size cut-offs for the manufacturing and service sector surveys, which hinders somewhat comparisons of the two sectors. However, as can be seen from Table 2, different innovation rates are obtained for different sizes of firms.

Table 2. **Share of innovative firms, European Union countries, 1994-96**
Percentages

Industry and size of firm	Share of innovators
Manufacturing	
20-49 employees	44
50-249 employees	58
250+ employees	79
All firms	**51**
Services	
10-49 employees	36
50- 249 employees	48
250+ employees	71
All firms	**40**

Source: Eurostat.

For the smallest firms included in the manufacturing sector survey (20-49 employees), the innovation rate was 44%. This is just over one-half that achieved by the largest manufacturing firms included in the survey (250 + employees). In the case of the service sector, again the smallest firms in the survey (10-49 employees) had an innovation rate of 36%, about half that of the largest enterprises surveyed. For the two largest size classes for which direct comparisons can be made between the industries, it can be seen that firms in the service sector (in total) are a little less technologically innovative than manufacturing sector firms of equivalent size. Nevertheless, substantial amounts of innovative activity are occurring in the service sector.

Other surveys corroborate these findings. The Australian surveys pointed to significant differences in innovation rates, with the rate of innovation being strongly influenced by firm size. These surveys measured innovation in businesses of all sizes for all firms with at least one employee, and thus provide an indication of the degree of innovation in the very smallest firms. The evidence is that very small firms were even less likely to innovate than the smallest groups of firms included in the CIS 2 programme. The 1994 and 1997 Manufacturing Surveys and the 1994 Services Survey in Australia indicated that the innovation rate for firms with less than ten employees was probably in the order of half that for firms in the 10-49 employee range.

Technological vs. non-technological innovation

A crucial issue in measuring innovation is the delineation of the boundaries of what can be considered technological innovation and which firms can be considered technological innovators. One of the key aspects of this is the boundary between technological innovation and other forms of innovative behaviour.

The central aspect of the CIS programme, and the *Oslo Manual*, has been the measurement of technological innovation. While technological innovation has unquestionably been one of the key driving forces behind economic growth over the past ten or 20 years, there is growing concern that non-technological innovation may also be a significant contributing factor to such growth. This was acknowledged at the time that the *Oslo Manual* was prepared, and a special Annex containing some initial proposals for data collection activities was added to that manual. Some Member countries have used this Annex to continue experimentation with the collection of information on non-technological innovation.

The difficulty for statisticians is that the frontier between technological and non-technological innovation is far from clear-cut, especially (but not only) in the service industries. Organisational change, marketing-related changes and financial innovation are widespread and play a key role, especially in the service activities of many firms. Moreover, in many cases, such changes are related in one way or another to technology; it is often necessary to change the organisation of the firm to reap the rewards from computer networks or to boost the capacity of the firm to innovate. Hence, measuring such innovation is important for a better understanding of technological innovation itself. It is also important to separately identify non-technological innovation so that a better (purer) measure of technological innovation can be obtained.

However, little reliable information is available on non-technological innovation. The initial surveys in Australia in 1994 collected some information on the occurrence of such innovation and the results are shown in Table 3.

This table shows that, for the manufacturing sector, the rate at which non-technological innovation occurred was lower than the rate of technological innovation. Nevertheless, the proportion of firms that undertook non-technological

Table 3. **Technological and non-technological innovation, Australia, 1993-94**

Percentages

Industry	Share of technological innovators	Share of non-technological innovators	Either technological or non-technological innovators
Manufacturing	34	24	43
Services	12	14	21

innovation was still fairly sizeable – one in every four firms, or some two-thirds of the technological innovation rate. Table 3 also shows that, for the service sector, non-technological innovation occurred more frequently than technological innovation. Overall, 14% of service sector firms were estimated to have undertaken non-technological innovation in 1993, compared to 12% for technological innovation.

A further aspect of interest was the proportion of cases in which the two types of innovative activity were occurring together. In the manufacturing sector, some three out of four of the firms that undertook technological also carried out non-technological innovation. In the service sector, it appears that about half the firms that were undertaking technological innovation also undertook non-technological innovation.

These results are, of course, subject to the definition and boundary issues referred to earlier. While considerable effort has gone into the definitional aspects of the measurement of technological innovation, as part of the reviews of the *Oslo Manual*, in particular, much less effort has gone into the definition of non-technological innovation. While, in theory at least, non-technological innovation covers all types of innovative activity other than technological innovation, it has generally been considered to mainly comprise the implementation of advanced management techniques (*e.g.* Total Quality Management – TQM), the introduction of significantly changed organisational structures or the implementation of new or substantially changed corporate strategic orientations. However, these types of activity may be difficult to measure statistically and hence the reliability of results will suffer somewhat.

At the same time, it is should be borne in mind that there also have been some significant problems in the statistical measurement of technological innovation. Many EU countries made this observation in their review of the outcomes of the CIS 2 programme in their country. The problem seems to stem from the use and understanding of the word "technological" in different countries and languages and whether the word itself was specifically included in the questionnaire.

Table 4 below shows the overall level of technological innovation in the manufacturing and services sectors of EU member countries, taken from CIS 2 and thus relating to the years 1994-96.

As can be seen from the table, the rates vary significantly across countries. For manufacturing, Ireland, Denmark and Germany have rates of approximately 70%, while the lowest rates are for Portugal and Spain, both at less than 30%. For the service sector, the rates are generally lower, with Belgium, Norway and Finland providing the lowest figures at less than 25%. The highest innovation rates in the service sector were Ireland and Austria, both around the 55-60% mark.

A number of EU countries have questioned the reliability of the data, particularly the different innovation rates between countries. It would appear that some

Table 4. **Share of technological innovators, European Union countries, 1994-96**
Percentages

	Manufacturing	Services
Ireland	73	58
Denmark	71	30
Germany	69	46
Austria	67	55
Netherlands	62	36
Sweden	54	32
Italy	48	n.a.
Norway	48	22
France	43	31
Luxembourg	42	49
Finland	36	24
Belgium	34	13
United Kingdom	34	40
Spain	29	n.a.
Portugal	26	28
All countries	**51**	**40**

Source: Eurostat.

of the problems involved in obtaining internationally comparable data stem back to the definitional issues raised above. For example, a detailed study of the Belgian results by Alfred Kleinknecht (1999) indicated that varying interpretations and wording differences may have played some part in the variability of the results.

Another possible explanation relates to the methodologies adopted in the surveys and the response rates achieved as a result of the collection process. The response rate ranges from less than 30% to more than 80%. In many countries, the profiles of respondents and non-respondents differ. These differences make it increasingly difficult to interpret the results; it is not clear whether a complementary survey of non-respondents would be sufficient to correct for such low response rates. An analysis of the results from CIS 2 shows that there appears to be a negative correlation coefficient between the response rate and the technological innovation rate across the participating countries. One possible interpretation of this is that countries' attempts to overcome response bias issues may not have been fully successful.

Non-boundary aspects of the definition

While the boundary problems are indeed important, they are not the only aspects of the definition of technological innovation that need to be considered.

OECD Member countries have raised a number of other issues which should also be taken into account when considering definitional matters. These are:

- The "novelty" of an innovation.
- The criteria used to determine whether a firm is classified as innovative.
- The time period relevant to the innovative activity.

The "novelty" of an innovation relates to the extent to which a particular innovation is new to the world, a world-first product or process, or whether the innovation is merely new to the firm but has previously been implemented somewhere else in the same country or in the same industry in another country. Paragraph 145 of the *Oslo Manual* recognises that in standard innovation surveys the minimum requirement is for an innovation to be new for the firm. Some analysts have recognised the importance of separately identifying and studying world-first innovations – see in particular Baldwin (1997) on Canadian innovation surveys.

In respect of the criteria used to determine whether or not a firm is innovative, a number of possibilities exist. These include:

a) a firm is innovative if it has implemented (*i.e.* introduced onto the market) technologically new or significantly technologically improved products or processes during the period under review, or

b) a firm is innovative if it has undertaken any of the set of predefined technologically innovative activities during the period under review, or

c) a firm is innovative if it meets either of the criteria in (*a*) or (*b*).

The *Oslo Manual* takes the first option (see *Oslo Manual*, paragraph 130). However, a number of analysts have suggested that the second approach may be more appropriate. Option (*c*) also appears to be a possible alternative that might be used in the definition.

The third aspect relates to the time period under review; that is, the timeframe within which the chosen criteria need to be fulfilled. Obviously, the longer this period, the higher the measured proportion of innovators. Paragraph 228 of the *Oslo Manual* sets the time period as three years and this was the timeframe used in the CIS 1 and 2 survey rounds. The three-year timeframe was set in the first version of the *Oslo Manual* primarily because of the long period that sometimes elapsed before large manufacturing product or process innovations could be brought to market or implemented into some large-scale manufacturing plant. While a three-year timeframe has the advantage of ensuring that such innovations fall within the definition, it is likely that it is also bringing with it many other technological innovations that are much smaller. As a result, technological innovation rates may be inflated.

There is, however, a body of opinion which suggests that this time period could be reduced to two years, to coincide better with the timing of surveys, or even one year, to coincide with the time period for the reporting of innovation expenditure data. The latter would become more attractive if options (*b*) or (*c*) above were chosen as the preferred definition of an innovating firm. A shorter time period is intuitively better for the measurement of innovation in the service sector, which appears to undergo a fairly high turnover of firms.

This article does not attempt to draw any conclusions on these particular issues as there is insufficient data to present an informed discussion about them. They are mentioned, however, as they need to be borne in mind in the overall context of the definition of an innovative firm, which is central to the major question being addressed in this article, *i.e.* the measurement of the outputs and impacts of innovation on innovating firms.

Other measures of the innovation rate

A firm is defined as being innovative if it has implemented one or more innovations in a three-year period. Since it is based on a yes/no response, such information is "qualitative". Summing qualitative data is straightforward when: *i*) the yes/no classification conveys all the relevant information; and *ii*) all respondents are equal. These assumptions work, for instance, in opinion polls. In the case of innovation surveys, however they do not hold. In the statistics presented above, a firm with one innovation is treated in exactly the same way as a firm with many innovations, *i.e.* it is considered to be an innovator. Hence, a country with many firms each with one innovation will be seen as more innovative than a country with few firms each having many innovations. Another way to look at the problem is to imagine that two innovative firms merge – although there is no reason to estimate that the innovative performance of the country will decline, the above indicator will show a reduction in the number of innovative firms. Aggregating the data by simple summing, as is done above, results in considering as equal firms which are actually very different with respect to the size of their innovative activities and output. A large, multinational firm will contribute no more than a small firm to the indicator. Since the probability for a small firm to innovate is lower than the probability for a large firm to do so, simple counts will tend to underestimate the innovative performance of countries with large numbers of small firms. Two ways of overcoming this problem are by:

a) weighting firms by their size (measured by turnover or by employment) and

b) using additional information from innovation surveys on the share of new or improved products in turnover.

The manufacturing component of the CIS 2 surveys collected information on these two methods and the results of this analysis are shown in Table 5. The data relate to product innovators only.

Table 5. **Share of innovative product sales in turnover (manufacturing)**
Percentages

	Share of innovative product sales in turnover	Share of turnover of product innovators in total turnover
Germany	45	90
Ireland	32	78
Austria	31	79
Sweden	31	83
Spain	27	62
Italy	27	63
Netherlands	25	76
Finland	25	76
United Kingdom	23	74
Denmark	21	71
France	20	71
Norway	20	60
Belgium	14	50
Portugal	14	35
All countries	**32**	**77**

Source: Eurostat.

Germany is clearly the country with the highest share of innovative products included in turnover, with an estimated share of 45%. At the other end of the scale, are Belgium and Portugal, with 14%. Of the G7 countries, France (20%) and the United Kingdom (23%) also had very low shares of innovative product sales in turnover, while Italy's share was 27%. It should be noted that these proportions relate to the turnover of product innovators only and so exclude any impact in respect of process innovations.

An examination of these results indicates that there is a significant difference between these proportions for different sizes of firms. For the smallest group of firms (20-49 employees), the share of innovative product sales in turnover is only 15%; for firms with 50-249 employees, the share is 21% and for the largest firms, it is 38%.

Another way of looking at the share of innovative firms is to express the turnover of all product innovators (whether relating to specific innovative products or not) as a percentage of all turnover of the firms covered by the survey. This provides a measure of the impact of innovative firms on the economy, rather than simply measuring the innovative products of innovative firms. This indicator is also shown in Table 5 and shows that 77% of all turnover is generated by innovative firms. In Germany, this percentage is 90%, the highest of all the countries studied. The other G7 countries are all slightly lower than the European average, with Italy being particularly low at 63%. Again, Portugal (35%) and Belgium (50%) have the lowest proportion of all the EU countries.

The difference between the two measures reflects the importance of measurement issues related to the size of innovative firms and the size of innovative activities within firms. Whether or not account is taken of these issues results in a quite different picture of innovation across countries. Another approach is to use econometric tools that allow the degree of innovativeness of any respondent firm to be inferred, *i.e.* qualitative data is transformed into quantitative data. This approach is presented in Dagenais and Mohnen (2000) and in Mairesse and Mohnen (2001, this issue of the STI R*eview*).

Who innovates?

The country, industry and size category of a firm are major determinants in its choice of whether or not to innovate; however, even among firms with the same nationality, industry and size, there are innovators and non-innovators. In order identify other factors that influence the innovative behaviour of firms, it is necessary to go beyond descriptive statistics and to use quantitative techniques that enable analysts to control for a number of characteristics of firms and address various statistical issues in the data.

A study by Mairesse and Mohnen (2001) on CIS 1 micro-aggregated data has used an econometric modelling technique to assess the effect of various characteristics of the firm on its propensity to innovate and on the intensity of innovation. They estimate a "generalised Tobit model", explaining both the fact that the firm innovated or not and the share of new and improved goods in sales. This approach allows the authors to control simultaneously for all these factors. This study showed that:

- More innovative firms are found in the electrical products, plastics, machinery and equipment and vehicles industries.
- Innovativeness increases with size.
- Innovativeness increases with the exports to sales ratio.
- Innovativeness increases if a firm is part of a group.
- Innovativeness increases if a firm undertakes R&D on a continuous basis.
- Innovativeness increases with the R&D to sales ratio.
- Innovativeness increases in firms undertaking co-operative R&D.

The study also showed that more innovation occurred in Germany, Ireland, Belgium and Ireland, and less in Italy, Norway and Denmark. However, it is important to remember that international comparability of CIS 1 data was fairly weak, thus care needs to be taken in interpreting results for different countries.

Statistical testing indicated that important factors of innovativeness remained unexplained by the model. It is a matter for future work to identify these determinants, some of which may not be inherent to the firm itself but may relate to the wider innovation and competitive environment.

Crepon *et al.* (1998) used a simultaneous equation framework to regress productivity growth on innovation, which is itself explained by a number of variables including R&D expenditure. This method allows various sources of statistical bias (selectivity, simultaneity) to be corrected for. The authors found that sales of new or improved goods rise with the research efforts of the firm. It is not surprising that R&D has a strong influence on innovation: what innovation surveys have shown with quantitative evidence is that R&D *is not the only factor at play*.

IV. THE ECONOMIC IMPACTS OF INNOVATION

Measuring the impacts of innovation on profitability and productivity

How to measure the effects of technological innovation on the firm's and the national economy's performance is a key question for policy makers. Before detailed innovation surveys came into being, many studies had been conducted on the effects of R&D on firm performance, and a few studies on patents (as a measure of inventiveness). Overall, such studies pointed to a positive impact of technology on the performance of a firm, whether measured by productivity growth, growth of sales, exports or profits. Studies based on innovation surveys generally lead to a similar conclusion.

Two complementary approaches can be used to answer the questions posed by policy makers. One involves a more descriptive approach which compares directly the performance of innovative and non-innovative firms (by industry, size category, etc.). The second is an econometric approach that tries to explain economic performance using a range of variables, some of which reflect innovation. The first approach has the advantage of simplicity and does not rely on any strong assumption; however, it has the disadvantage of not being able to be conclusively prove any causal relationships. The econometric approach has the advantage of controlling the effect of innovation for various effects such as industry or size and thus can lead to more generalisable results.

Measuring the impact of innovation on firm performance, including profitability and productivity, is thus a key objective of innovation surveys. Both approaches described above have been tried in different countries and at different times. This section brings together some of the conclusions drawn from the work to date.

One of the most comprehensive studies undertaken using innovation survey data is that carried out by the Dutch Central Bureau of Statistics on a matched sample of CIS 2 and annual Production Survey respondents. This is reported in their LNM-series 9902 entitled "The Importance of Innovation for Firm Performance" (Klomp and van Leeuwen, 1999). From a sample of over 8 000 firms, the authors were able to produce a set of growth rates for sales over the period under review (1994-96). These are shown in Table 6.

Table 6. **Growth in sales, Netherlands, 1994-96**
Percentages

Category	Growth in sales – innovating firms	Growth in sales – non-innovating firms
Manufacturing	5.3	3.9
Services	8.0	6.7
Other industries	10.0	11.0
Small firms	8.6	9.8
Medium firms	7.7	5.8
Large firms	7.1	8.3
All firms	**7.3**	**7.2**

There is clearly no difference at the "all firm" level. However, some differences are discernible at lower levels of aggregation. As pointed out by the authors, these differences are more apparent when the sample is broken down into deciles based on average growth in sales. This has led to one of their final conclusions, based on an econometric analysis of the data, that a "significantly positive effect of the level of innovation output on sales growth has been observed".

A similar matched analysis was undertaken by the Australian Bureau of Statistics (ABS) based on the results of its 1994 Innovation Survey. In this analysis, the ABS matched the unit record information from its Innovation Survey with data on labour productivity (gross product per person employed) and firm profitability (operating profit margin) from its annual Production Surveys.. It was able to do this for 2 000 manufacturing enterprises out of the 5 000 covered by the original Innovation Survey. As it was more likely that larger firms would be included in both surveys, this sample is likely to be skewed towards larger firms, although aggregate results were re-weighted using the original stratification to remove biases to the greatest extent possible. This analysis yielded the results shown in Table 7.

As is shown in the table, there appear to be differences in labour productivity between technological innovators and non-technological innovators for all sizes of business. However, for profitability, the results appeared to be different only for the smallest firms. Econometric analysis was carried out by fitting linear regression models to the data. The results showed that innovation status had significant effects on labour productivity within each size category and at the total level. However, within each model, the R-squared value was low, showing that little of the variability was being explained by the model. For firm profitability, significant

Table 7. **Firm productivity and profitability, Australia, 1993-94**

Size of firm	Labour productivity – non-technological innovators	Labour productivity – technological innovators	Firm profitability – non-technological innovators	Firm profitability – technological innovators
0-19 employees	34	42	10.4	5.9
20-199 employees	45	48	7.4	7.6
200 + employees	59	67	8.0	7.7
All firms	**35**	**44**	**10.0**	**6.4**

differences are found only for the smallest size group of firms and, here again, the R-squared value is low. Thus the results of the work were inconclusive.

Crepon *et al.* (1998) found a significant effect of innovation on productivity, using French CIS 1 data. They estimate a Cobb-Douglas type equation, explaining production with physical capital, labour, skill composition and innovative output (measured as share of innovative goods in total sales). They found a statistically significant elasticity of 0.065 of productivity with respect to product innovation; for instance, a firm with 70% of its sales in innovative goods has 13% higher productivity than a firm with 10% of its sales in innovative goods.

A different approach to analysing impacts of innovation on production and profitability was used by ABS in its 1997 Innovation Survey. Firms were asked to subjectively answer a question on whether innovative activities had a positive or a negative impact on a range of production activities and overall profitability. The findings are shown in Table 8.

This clearly shows that there is an overall positive impact on profitability at the firm level, even though it is impossible to quantify these impacts.

Table 8. **Impact of innovation on production activities, Australia, 1996-97**

Percentages

Production activities	Technological innovators reporting a decrease	Technological innovators reporting an increase
Production levels	2	61
Cleaner processes	1	27
Labour usage	17	29
Materials consumption	10	37
Energy consumption	8	30
Wastage	21	15
Capital utilisation	2	33
Maintenance support	4	17
Overall profitability	7	38

Thirty-eight per cent of firms indicated that their innovative activities had a positive impact on profitability, while only 7% reported a decrease. This appears to be due to the high number of firms reporting an increase in their production levels. In turn, this, of course, led to an increase in labour usage, materials and energy consumption and capital utilisation.

Measuring the impacts of innovation on employment

The question most frequently asked by policy makers about innovation relates to its impact on employment, especially in countries with high levels of unemployment. Although economic theory denies (at the macroeconomic level and over the long run) any link between innovation and employment, provided that market forces function properly, it recognises that innovation might affect employment levels in the short and medium term and at the enterprise and sector levels. Another issue is the impact of innovation on the quality of jobs (demand for skilled labour).

Klomp and van Leewen (1999) also analysed growth in employment by innovating and non-innovating firms. The results are shown in Table 9.

Table 9. **Growth in employment, Netherlands, 1994-96**

Category	Growth in employment – innovating firms	Growth in employment – non-innovating firms
Manufacturing	–0.2	–1.2
Services	4.1	3.1
Other industries	2.6	4.2
Small firms	4.1	5.0
Medium firms	3.8	1.9
Large firms	1.5	2.1
All firms	**2.3**	**2.5**

As can be seen from the table, there is little difference in the employment growth of innovating and non-innovating firms. While some differences are perceptible at the more disaggregated industry and size of firm level, in total there is little difference. Perhaps not surprisingly, subsequent econometric work was also unable to differentiate between innovating firms and non-innovators in respect of employment growth.

Little evidence can be gleaned from the Australian Innovation Surveys on the issue of employment generation. However, it is possible to draw some conclusions from a business longitudinal survey (The Business Growth and Performance Survey) which was set up in the mid-1990s to investigate the factors that affect firm growth and performance. One of the areas studied by this survey was innovation and one of the growth measures adopted was employment growth. The results of the 1997-98 survey are shown in Table 9. In this table, a firm was considered to grow if its employment grew by more than 10% and to have decreasing employment if its employment decreased by more than 10%. Firms whose employment did not change by more than +/–10% over the year were considered to have static employment.

Table 10. **Proportion of firms increasing employment, Australia**

Percentages

Type of firm	Decreasing employment	Static employment	Increasing employment
Non-innovators	18	64	18
Innovators	17	52	31

Source: ABS.

As can be seen from the table, approximately the same proportion of firms decreased their employment, irrespective of whether they were innovators or not. However, a greater share of innovators would seem to have increased their employment by more than 10%.

A similar question was asked in each of the three preceding years of the survey and on each occasion the answers have been similar, *i.e.* little difference between the proportion of innovators and non-innovators with decreasing employment, but a greater proportion of innovators increasing their employment. The conclusion that can be drawn is that there have been impacts on employment at the level of the firm, and that these are sometimes positive and sometimes negative (on a smaller number of occasions). For half the number of firms studied, there have been no employment impacts.

All the studies presented above are directly based on cross tables, which allow a clear presentation of the data but do not allow to control for the many factors other than innovation that might have affected employment. Using an econometric approach, Licht (EC, 1997, pp. 139-140), found positive links between innovation and job creation at the firm level, both in the Netherlands and in Germany. In the Netherlands, from the 1988 and 1992 innovation surveys, 700 firms that performed product or process innovation or implemented new automated equipment created more jobs than others (after controlling for size). In Germany, from the 1992-93-94 innovation and CIS surveys, Licht found that both product and process innovation led to job creation. It is striking that, in innovating companies, there were as many jobs generated by unchanged goods as by new or improved ones. This probably points to a "company effect" that underlies innovation; it is not only innovation *per se* that gives rise to new jobs, innovative companies create employment.

However, "creative destruction" is also going on, which makes it difficult to generalise the results observed at the firm level – gains for one company may, at least partly, be obtained at the expense of other firms (competitors), so that the net gain for the economy as a whole is not that high.

Greenan and Guellec (2001) explore the link between changes in employment due to innovation at the firm and the industry level, using French data from CIS 1. They use a firm sample of 15 000 firms, over the 1986-90 period. Innovating firms and sectors create more jobs than do non-innovators over the medium run (five years). Process innovation is more job creating than product innovation at the firm level, but the converse is true at the sector level. This may be due to substitution effects. A firm which introduces a new process may reduce its costs and gain employment at the expense of its competitors (who lose market shares), whereas a firm which manufactures a new product experiences a lower gain but one which emanates from an increase in the demand addressed to the sector. This interaction between firms results in the fact that aggregating firms' performance at a sectoral level may lead to different results than when aggregation is carried out at the level of individual firms.

Studies have been carried out, especially in the United States, on the impacts of innovation on the skill structure of labour demand, using R&D expenditure or plant equipment surveys. However, very few studies have been conducted on the basis of innovation survey data. The reason for this probably lies with the difficulties involved in accessing micro data. Greenan and Duguet (1998), studying French companies with CIS 1 (and data on skills from other sources), found that innovative firms have a higher share of skilled labour, and that the share increased more in innovative firms than in other firms over the study period.

V. THE EFFECTIVENESS OF PUBLIC POLICY

Assessing the effectiveness of policies is a very relevant topic for policy makers, and clearly innovation surveys have a unique comparative advantage in addressing such issues. However, few studies have tried to tackle this to date.

The Italian CIS 1 survey, which covered the years 1990-92, asked firms about their reaction to various innovation policy initiatives. As reported by Pianta and Sirilli (1998), a large majority of innovative firms declared that existing innovation policies had no relevance for the introduction of their innovation. Sixty per cent of firms attached no importance to the provision of government funds, while 85% made no use of EC funds, 74% did not use financial incentives (tax credits), and more than 90% viewed the provision of R&D and technological services or public procurement as irrelevant. These shares are 30%, 50%, 60% and 70%, respectively, for firms with 1 000 employees or more. Hence, technology policy seems to target mainly large firms. Indirect incentives showed the lowest differences in uptake in relation to firm size. In addition, firms in high- and medium-high-technology industries are more sensitive to government policies than are firms in other industries. Firms with higher innovation expenditure per employee are more sensitive than others (average expenditure is ITL 584 000 for firms which view policies as irrelevant, and ITL 2 890 000 for those that find them relevant).

Arundel (EC, 1997, p. 104) estimates a logit model (econometric method for qualitative variables) using data for all European CIS 1 countries where the dependant variable is a score of 3 or higher for at least one of the three types of public research: universities, technical institutes, government laboratories. The probability that a firm considers public research to be important increases with firm size, R&D intensity and the share of innovative products in total sales. Public research is considered more important by firms seeking to expand their product range than by those which plan to develop new products within their current range. Firms seeking markets outside Europe are more likely to rate public research as important.

Mohnen and Hoareau (2000) make use of data from CIS 1 on information sources (universities, government research institutes) and innovation collaboration (again, universities, government research institutes), for assessing the direct usefulness of public research to business. The study, conducted for France, Germany, Ireland and Spain, found that larger firms have more links with public research than do small ones, and that firms receiving government support and firms owning patents have closer links with public research. Other aspects, such as industry ranking, seem to be country specific.

In the 1993 Canadian Innovation Survey, universities were cited as a source of technology ideas by 27% of "world firsts", but by only 3% of other innovators. The figures for government labs are 11% and 3% (Baldwyn, in EC, 1997, p. 51). Universities and government labs are of interest for firms that make radical innovations.

While the above studies have looked at some aspects of the effectiveness of public policy, it is important to expand the scope of these studies to enable an analysis of various types of policies across different countries. However, this would require a better range of internationally comparable data than is currently available, and would entail international access to firm-level data.

VI. OUTSTANDING ISSUES

In terms of statistics compiled on the basis of CIS and related surveys, a considerable range of analyses have been undertaken. These studies have helped to resolve a number of issues. However, solutions will need to be found for a number of other issues if innovation surveys are to realise their full potential. The major outstanding issues are described below.

Defining innovation and innovating firms

The concept of "technological innovation" – which is at the very origin of innovation surveys – has yet to be stabilised, having changed between the CIS 1 and CIS 2 surveys. The CIS 3 questionnaire tends to weaken the distinction between technological and non-technological innovation. The reason for this is twofold: there is a sense among statisticians that innovation lacks a sound conceptual basis, and there is a feeling that it is not understood consistently by respondents both within a country and between countries.

The difficulty in defining technological innovation lies both with innovation and with technology. There is a hierarchy of innovations (along a continuum between radical and incremental), and it would be useful to be able to draw a borderline (possibly based on some notion of "novelty" as used in a number of CIS 1 surveys) and a scale for differentiating large and small innovations. There are innovations that, despite close links with technological change, are not technological. Thus, there is a need to draw a line between technology, on the one hand, and organisation, design, marketing, etc., on the other. There may also be a need to examine the connectivity between such forms of innovative behaviour and technological innovation. Indeed, a study of activities on the borderline of technological innovation would greatly assist the understanding that can be applied to the results in respect of technological innovation.

It is not clear whether the same definition applies equally across industries; this is why some countries do not include the service sector in the scope of their surveys. Even then, the breadth of the service sector is so wide that it is likely that different concepts and understanding will often be applied. For example, is the relevant definition of a technological innovation the same in the telecommunications industry, the steel industry, in restaurants and in aerospace? Given such heterogeneity, it is not clear that applying the same definition to all industries will deliver comparable cross-industry results. This is all the more worrying as the (very few) experiments conducted so far have pointed to a high sensitivity of respondents to apparently minor changes in the definition.

Measuring the output from process innovators

As part of the above discussion, various sets of statistics have tried to show the relative importance of technologically innovative products and the firms that implement technologically innovative products to industry output. However, no attempts have been made to measure the output from process innovation. No data are collected, for instance, on the share of output affected by new processes, or on the effect of new processes on productivity. These effects can be measured only indirectly, through econometric estimates.

Measuring the impact of innovation of firm performance and employment

This article has shown that there is a desire by researchers round the world to study issues associated with the impact of innovative activity on the performance of individual firms and on industries. The difficulty lies in being able to obtain the data needed to allow these analyses to be undertaken efficiently. It is particularly important that quantitative measures of productivity, profitability and employment generation be made available at the firm level so that econometric work can be undertaken in a more thorough way. Such exercises usually require matching several databases, which is not a straightforward exercise due to technical as well as legal barriers.

As in many other fields, there is a trade-off between the amount of statistical data collected or compiled on an issue and the amount that can be made available by statistical authorities due to confidentiality and security concerns and constraints. Nevertheless, this is an area where access to unit record data, or at least to micro-aggregated data, is essential for detailed econometric analyses. This article does not explore the possible options that can be used to make data available; rather it makes the plea for statisticians to look to all possible options to maximise the benefits of the data collection exercise.

Achieving greater international comparability

As is the case for many science and technology indicators, international comparisons are at the centre of requests by policy makers. Thus, it is vitally important that the data compilation is done in an internationally comparable way. One essential component of this is agreement on the definitional issues referred to earlier. There also appears to be a need to strengthen international compatibility of survey methodologies (*e.g.* sampling, treatment of non-responses).

In addition, there needs to be consistency among the indicators. As reported in this article, even for perfectly comparable basic data, special methods have to be adopted for calculating aggregate indicators that are free of biases caused by differing industrial structures across countries (notably the structure of the population of firms by size classes, and the relative innovativeness of small and large firms). As such indicators can be calculated only by starting from the basic, firm-level data, some mechanism has to be implemented for allowing international co-ordination in this regard.

VII. CONCLUSION

As the present, non-exhaustive study has shown, innovation surveys have substantially improved our knowledge of innovation. They have enabled investigations of phenomena that were previously not possible and have enabled the confirmation of previously unsubstantiated ideas. Some examples of these are:

- A high proportion of firms undertake technological innovation.
- Innovativeness is as important for services as for manufacturing.
- Size of firm is an important determinant of innovative behaviour.
- There appear to be many country differences in innovation rates.
- Innovation appears to have impacts on the performance of firms in terms of profitability, productivity and employment generation.
- Innovation reallocates jobs across firms and industries.
- Innovation policies are concerned more with large firms more with small ones.
- University knowledge is important to firms.
- Co-operation with other firms is an important source of innovation.

The demand for comprehensive, internationally comparable statistics is really only just beginning. The standards and definitions need to be reviewed, modified (where necessary) and put into place to enable statistical authorities to proceed with the task of collecting the information. The data need to be made more accessible to analysts.

Recently, certain countries have introduced the notion of "innovative firms" in their policies, including Canada (for tax breaks) and France (for access to tax-friendly financing). This increased policy interest calls for further improvement in innovation surveys and for more studies using these data.

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I. INTRODUCTION

Out of a growing concern that inputs into the innovation process were insufficiently covered by the notion of R&D expenditures as defined in the *Frascati Manual* (OECD, 1963), that the output of that process had to be measured in a more direct way than through patents, and, last but not least, that information was lacking on the organisation of research and innovation activities, statistical experts met under the auspices of the OECD to set guidelines for the design of innovation surveys. These have been formulated in the so-called *Oslo Manual* (OECD, 1992; OECD and Eurostat, 1997).

To date, a number of countries have launched two or three innovation surveys, which have been conducted in more or less the same fashion, following the guidelines set out in the *Oslo Manual*. In Europe, these surveys are known as CIS (Community Innovation Surveys). Despite efforts by Eurostat towards harmonisation, the first round of surveys, CIS 1, performed in 1993 and relating to 1990-92, suffered from major differences in terms of coverage, sampling, questions asked, reporting unit, and organisation of the survey (see Archibuggi *et al.*, 1994, for details). The second round of surveys CIS 2, performed in 1997 and pertaining to the period 1994-96, was more comparable across countries, and the third round of surveys, CIS 3, which is currently under way, is expected to show considerable improvements. In addition to exploitation of the results by national statistical agencies, Eurostat assembles and analyses the country data in a consistent way in an effort to render them, to the fullest extent possible, suitable for international comparisons. Eurostat also contributes to making the CIS data available to researchers for further investigation. However, in order to strictly preserve the confidentiality of firm-level information, Eurostat delivers the data in micro-aggregated form.[1] The micro-aggregation process adopted by Eurostat for CIS 1 and CIS 2 consists of replacing each observation of a given variable by an average of itself and the two adjacent observations in a ranking order of the observations for that variable.[2]

To compare innovation performance across industries or countries, we have elsewhere proposed two related indicators (Mohnen and Dagenais, 2001; Mohnen, Mairesse and Dagenais, 2001). Both use information retrieved from the innovation surveys. The first is the expected share of innovative sales in total turnover. It estimates the percentage of innovative sales that can be expected for a firm, an industry or a country, when controlling for a number of explanatory variables that influence innovation. The second is what we call innovativeness, which is defined as the difference between the observed and the expected share of innovative sales. In a model or framework which aims to account for innovation, innovativeness can be viewed as an analogue to total factor or multifactor productivity in the standard production (or output growth) accounting framework.

In this article, we do two things. We first illustrate the construction and interpretation of the two proposed innovation indicators, while checking how robust they are to the use of micro-aggregated *vs.* individual firm data. To do so, we contrast the estimation results obtained on two random samples of French firms, both drawn from CIS 2. One is drawn from the raw data set, the other one from the micro-aggregated data set. We further illustrate the use of the two indicators by comparing innovation across seven European countries on the basis of the CIS 1 micro-aggregated data for these countries.

The article is organised as follows. In Section II, we define the two analytical innovation indicators as they can be constructed from an appropriate econometric analysis of the available innovation survey data. In Section III, we examine to what extent these two indicators may be sensitive to the micro-aggregation of the individual data, putting them to test in a comparison of innovation across French manufacturing industries based on the French CIS 2 survey. In Section IV, we proceed to an international comparison of innovation across seven European countries using CIS 1 data. In Section V, we conclude by discussing how the two analytical indicators compare to other innovation metrics and by suggesting possible avenues of future research to refine our measurement and understanding of innovation.

II. INNOVATION INDICATORS FROM INNOVATION SURVEY DATA

Innovation surveys based on the guidelines of the *Oslo Manual*, such as the CIS surveys, typically provide information on the input and output of a firm's innovative activities, as well as on the modalities of these activities. On the input side, we have quantitative data on R&D expenditures and other current and capital expenditures on innovation, and know whether or not firms engage in R&D, in R&D collaboration or in the outside acquisition of technology. On the output side, we know whether or not firms have introduced new products or processes, and have quantitative estimates on the share of sales broken down into unchanged or marginally modified products, significantly improved or entirely new products and new or improved products which are not only new to the firm but also to its market. Regarding the modalities of innovation, we know whether R&D was performed continuously or not, and can obtain qualitative information on sources of knowledge, reasons for innovating, perceived obstacles to innovation and perceived strengths and weaknesses of various appropriability mechanisms.

In this work, as in other related work, we assess the extent of innovation in a given industry or country by the share of innovative sales. Innovative sales can be viewed as a sales weighted measure of the number of innovations. Compared to R&D expenditures – and even to the broader concept of innovation expenditures defined in the *Oslo Manual*, which embraces expenditures such as pilot studies and market analyses – innovative sales have the advantage of being an output measure of innovation. Also, in contrast to patents, they have a much broader scope and are defined in a more straightforward way than through the decisions of the innovating firms to protect their intellectual property rights.[3] Innovative sales, as we define them here, are constructed on the basis of the CIS 1 and CIS 2 questionnaires, as the sales due to new products which are or improved for the firm (but not necessarily for the market) in the last three years (1990-92 for CIS 1 and 1994-96 for CIS 2).[4]

In assessing the extent of innovation in a country or an industry by the share of innovative sales, we believe that an important first step in an inter-country or -industry comparison, irrespective of more focused and deeper analyses, is to control for differences in industry composition, average firm size, as well as average intensity firm R&D effort, and possibly characteristics of the economic environment. This implies the explicit choice of an econometric model, or to use a different vocabulary, an (econometrically based) "accounting framework", whose implementation would be, of course, largely dependent on the available information.

In particular, we consider it important to base a country or industry comparison not just on the innovative sales of innovating firms but also on the propensity of firms to innovate or not. If we restrict the analysis to innovating firms only, we ignore the information about the non-innovating firms, and as a matter of fact our analysis would be conditional on that restriction, or otherwise would be likely to suffer from selection biases if we wanted to extend its results to the whole population of firms. If we limit ourselves to qualitative information on whether or not firms are innovative (responding yes or no to the question of whether or not they had introduced any new or improved products or processes in the last three years), we can compute an index of ability or propensity to innovate for all firms, but we then fail to exploit the quantitative information that we have on innovating firms but that we do not have for non-innovating ones.[5] Therefore, we surmise that the appropriate way to proceed is to combine both types of information by implementing an appropriate econometric model or accounting framework which tries to account for the fact that firms are either innovative or not, and, for those that are innovative, the extent to which they are so.[6] In what follows, we thus focus on a generalised tobit model, which seems to be the natural two equation specification to consider (Mohnen and Dagenais, 2001; Mohnen, Mairesse and Dagenais, 2001).

As an important outcome of such an accounting framework, we propose to focus on two types of innovation indicators: "expected innovation" and "innovativeness". The expected (or explained) innovation indicator is the share of innovative sales which can be predicted given the model adopted to account for both the propensity to innovate and the intensity of innovation, for a given set of values of the exogenous variables in this model. It measures the share of innovative sales that we would predict for firms in a particular industry, of a given size and given intensity of R&D effort, in a certain economic environment, and so on. Innovativeness is the unexpected (or unexplained or residual) part of the actual observed share of innovative sales, which remains unaccounted for by the model as it stands.

The interest of the expected innovation indicator (and the underlying accounting framework) is that it goes beyond merely reporting the observed share of innovative sales, and attempts to explicitly assess the differences which are imputable to the differences in industry, size, R&D effort, economic environment, and so on. It should allow for a better-informed comparison of innovation performances across different countries, industries or groups of firms and for different time periods.[7]

Innovativeness is to innovation what multifactor productivity or total factor productivity (TFP) is to output. The measure of innovativeness is conditional on a model of the "innovation function" and a set of innovation factors, just as TFP is conditional on an explicit or implicit specification of the production function and measured factors of production.[8] Innovativeness is the "residual" of the innovation function, just as TFP is that of the production function. Both thus correspond to omitted factors of performance such as technological, organisational, cultural or environmental factors, although TFP is commonly interpreted as an indicator of technology. However, both also correspond to other sources of mis-specifications and errors in the underlying model of the innovation or production function, and could be rightly viewed as "measures of our ignorance". Both innovativeness and TFP can, in principle, be measured in terms of growth and levels, and for intertemporal comparisons (between time periods) as well as for interspatial comparisons (across countries, industries or firms). In this article, however, we shall estimate and compare levels of industry or country innovativeness, whereas TFP is usually considered and measured as TFP growth.[9]

Innovativeness could ideally acquire, in the context of innovation comparisons, a usefulness that would be similar to, if not on a par with, that acquired by TFP over the years in the context of productivity comparisons. However, it remains true, both in the case of innovativeness and in that of TFP, that these are not simple indicators, but elaborate constructs, and that their meaning and usefulness ultimately rely on the consideration of the entire underlying accounting framework from which they arise.

III. INNOVATION INDICATORS FOR FRENCH MANUFACTURING BASED ON CIS 2 DATA: ROBUSTNESS TO MICRO-AGGREGATION AND COMPARISON ACROSS INDUSTRIES

To illustrate the construction of the proposed expected innovation and innovativeness indicators and, at the same time, examine their robustness to the micro-aggregation procedure used by Eurostat to protect statistical confidentiality, we estimate our generalised tobit model, using the raw and micro-aggregated French CIS 2 data. The raw data are those collected by SESSI (Service des Statistiques Industrielles) of the French Ministry of Industry. The micro-aggregated data are those provided by Eurostat. The industries to which the firms belong are defined using the NACE 1 (Rev. 2) classification. In order to have a sufficient number of observations per cross-sectional unit, industries are grouped into ten sectors, following Eurostat's (1997) presentation of descriptive statistics from CIS 1 (see Annex for the NACE codes corresponding to these sectors).[10]

To make the SESSI data comparable to those from Eurostat, the nominal data from SESSI are converted to euros, divided by the raising factor, and codified in the same way as Eurostat data, *e.g.* as missing data for all variables corresponding to questions that needed be answered by innovators only. Both data sets are cleaned for outliers. Firms with more than 100 000 or less than 20 employees are eliminated, as are those with an R&D/sales ratio of over 50%. From each of the two data sets, we take a random sample of 1 000 firms in the high-R&D sectors (regrouping chemicals, machinery and equipment, electrical machinery and transportation equipment), and a random sample of 1 000 firms in the low-R&D sectors (regrouping textiles, wood, rubber and plastics, non-metallic mineral products, basic and fabricated metals, and furniture and not-elsewhere-classified industries). As a first rough control for industry heterogeneity, we estimate separately our model from the samples in the high-R&D and the low-R&D sectors, based on previous econometric evidence showing large differences not only in R&D intensity but also in the returns to R&D between these two groups of sectors (Griliches and Mairesse, 1984). Note that to control further for industry heterogeneity, we also introduce industry dummies in each of the two equations of the generalised tobit model (four in the high-R&D sector samples; six in the low-R&D sector samples).

The first equation of our tobit model explains the ability or propensity to innovate. Are considered as innovators, those enterprises that declare having introduced a technologically new or improved product or process, or having unsuccessful or not yet completed projects to introduce such a product or process in 1994-96. The second equation explains the intensity of innovation (for firms that do innovate). The intensity of innovation is captured by the share in sales of innovative products, defined as technologically new or improved products introduced between 1994 and 1996.[11] The explanatory variables introduced in the first equation to explain the ability to innovate are, in addition to the industry dummies, the fact of being part of an enterprise group, and size, measured by the number of employees (in logarithm). For the intensity of innovation we have, in addition to the preceding explanatory variables, an indicator for the strength of competition, an indicator for the proximity to basic research, the existence of any kind of co-operation in innovation, the absence of any R&D activity, the existence of continuous R&D activity, and the R&D intensity. Competition is deemed to be strong when opening new markets or increasing market share is given the highest mark, *i.e.* three. Proximity to basic research is given the value of one when sources of information from universities/higher education or government laboratories have a score of two or three. Firms conducting both transitory and permanent R&D are classified among the continuous R&D performers.

An ideal test of the robustness of the estimates to micro-aggregation would have been to contrast the results obtained from the same firms once with raw data and once with micro-aggregated data. Instead, we pick two random samples from both data sets for each of two sub-samples, high-R&D sectors and low-R&D sectors, and contrast our results for these random samples. In a sense, this is a more demanding (and more realistic) test since the individual and "micro-aggregated" firms in the corresponding samples are not necessarily the same, but are randomly drawn from the same population of firms, in the high-R&D and low-R&D sectors, respectively.

Before comparing the estimates of our model, it is instructive to compare the descriptive statistics for the individual and micro-aggregated data samples. This is done in Table 1 and Figures 1 and 2. As is evident from Table 1, the sample means of the different variables entering into our model are very close in the two types of samples. First, the sample distribution with respect to the industrial composition is very similar. Only for textiles does the share of firms in the two samples differ by more than two percentage points. For all the other variables (other than the industry dummies), we report the sample means and the sample standard deviations. We also give the standard error of the test of comparison of the sample means for the two types of sample.[12] A difference between the sample means of a variable in the two types of sample is statistically significant (at the 5% confidence level) if it exceeds roughly two times the corresponding standard error for the test. An asterisk marks these cases. In the case of the high-R&D sector samples, we find significant differences among the two types of samples only for the percentage of R&D-performing firms among the innovators and, among those, for the share of continuous R&D performers. In the low-R&D sector samples, we find significant differences for the share in sales of innovative products, the percentage of R&D performers, the percentage of continuous R&D performers, the R&D/sales ratio, and the percentage of firms close to basic research. However, even in these cases,

Table 1. **Summary statistics: CIS 2 data for France**

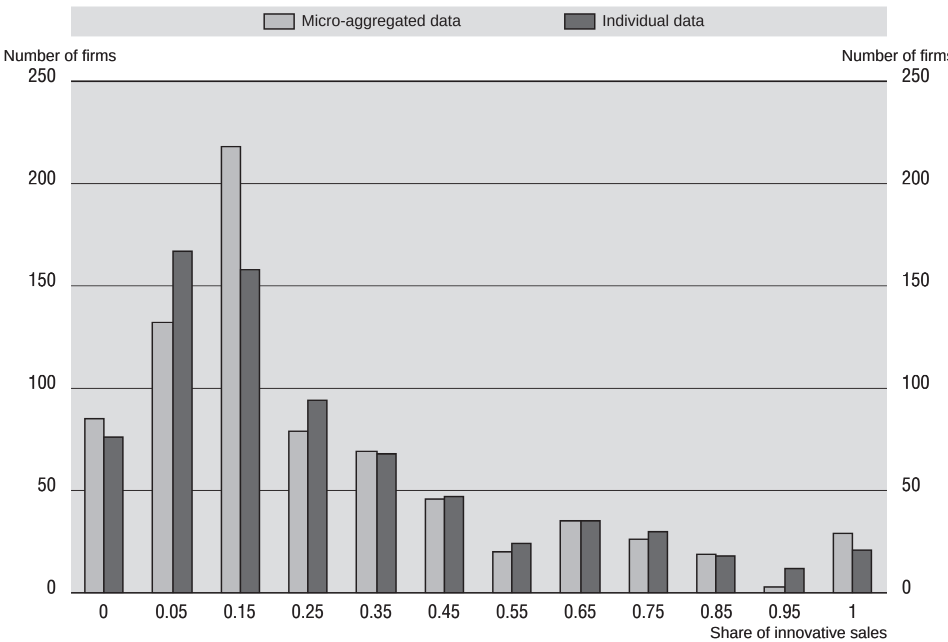
Individual data from SESSI and micro-aggregated data from Eurostat "high-R&D" and "low-R&D" sectors

Variable	High-R&D sector		Low-R&D sectors	
Type of data	Individual data	Micro-aggregated data	Individual data	Micro-aggregated data
Number of firms	1 000	1 000	1 000	1 000
% of firms in vehicles	15.6	14.3	–	–
% of firms in chemical	22.7	24.2	–	–
% of firms in M&E	29.4	29.4	–	–
% of firms in electrical	32.3	32.1	–	–
% of firms in textile	–	–	22.6	19.8
% of firms in wood	–	–	20.4	20.7
% of firms in plastic	–	–	9.3	10.7
% of firms in non-metal.	–	–	8.6	8.8
% of firms in metals	–	–	31.1	31.3
% of firms in nec	–	–	8.0	8.7
Average number of employees (in logs)	5.21	5.18	4.51	4.56
	(0.05)	(0.05)	(0.04)	(0.04)
	[1.46]	[1.46]	[1.20]	[1.21]
% of firms belonging to a group	69.4	67.8	45.8	49.2
	(1.47)	(1.47)	(1.58)	(1.58)
	[46.1]	[46.8]	[49.9]	[50.0]
Percentage of innovators	75.0	76.1	48.2	45.9
	(1.36)	(1.36)	(1.56)	(1.56)
	[43.3]	[42.7]	[50.0]	[49.9]
Share in sales of innovative products, for innovators (y2)	28.4	27.8	23.3*	21.2*
	(0.86)	(0.86)	(0.84)	(0.84)
	[27.2]	[27.4]	[28.5]	[24.8]
Log of y2/(1-y2), trimmed	–1.38	–1.40	–1.83*	–1.97*
	(0.06)	(0.06)	(0.07	(0.07)
	[2.0]	[2.1]	[2.5])	[2.1]
% of R&D firms among innovators	83.9*	76.0*	56.9*	49.9*
	(1.26)	(1.26)	(1.58)	(1.58)
	[36.8]	[42.8]	[49.6]	[50.1]
Average R&D/sales in%, if performing R&D	4.6	4.8	1.8*	2.4*
	(0.19)	(0.19)	(0.08)	(0.08)
	[6.0]	[5.7]	[2.4]	[2.5]
% of continuous R&D, if performing R&D	80.0*	84.1*	67.9*	74.2*
	(1.21)	(1.21)	(1.43)	(1.43)
	[40.1]	[36.6]	[46.8]	[43.8]
% of co-operating firms among innovators	52.7	52.7	33.4	34.4
	(1.58)	(1.58)	(1.50)	(1.50)
	[50.0]	[50.0]	[47.2]	[47.6]
% of strongly perceived competition among innovators	68.0	66.0	54.8	57.1
	(1.49)	(1.49)	(1.57)	(1.57)
	[46.7]	[47.4]	[49.8]	[49.6]
% of close proximity to basic research among innovators	25.7	26.3	15.6*	13.1*
	(1.39)	(1.39)	(1.11)	(1.11)
	[43.8]	[44.1]	[36.3]	[33.8]

Note: The first figures in each cell are the sample means, while those in brackets are the sample standard deviations. The figures in parentheses are the standard errors of the tests of comparison of the sample means for the individual and micro-aggregated data samples (computed as the average of two corresponding standard deviations divided by the square root of 1 000). An asterisk (*) indicates that these sample means are significantly different at the 5% confidence level.

Figure 1. **Histogram of the share of innovative sales for the sub-sample of innovative firms in the high-R&D sector samples**

Individual data from SESSI and micro-aggregated data from Eurostat

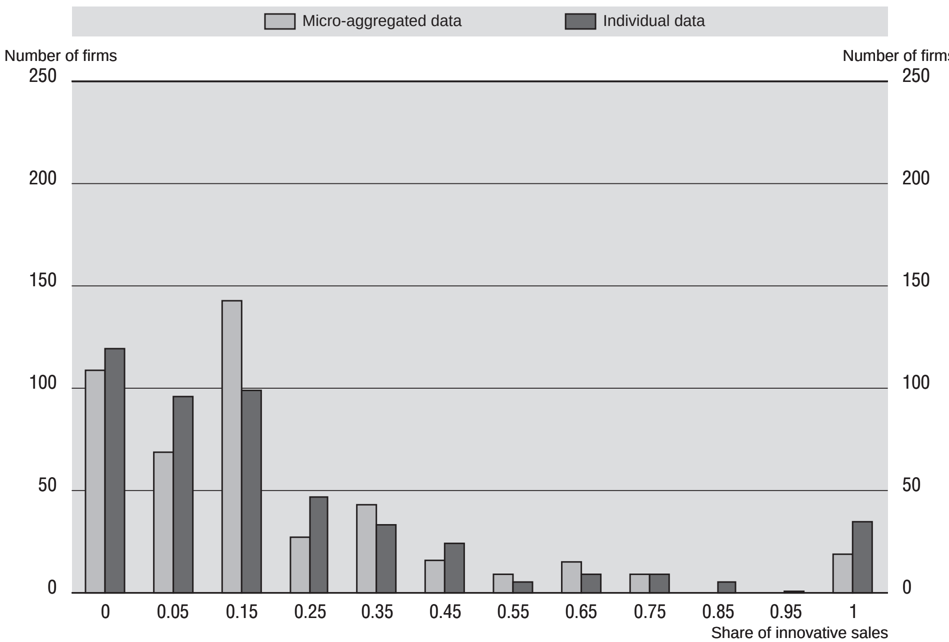


the differences are not very large. We also note that differences between the sample standard deviations for the individual and micro-aggregated data samples are quite small. In fact, the differences of the means of all the variables are much greater and statistically significant between the high-R&D and the low-R&D sector samples (which is consistent with our choice to consider them separately in estimating our model). Firms in the high-R&D sectors are larger, more innovative (in frequency and in size), and more R&D-intensive. They also collaborate more in innovation, face more competition, are closer to basic research, and more often belong to an enterprise group.

In Figures 1 and 2, we present the decile distribution of the share in sales of innovative products in the four samples. Again, it is clear that, by and large, the distributions are very close for the micro-aggregated and individual data samples, and the distributions show greater differences between the low-R&D and high-R&D sector samples (although in both cases, the bulk of the firms have a relatively low share of innovative sales).

Figure 2. **Histogram of the share of innovative sales for the sub-sample of innovative firms in the low-R&D sector samples**

Individual data from SESSI and micro-aggregated data from Eurostat



In Table 2, we present the estimation results of the generalised tobit model that underlies the constructed indicators of innovation. We experienced difficulties in estimating the correlation coefficient ρ between the error terms in the two equations of the model. A grid search revealed that the highest likelihood was obtained at values of ρ tending towards one, and we therefore decided to settle for a value of 0.95.[13]

We can see first that the estimates are rather similar whether we take the individual or the micro-aggregated data. If we leave aside the industry dummies, there is only one occurrence of a significant coefficient in one sample and not in the other for the high-R&D sectors, and four occurrences for the low-R&D sectors. Actually, the confidence intervals of the estimates always overlap, except for the wood industry dummy. The two types of data thus do not seem to yield systematically different estimates, even in such a non-linear model as our tobit model. These results confirm and reinforce the conclusion already drawn for CIS 1 by Hu and DeBresson (1998) that the use of micro-aggregated data produces reliable

Table 2. **Maximum likelihood estimates of the generalised tobit model of innovation: CIS 2 data for France**

Micro-aggregated data from Eurostat and individual data from SESSI

	High-R&D sectors			
Variables	Micro-aggregated data		Individual data	
	Propensity to innovate	Intensity of innovation	Propensity to innovate	Intensity of innovation
Vehicles	0.51* (.13)	–3.33* (.33)	0.44* (.12)	–3.45* (.30)
Chemicals	0.63* (.12)	–3.71* (.32)	0.40* (.12)	–3.66* (.30)
Machinery and equipment	0.82* (.12)	–2.82* (.29)	0.66* (.11)	–2.75* (.28)
Electrical	0.71* (.10)	–3.03* (.30)	0.60* (.10)	–2.97* (.28)
Log-employees	0.29 (.04)	0.45* (.07)	0.24* (.04)	0.50* (.07)
Part of a group	0.15 (.04)	0.27 (.23)	0.30* (.11)	0.31 (.23)
R&D/sales	-x-	3.17* (1.42)	-x-	3.17* (1.30)
Innovators not doing R&D	-x-	–0.19 (.23)	-x	–0.31 (.21)
Doing R&D on a continuous basis	-x-	0.52* (.21)	-x-	0.39* (.18)
Co-operating in innovation	-x	0.11 (.14)	-x-	0.22 (.14)
Perceived competition	-x-	0.22 (.14)	-x-	0.10 (.14)
Proximity to basic research	-x-	–0.02 (.16)	-x-	–0.13 (.16)
Standard error of error terms	1 (assumed)	2.47* (.07)	1 (assumed)	2.45* (.07)
Correlation coefficient of the two error terms	0.95 (imposed)		0.95 (imposed)	

	Low-R&D sectors			
Variables	Micro-aggregated data		Individual data	
	Propensity to innovate	Intensity of innovation	Propensity to innovate	Intensity of innovation
Textile	–0.44* (.10)	–5.08* (.42)	–0.33* (.09)	–5.28* (.42)
Wood	–0.50* (.10)	–5.56* (.44)	–0.23* (.11)	–5.03* (.44)
Plastic and rubber	0.18 (.14)	–3.77* (.49)	0.29* (.14)	–4.09* (.51)
Non-metallic products	–0.24 (.14)	–4.61* (.54)	0.03 (.14)	–4.89* (.54)
Basic metal	–0.18 (.09)	–4.90* (.40)	–0.12 (.08)	–5.10* (.38)
NEC	0.01 (.14)	–3.19* (.51)	0.04 (.14)	–4.11* (.53)
Log-employees	0.23* (.04)	0.38* (.12)	0.23* (.04)	0.48* (.14)
Part of a group	0.28* (.10)	0.40 (.29)	0.18 (.10)	0.74* (.34)
R&D/sales	-x-	–2.64 (5.14)	-x-	8.35 (5.50)
Innovators not doing R&D	-x-	–0.66* (.31)	-x-	–0.66* (.27)
Doing R&D on a continuous basis	-x-	0.31 (.30)	-x-	–0.36 (.29)
Co-operating in innovation	-x-	0.18 (.20)	-x-	–0.05 (.20)
Perceived competition	-x-	0.37* (.17)	-x-	0.55* (.19)
Proximity to basic research	-x-	0.16 (.28)	-x-	0.30 (.29)
Standard error of error terms	1 (assumed)	3.03* (.11)	1 (assumed)	3.43* (.12)
Correlation coefficient of the two error terms	0.95 (imposed)		0.95 (imposed)	

Note: Standard errors of estimates in parentheses. An asterisk (*) indicates a coefficient statistically different from zero at a 5% confidence level.

results. However, it should be noted that our model does not perform very well, and, hence, the lack of significant differences between the two sets of estimates could very well be due in part to their poor precision.

Table 2 also reveals clearly that the model performs somewhat better in the high-R&D than in the low-R&D sectors. Firm size, R&D intensity and the characteristic of conducting continuous R&D are strong explanatory factors of innovation for the high-R&D sectors. The same can be said for firm size, for being part of a group or being an R&D performer, or for the strength of competition in the case of the low-R&D sectors but, surprisingly, R&D intensity does not appear to be significant.

In Table 3, we present the results of applying our innovation accounting framework to the comparison of the innovation performance of the industries in the high-R&D and low-R&D sector samples, as estimated respectively on the individual data (in the two upper panels) and on the micro-aggregated data (in the two lower panels). We account for the observed innovation intensity in terms of the innovation intensity expected (explained by the underlying model) and innovativeness (unexplained by the model). We also decompose the expected intensity into an overall average intensity and three categories of "structural" effects corresponding to the explanatory variables introduced in our model: size and group effects, R&D effects, and environment effects (perceived competition and proximity to basic research).

For each industry in a given sample, we start (column 1) from the overall average of observed innovation intensity for the full sample (*i.e.* a weighted average of the different industry averages). Note that this average is defined over all firms in the sample, irrespective of whether they innovate or not, taking observed intensity of innovation to be zero for non-innovating firms. We then compute the expected intensity of innovation for each industry by taking a linear approximation of the expected intensity of innovation around the overall observed averages of the different variables in the model. The different terms of this decomposition are thus approximate measures of the respective contributions of the variables to the expected intensity in each industry. By taking a linear approximation, we ensure that these measures are independent of the sequential order of the variables in the decomposition. The "average" row in each panel of Table 3 makes it clear that this decomposition is to be interpreted in terms of industry effects relative to full sample effects (industry deviations to full sample effects). It also makes clear that innovativeness, computed as the difference between the observed and expected average innovation intensity in each industry, is to be viewed as industry innovativeness relative to overall innovativeness.[14] When weighted appropriately by the different number of observations in each industry in the full sample, the three categories of effects and innovativeness (shown in the "industry" rows in each panel) average out to zero.

Table 3. **Average observed and expected innovation intensities, and innovativeness**
Eleven manufacturing sectors, individual and micro-aggregated CIS 2 data for France

	Average intensity: full sample	Size + group effects	R&D effects	Environment effects	Sum of structural effects	Expected intensity	Innovative ness	Observed intensity
	High-R&D sectors – individual data							
Vehicles	21.3	3.6	0.1	0.0	3.7	25.0	–1.0	24.0
Chemicals	21.3	1.3	0.4	0.0	1.7	23.0	–6.7	16.3
Machinery and equipment	21.3	–2.5	–0.6	0.0	–3.0	18.3	2.2	20.5
Electrical products	21.3	–0.6	0.2	0.0	–0.4	20.9	3.3	24.2
Average	21.3	0.0	0.0	0.0	0.0	21.3	0.0	21.3
	Low-R&D sectors – individual data							
Textiles	11.2	–0.5	0.1	-0.3	–0.7	10.5	–1.5	9.1
Wood	11.2	0.1	–0.3	-0.2	–0.4	10.9	–0.4	10.5
Plastics, rubber	11.2	2.0	–0.2	0.8	2.7	13.9	1.7	15.6
Non-metallic mineral products	11.2	1.8	–0.1	0.8	2.5	13.7	–3.0	10.7
Basic metals	11.2	–0.4	0.2	0.0	–0.2	11.1	–0.5	10.6
NEC	11.2	–0.3	–0.1	0.0	–0.4	10.8	6.5	17.4
Average	11.2	0.0	0.0	0.0	0.0	11.2	0.0	11.2
	High-R&D sectors – micro-aggregated data							
Vehicles	21.1	2.0	–0.3	0.0	1.7	22.8	1.2	24.0
Chemicals	21.1	1.3	0.4	0.0	1.7	22.9	–6.9	16.0
Machinery and equipment	21.1	–1.8	–0.8	0.0	–2.6	18.5	2.4	20.9
Electrical products	21.1	–0.4	0.5	0.0	0.1	21.3	2.7	24.0
Average	21.1	0.0	0.0	0.0	0.0	21.1	0.0	21.1
	Low-R&D sectors – micro-aggregated data							
Textiles	9.7	–0.4	0.0	–0.1	–0.5	9.2	–1.7	7.5
Wood	9.7	0.0	–0.1	–0.1	–0.2	9.5	–2.7	6.8
Plastics, rubber	9.7	1.5	0.0	0.5	2.0	11.7	2.7	14.4
Non-metallic mineral products	9.7	0.6	0.3	0.2	1.2	10.9	–1.4	9.5
Basic metals	9.7	–0.3	0.1	0.0	–0.2	9.5	–0.7	8.8
NEC	9.7	0.7	–0.5	0.1	0.3	10.0	9.7	19.7
Average	9.7	0.0	0.0	0.0	0.0	9.7	0.0	9.7

If we take, for example, the vehicles industry in the case of the individual data sample (first row of first panel), we see that the average observed innovation intensity in this industry is 24%; that is 2.7% higher than the 21.3% average observed intensity for all firms operating in the high-R&D sectors. This difference

(2.7%) is accounted for by the sum of structural effects of 3.7% and the relative innovativeness of –1%, the former being mainly due to the combined effect of size and group-participation (3.6%) and to a tiny extent to the combined effect of all R&D variables (0.1%).

If we compare the innovation performance in the vehicles and machinery and equipment industries, we see that according to our estimates the vehicles industry has a clear size/group advantage as well as an R&D advantage, both types of effects explaining a difference in expected innovation intensity of 6.7% between the two industries. Actually the difference in the observed innovation intensity is significantly smaller, of 3.5%, since innovativeness is higher in the machinery and equipment industry (2.2% compared with –1%).

As a general observation, it appears that most of the inter-industry differences in expected innovation intensity are due to the size/group effect, and that the sum of structural effects and innovativeness vary roughly in about the same range from 0% to about + or –3% (with the exception of the chemicals industry

Figure 3. **“Structural effects” and innovativeness in the high-R&D sector samples**
Individual data from SESSI and micro-aggregated data from Eurostat

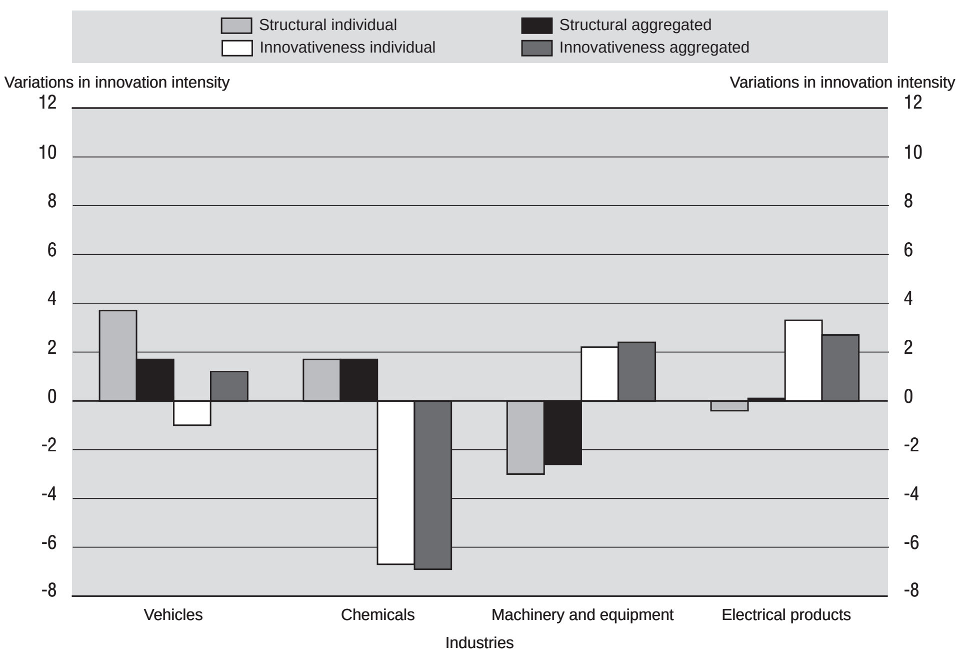
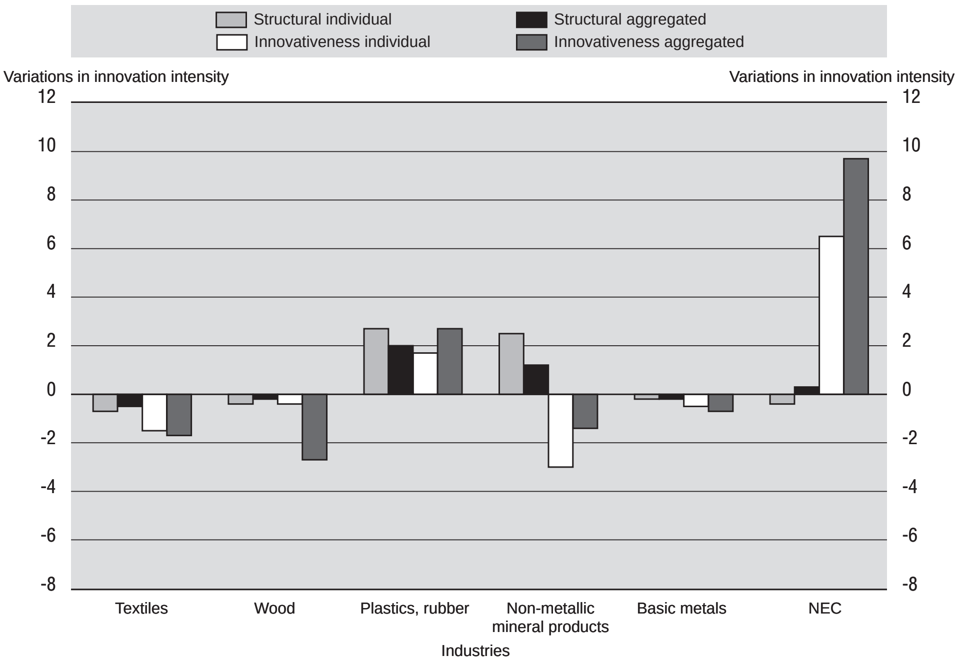


Figure 4. **"Structural effects" and innovativeness in the low-R&D sector samples**
Individual data from SESSI and micro-aggregated data from Eurostat



and the non elsewhere classified (NEC) products industry where innovativeness exceeds + or –6%). In fact, the inter-industry differences in the observed innovation intensity tend to be relatively limited, in the range of 0 to + or –8% within the high-R&D and low-R&D sectors (while much wider across the two types of sectors).

Figures 3 and 4 permit an easy industry-by-industry comparison of the differences in innovativeness and the sum of "structural effects", as estimated on the individual and the micro-aggregated data. By and large, the figures confirm that it does not matter much whether we work with micro-aggregated data or with individual data. Only for innovativeness in the vehicles industry do we see a sizeable difference, with a change in the sign.

IV. COMPARISON OF INNOVATION INDICATORS BETWEEN SEVEN EUROPEAN COUNTRIES BASED ON CIS 1 DATA

To further illustrate the construction of our expected innovation and innovativeness indicators, and our innovation accounting framework, we now turn to an international comparison of innovation. In Mohnen, Mairesse and Dagenais (2001), we estimated a generalised tobit model on the pooled CIS 1 micro-aggregated data of the manufacturing sectors of seven European countries: Belgium, Denmark, France, Germany, Ireland, the Netherlands, Norway and Italy. Again, we estimated the model separately for high-R&D and low-R&D sector samples. In pooling all observations, we estimated a common structure that was applied to individual country data in order to compare their innovation performance.

We defined an innovating firm as one that reports positive values of innovative sales. Indeed, some firms declare having introduced a new product or process and yet report no innovative sales. We treated such firms as non-innovative.[15] As explanatory variables, we have basically the same variables as in the preceding model applied to French CIS 2 data, with a few minor differences. We now have not only industry but also country dummies to control for heterogeneity. The two continuous variables, size (the number of employees, in logarithm) and R&D intensity, are expressed in deviations from the average of country averages, *i.e.* in deviation from a hypothetical Europe where each country has equal weight. Co-operation relates to R&D only. Competition is deemed to be strong when increasing or maintaining market share receives a rating greater than or equal to four, and proximity to basic research is given the value of one when sources of information from universities/higher education or government laboratories are given a score greater than or equal to two (on a five-point Likert scale). These cut-off values correspond roughly to the median responses. Prior to estimation, the data were cleaned for outliers and missing values.

In Table 4, we present the results of applying our innovation accounting framework to the comparison of the innovation performance of seven European countries, in the same format as we did in Table 3 for the comparison of innovation performance of French manufacturing industries. Here the reference point is the innovation intensity of the hypothetical European average country, constructed as the simple average of country averages (each country being given equal weight). The "average" rows in the two panels are thus the simple averages of country-specific deviations with respect to this European average.

Again, we clearly note a lower intensity of innovation for low-R&D sectors than for high-R&D sectors. However, the inter-country differences within the two groups of sectors tend to be wider than those observed for the inter-industry differences

Table 4. **Average observed and expected innovation intensities, and innovativeness**
Seven European countries, micro-aggregated CIS 1 data from Eurostat

	European intensity	Industry effect	Size + group effects	R&D effects	Environ-ment effects	Sum of structural effects	Expected intensity	Innovative ness	Observed intensity
	High-R&D sectors								
Belgium	34.7	–1.2	2.6	0.9	0.7	3.0	37.7	0.2	37.9
Denmark	34.7	1.3	–0.7	0.4	0.4	1.4	36.1	0.7	36.8
Germany	34.7	1.3	0.6	0.9	1.7	4.5	39.2	4.6	43.8
Ireland	34.7	–0.6	–2.2	0.1	–0.1	–2.6	32.1	3.1	35.2
Italy	34.7	0.4	1.1	–0.9	–1.6	–1.0	33.7	–8.1	25.6
Netherlands	34.7	–0.8	–1.1	–0.6	0.1	–2.4	32.3	1.0	33.3
Norway	34.7	–0.5	–0.2	–0.7	–1.5	–2.9	31.8	–1.6	30.2
Average	34.7	0.0	0.0	0.0	0.0	0.0	34.7	0.0	34.7
	Low-R&D sectors								
Belgium	22.3	0.4	0.3	0.2	0.1	1.0	23.3	5.5	28.8
Denmark	22.3	0.0	0.7	0.0	–0.1	0.6	22.9	–2.7	20.2
Germany	22.3	0.3	0.4	0.4	0.6	1.7	24.0	13.5	37.5
Ireland	22.3	0.4	–0.9	0.2	0.2	–0.1	22.2	3.3	25.5
Italy	22.3	0.7	–0.1	–0.4	–0.6	–0.4	21.9	–11.7	10.2
Netherlands	22.3	–1.0	–0.2	–0.2	–0.1	–1.5	20.8	–2.4	18.4
Norway	22.3	–0.8	–0.2	–0.1	–0.2	–1.3	21.0	–5.4	15.6
Average	22.3	0.0	0.0	0.0	0.0	0.0	22.3	0.0	22.3

Note: Small discrepancies are due to rounding errors.

in French manufacturing. The size/group variable again dominates all the structural effects. Innovativeness varies in about in the same range as the sum of "structural" effects in the high-R&D sectors, but not in the low-R&D sectors where it is always much greater.

The biggest observed difference in innovation intensity is between Germany and Italy – 18.2% in the high-R&D sectors and 27.3% in the low-R&D sectors, in favour of Germany. However, the difference in expected innovation intensity in the high-R&D sectors is only 5.5%, of which 1.7% can be explained by industry composition, 1.8% by R&D effects and 3.4% by environment effects (differences in competition and proximity to basic research). The difference in expected innovation intensity is even smaller in the low-R&D sectors – 2.1%, of which 0.8% correspond to R&D effects and 1.2% to environment effects. It is thus the case that the difference in innovativeness accounts for the bulk of the observed differences in the innovation intensity between these two countries. And, of course, the sources of such large difference in innovativeness remain unclear.

V. DISCUSSION OF THE INNOVATION INDICATORS

Innovation surveys serve to increase our understanding of the innovation process. Two important pieces of information contained in these surveys are the proportion of innovative firms by sector or country and the percentage of innovative products in sales. These variables complement traditional measures of innovation, based on R&D, patents or publications. In particular, the share of innovative products in sales provides a direct measure of an innovation output and gives greater weight to successful innovations, *i.e.* those accepted by the market. There is no need to rely on additional pieces of information in order to attribute more weight to important innovations, as would be necessary in the case of patent applications, such as renewal fees, forward citations, number of claims, number of parallel patents, or litigation expenses incurred (Lanjouw and Schankerman, 1999).

However, the point here is not to argue in favour of innovation-survey-based indicators over R&D, patent or bibliometric data (Brouwer and Kleinknecht; 1996; Mohnen and Dagenais, 2001, for a more detailed discussion comparing various innovation indicators). The aim of this article is to demonstrate the usefulness of going beyond descriptive statistics towards model-based innovation indicators to gain a better understanding of differences in innovation performance. We propose two constructed indicators that combine information on the propensity to innovate and the intensity of innovation (for innovating firms): expected innovation and innovativeness. The former corresponds to the share in sales of innovative products accounted for by variables such as size, R&D effort, closeness to basic research or competition, while the latter measures the residual share of innovative sales not accounted for by these explanatory variables. In other words, we propose an innovation accounting framework similar to the familiar growth accounting framework, where innovativeness plays a role comparable to that of TFP.

These indicators, however, require some caveats. First, the share of innovative sales refers essentially to product innovations. Looking at the data, it appears that most product innovators also declare themselves to be process innovators. The two innovations are thus largely confounded and the share in innovative sales reflects, in part, the rewards from the introduction of new processes. Second, how do we define an innovation? It is not only a question of what constitutes an innovation, which in itself is debatable and subject to the respondent's appreciation, but also a question of relying on one notion rather than on another: should we consider the notion of products new to the enterprise but not to the industry, the notion of products new to the industry or else that of products that are in the initial phase of their product life cycle? Third, it will be important for a sound comparison of innovation across space and time to have as much homogeneity as possible in the survey questionnaire. Efforts are under way to ensure greater harmonisation of the innovation surveys. If some questions are neglected in one survey, the analysis we prone in this article will be handicapped because some explanatory variables are absent for one country. In this respect, it will be useful also to ask more questions to non-innovating firms in order to gain a better understanding of the reasons why they do not innovate (using perhaps a different version of the questionnaire with a specific set of questions for such firms, or preferably by including a larger set of questions common to the two groups of firms).[16]

In this article, which we view mainly as an exercise in measurement, we have tried to make good use of the qualitative and quantitative data contained in the innovation surveys. Although the first results and insights gained are rewarding, the analysis would need to be generalised in various dimensions. More systematic sensitivity analyses would be useful. In particular, it would be interesting to compare the innovation indicators obtained using a given country or industry's innovation structure instead of estimating a common structure by pooling data. Mohnen and Dagenais (2001) find that the predicted innovation measure for Ireland and Denmark is similar regardless of whether the econometric structure used to perform the country comparison is the Danish or the Irish one. It would be also useful to analyse in more detail the sources of some of the econometric difficulties we encountered in estimating the generalised tobit specification. Beyond such analyses, it would, of course, be useful to combine innovation surveys with other survey data in order to increase the number of relevant explanatory variables in our model as it stands here and to be able to contrast indicators of R&D, patents, commercial innovations, publications, etc. Another promising line of research would be to extend the model (by adding more equations) in order to be able to analyse jointly, and hopefully better, the relations between R&D, innovation, productivity and other dimensions of firm performances (see Crépon, Mairesse and Duguet, 1998, for a step in this direction).

Finally, we wish to conclude by bringing to the fore the confirmation that the micro-aggregation procedure used by Eurostat to protect the statistical confidentiality of the data does not seem to significantly affect the results arising from a relatively sophisticated analysis of the kind conducted in this article, where in particular the estimated equations of interest are highly non-linear. We can thus hope that this procedure will be further developed and will make an important contribution to the diffusion of micro level information for research purposes, and hence to its progress.

NOTES

1. It does so only with the explicit and specific consent of the countries and under some other conditions.
2. The micro-aggregation process adopted by Eurostat for CIS 1 and CIS 2 and its justification are explained in detail in Eurostat (1996, 1999).
3. Since what is most generally known is the *number* of patents rather than their *value*, the innovative sales variable has the practical advantage of being continuous (rather than a count data variable).
4. We thus adopt the widest definition, although it would, of course, be interesting to consider and take advantage of the distinctions between new and improved products and between products new to the firm and new to the market.
5. There are, in principle, two categories of reasons to explain why we do not have the same information for the two types of firms: either a given information is only meaningful for innovating firms (the question is not posed to non-innovating firms because it makes no sense to ask them); or it is not collected because of the design of the questionnaire (the question is not posed to non-innovating firms but it could be asked with a different questionnaire). For example, most of the questions concerning the sources or objectives of innovation fall into the first category, while the questions concerning R&D expenditures and its modalities fall into the second one (these questions make sense for the two types of firms, even if we can expect that most non-innovating firms do not perform R&D, while most R&D-performing firms are innovators). In practice, however, the reasons why many questions are restricted to innovating firms are not straightforward and fall more or less into the two categories (it is conceivable and it would be interesting to ask such questions of non-innovating firms, but it is probable that they would have particular difficulties in understanding and answering them).
6. A related option would be to consider that the same model specification will apply to both non-innovating and innovating firms. In this case, the variables which are not available for the non-innovating firms will be treated as missing variables, and the share of innovative sales of non-innovating firms will be simply taken as being zero (or a very small but unknown value to be estimated jointly with the other parameters of the model). This approach is, however, *a priori* less satisfactory, and might prove impossible to implement in practice. For an example in the context of an econometric analysis of the productivity of R&D (for a sample of R&D- and non-R&D-performing French manufacturing firms) where this approach worked fairly well, see Cuneo and Mairesse (1985).
7. It also opens up the possibility of counterfactual comparison with respect to a country, an industry or a group of firms of reference (with hypothetical characteristics).

8. The analogy is direct when TFP is estimated on the basis of an econometrically estimated explicit production function; it is not as straightforward when TFP is measured on the basis of an overall weighted index of the measured factors of production, where the weights are taken to be equal to the corresponding factor shares (in total revenue or total cost) available from the firms accounts. In practice, it is impossible to measure innovativeness based on a similar overall index of the factors of innovation for lack of external measures of appropriate weights (and of a theory of how, and under which hypotheses, they could be defined and measured). In theory, that could be conceivable (and the analogy with TFP could then be complete) if we had well-functioning markets for innovation and factors of innovation where relative prices and marginal productivities would tend to become equal.

9. See Caves, Christensen and Diewert (1982) for a rigorous generalisation of TFP in the context of interspatial productivity comparisons.

10. The SCESS, the statistical office of the Ministry of Agriculture, (not the SESSI) collected the French CIS 2 data for the food sector. We have excluded the food sector from our analysis.

11. More precisely, we do not take as the dependent variable of the second equation the share of innovative sales itself, say y_2, which is limited to the 0 to 1 interval, but the logit-transformed share of innovative sales, that is $z_2 = \log(y_2/(1 - y_2))$ which is unbounded. However, the logit transformation is undefined for the innovating firms declaring that none of their sales are innovative sales or on the contrary that all of their sales are innovative sales. For these firms, we replaced shares equal to 0 by 0.01 and shares equal to 1 by 0.99. We have verified that taking somewhat different values for these extreme shares does not affect our estimates in practice.

12. The standard error for the test of comparison of the sample means for the two types of samples is calculated as the average of the individual and micro-aggregated sample standard deviations (which are usually quite close) divided by square root of the common size of these samples (*i.e.* $\sqrt{1000}$). Note that we do the test as if the individual and micro-aggregated firms in these samples were the same (which can only be the case for a fraction of them, since they are randomly drawn from a larger population); if we were to assume that they were all different, it would be more appropriate to multiply the standard error calculated as above by $\sqrt{2}$ and the test of comparison would thus be less stringent.

13. The difficulties we experienced in estimating ρ seem to be rather typical of the generalised tobit model. They are sometimes ignored when the likelihood function has not a unique (absolute) maximum but several local maxima, if the software program used converges to one of the local maxima (without searching for the others). However, it is reasonable to think that these difficulties are not only technical. They also reflect the fact that the specification of the model leaves something to be desired, if only for lack of more explanatory variables (and particularly so for the probit equation).

14. If our model was linear, relative innovativeness would be nothing but the industry dummy effect. However, since it is non-linear, relative innovativeness as computed also captures the linear approximation error. We have found, however, that for most industries, the linear approximation error remains small compared to the industry dummy effect.

15. In the estimation on French CIS 2 data (in Section III), we make a slightly different assumption. There, a firm which declares itself to be innovative, but which gives a zero response to the percentage of innovative sales, is classified among innovating firms with a share of innovative sales taken to be 0.01. However, as previously, we take as the dependent variable of the second equation the logit-transformed share of innovative sales (and replace shares equal to 1 by 0.99).

16. See endnote 5 above.

Annex

INDUSTRY DEFINITIONS

Industry	NACE code (Rev. 1)	Industry definition
		High-R&D sectors
Vehicles	34-35	Manufacture of motor vehicles, trailers, semi-trailers, and other transport equipment
Chemicals	23-24	Manufacture of coke, refined petroleum products and nuclear fuel, manufacture of chemicals and chemical products
Machinery	29	Manufacture of machinery and equipment nec
Electrical	30-33	Manufacture of office machinery and computers, electrical machinery and apparatus, radio, television and communication equipment and apparatus, medical, precision and optical instruments, watches and clocks
		Low-R&D sectors
Food[1]	15-16	Manufacture of food, beverages and tobacco
Textiles	17-19	Manufacture of textiles, wearing apparel, dressing and dyeing of fur, tanning, and dressing of leather, luggage, handbags, saddlery, harness and footwear
Wood	20-22	Manufacture of wood and products of wood and cork, except furniture, manufacture of straw and plaiting materials, pulp, paper, and paper products, publishing, printing, and reproduction of recorded media
Plastics, rubber	25	Manufacture of rubber and plastic products
Non-metallic	26	Manufacture of other non-metallic mineral products
Basic metals	27-28	Manufacture of basic metals, fabricated metal products, except machinery and equipment
NEC	36	Manufacture of furniture, manufacturing nec

1. The food industry is excluded from the analysis of the French data in Section III.

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USING PATENT COUNTS FOR CROSS-COUNTRY COMPARISONS OF TECHNOLOGY OUTPUT

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I. INTRODUCTION

A patent is an intellectual property right relating to inventions in the technical field. A patent may be granted to a firm, individual or public body by a national patent office. An application for a patent has to meet certain requirements: the invention must be novel, involve a (non-obvious) inventive step and be capable of industrial application. A patent is valid in a given country for a limited period (generally 20 years). Box 1 describes the patenting process in detail.

Among the few available indicators of technology output, patent-based indicators are probably the most frequently used. Most national S&T publications include a section on patents. The scientific literature on the determinants and impact of innovative activities increasingly uses patent data at the aggregate (national) or firm levels. This is because the close relationship between patents and innovative output is widely recognised and because patents are such a rich source of information. However, there is no standard method of calculating indicators from patent data, with the result that the analytical and policy lessons that can be drawn from patent statistics are widely divergent. The wide variety of indicators published (Box 2) or used in economic studies can be contrasted with the homogeneity of other S&T indicators such as R&D (based on the F*rascati* M*anual*) or even references to scientific publications (most of which are based on the same database, the Science Citation Index). Since the messages drawn from the various patent-based indicators differ widely and are often contradictory, it seems necessary to improve standardisation in this field. This is all the more necessary at a time when patenting activity by firms, but also universities and government laboratories, has been expanding rapidly, increasing the "noise" (lack of precision) and sometimes biases (misleading information) as well as the information conveyed by patent statistics.

Why are patents statistics so complex? As legal instruments, patents are a complex mix that reflect inventive activity, which is itself complex: they are governed by different national regulations, follow different, multistage procedures, and may allow for co-owners, co-inventors, etc. Counts can be made of different types of patents, within each type, and some selectivity may or may not be exercised. For instance, one can count all applications in one country, or only patents granted. A patent can be attributed to the applicant (the patentee at the date of application) or the inventor or the country where it has been filed first (priority

Box 1. **The patenting process**

This box describes the patenting process from filing an application through to granting of a patent or denial of the application. Thorough familiarity with this process is necessary in order to be able to interpret statistical indicators for patents. More detailed information is given in the "OECD Patent Manual" (OECD, 1994).

1) G*eneral procedure*. When the owner of a new technology (an individual, company, public body, university, non profit-making organisation) decides to protect an invention, the first step is to file an application with a national patent office (generally the national office of the applicant's country). The first application filed (in any patent office) and the date of filing are known as the "*priority application*" and the "*priority date*". The patent office then begins examining the application in order to check whether a patent may be granted or not, *i.e.* that the invention is, in fact, novel, inventive and capable of industrial application. The application is published 18 months after it is filed (*publication date*), except in the United States, where an application is published when the patent is granted and only if it is granted. The lapse of time between filing and granting or denial of a patent ranges from two to ten years, with significant differences from one country to another.

2) EPO (E*uropean* P*atent* O*ffice*). The EPO is a regional office which examines patent applications for 19 European countries. When it grants a patent, the rights of the applicant are protected in all of the countries of Europe that the applicant has designated in the application. This procedure is used by applicants who wish to protect their inventions in several countries of Europe (it is cheaper than filing separate applications with the national patent office of each individual country).

3) I*nternational application*. Since 1883, when procedures were standardised under the Paris Convention (which now has over 100 signatory countries), applicants who wish to protect their invention in more than one country have 12 months from the priority date to file applications in other Convention countries.

Another procedure for protecting a patent in several countries is to file an application under the Patent Co-operation Treaty (the PCT), which has been in force since the beginning of the 1980s) with the World Intellectual Property Organization (WIPO). The PCT procedure is an intermediate step between the priority application and filing for patent protection abroad. It is more of a way of keeping the option to file future applications open than an actual patent application. It gives the applicant time to decide whether or not to file an application in other PCT contracting countries, and protects the invention in the meantime. When filing a PCT application, the applicant designates any of the 100 PCT contracting countries in which he may wish to patent the invention. If the applicant designates countries covered by the EPO, the application is known as a "Euro-PCT" application.

Box 1. **The patenting process** (*cont.*)

The first stage in the PCT procedure (the Chapter I procedure), is to send a copy of the application to a body authorised under the PCT to conduct international searches for prior art. This body, the International Searching Authority (ISA), may be a regional or international patent office. The EPO, for instance, carries out more than half of all worldwide searches [other ISAs are the United States Patent and Trademark Office (USPTO), the Japanese and Swedish patent offices, etc.]. PCT applications are published by the WIPO 18 months after the priority application (as in the other offices). The international search report, published at the same time, gives the applicant some indication of whether or not a patent may be granted. Once the ISA has made its report, the applicant has three options, namely: to extend the application to the national and regional patent offices he has designated (entering the national or regional phase); to request a preliminary international examination; or, to withdraw the application. If the applicant opts for the regional phase and designates the EPO, the application is then termed an *extended* Euro-PCT *application*.

An applicant who opts for an international preliminary examination (as in most cases) enters the second phase of the PCT procedure (the Chapter II phase). The International Preliminary Examining Authority (IPEA) is the same as the ISA. The findings of the examination are not legally binding on the patent offices designated in the national or regional phase. Nevertheless, the EPO does take account of the outcome of the preliminary examination during the regional phase – in other words, if the Euro-PCT application is effectively extended to the EPO. The Chapter II procedure enables the applicant to delay the national or regional phase by up to 31 months from the priority date: the patentee may then decide to extend the application to any or all of the countries he has designated or to withdraw the application.

application). Regarding the attribution of dates, a patent has several of them: the priority date (first application worldwide), the date of application in a given country, the date of publication, or the date of grant. Depending on the selection made, the resulting indicators will give substantially different results.

The "Patent Manual" (OECD, 1994) marked a first step in the process of clarifying and harmonising patent-based indicators. It described the legal and economic background to patents – a necessary step before designing statistics – and listed indicators that could be constructed from patent databases. It also listed a limited number of methodological problems encountered when calculating indicators based on patents. However, the "Patent Manual" fell short of analysing these very problems and proposing practical solutions. The increasing diversity of

Box 2. **A sample of recently published patents statistics**

Australia (1996)

- Foreign patent applications, date of application, by inventor.
- USPTO grants, date of grant, by inventor.

European Commission (1997)

- EPO applications, date of priority, by inventor, including non-extended Euro-PCT since 1989.
- EPO applications, date of publication, by inventor, including non-extended Euro-PCT.
- USPTO grants, date of priority, estimates since 1992.
- USPTO grants, date of grant.
- Triad applications (patents which, in addition to the country of origin, are filed in at least two foreign markets in two different triad regions).

Germany, BMBF (1998)

- Triad applications (patents which, in addition to the country of origin, are filed in at least two foreign markets in different triad regions), figure I/15.

France, OST (1998)

- EPO applications, date of application, by inventor, including non-extended Euro-PCT for the last few years.
- USPTO grants, date of grant, by inventor.

Japan, STA (1996)

- JPO applications, and grant.
- Domestic (resident) patent applications (including PCT), and domestic grants.
- Foreign applications (including PCT) and grants.

The Netherlands (1994)

- EPO grants, date of priority.

OECD, MSTI (2000)

- Applications from OECD Member countries, resident and non-resident applications, by date of application/ or publication, by country of residence of the applicant.

Box 2. **A sample of recently published patents statistics** (*cont.*)

United States, NSF (1998)

- USPTO grants, date of grant, by inventor.
- Grants in large countries, date of grant, by inventor.
- Patent families for certain technology areas, by priority date, by priority country.

Sources: BMBF (1998), Bundesministerium für Bildung und Forschung, *Facts and Figures* 1998.
Department of Industry, Science and Technology (1996), *Australian Business Innovation – A Strategic Analysis*.
European Commission (1998), *Second European Report on S&T Indicators*, 1997 – *Appendix*.
Japanese Science and Technology Agency (1996), *Indicators of Science and Technology*.
Het Nederlands Observatorium van Wetenschap en Technologie (1994), *Wetenschap – en technologie – Indicatoren*, 1994.
NSF (1998), *Science and Engineering Indicators*, 1998.
OECD (2000), *Main Science and Technology Indicators*, 2000-2, Paris.
OST (1998), *Science et Technologie – Indicateurs* 1998, Paris.

patent-based indicators in response to the steady increase in demand for indicators for economic analysis, coupled with a distinct improvement in data supply (databases are a richer source of information and more widely available), underlines a crucial need for harmonisation.

This article addresses basic methodological problems associated with patent counts. Its aim is to propose rules and methods for calculating higher-quality patent-based indicators of the technology produced and used by countries. A range of issues relating to the counting process are addressed: choice of patent office, choice of a reference date, choice of country of attribution, and choice of the set of patents to be counted (domestic patents and patent "families").

II. PATENTS AS A SOURCE OF STATISTICAL DATA

The information content of patent documents

A patent applicant files a document with the patent office of the country in which he is seeking protection for his invention. The patent document is a rich source of information on the invention it covers; information that can be used directly in constructing statistical indicators. This article looks only at information that is currently used for indicators – in the full knowledge that data that is currently "silent" for statisticians could well prove pertinent and useful tomorrow thanks to progress in this area – primarily the patent specification, which can run to dozens of pages.

A first set of information relates to the *technical features* of the invention:

- The list of "claims" describes the innovative content of the given invention thus defining the patent's field of coverage.
- The technical classification to which the invention belongs. There are different classifications, the principal being the International Patent Classification (IPC) kept by the World Intellectual Property Organization, which contains more than 60 000 sub-divisions.
- Cited patents (each patent lists prior art relevant to the invention, which is usually described in other patents).
- Scientific papers cited.

A second set of information relates to the "development" *of the invention*:

- The list of inventors (individuals), their address and country of residence.
- The list of applicants, who will have legal title to (be the owners of) the patent if it is granted. In the vast majority of cases, the applicants will be companies and the inventors their employees. Their address and country of residence is supplied.

A third set of information relates to the *history of the application*:

- Priority date (date of first filing worldwide).
- Date of filing in the country concerned.
- Date of publication (18 months after the priority date).
- Date of denial or withdrawal.
- Date of grant.
- Date of termination (non-payment of renewal fee).

Lastly, by cross-referencing information from different national patent offices, it is possible to determine the countries in which protection is being sought, since prior art worldwide must be cited (priority number).

Patent-based indicators

The most commonly used indicators are counts of patents that share a number of common elements. For instance, statistics from a count of patents by inventors resident in Korea and by inventors resident in Japan will be used to compare the innovative output of both countries. At a more general level, one can also calculate the share of each country in the OECD area and observe trends in these shares over time. The count can also be confined to specific fields of technology. In all of these cases, patent counts by inventor resident in a given country are considered to reflect a country's innovative output.

As well as straightforward counts, more complex indicators can be constructed. For instance, the count can be restricted solely to patents applied for abroad or to a given patent "family" (all patent applications relating to the same invention in a number of different countries). Then, there are weighted counts, which allocate different weightings to each patent – instead of the uniform values used in straight counts – in order to reflect characteristics which are considered to reflect patent quality, such as number of citations, number of claims, or renewal period.

Advantages and limitations of patent counts

Patents are the source of data most widely used to measure innovative activity. There are good reasons for this.

- Patents have a ***close*** (if not perfect) *link to invention*. There are very few examples of major inventions that have not been patented in the last two centuries (James Watt patented the steam engine in 1785).
- Patents cover *a broad range of technologies* on which there are sometimes few other sources of data (biotechnology, nanotechnology, etc.).
- The contents of patent documents are a *rich source of information*: on the applicant, inventor, technology category, claims, etc.
- Patent data are quite *readily available* (now by electronic means) from national and regional patent offices and the marginal cost for the statistician is much less than when conducting surveys.

However, patents are subject to certain drawbacks as indicators of innovative activity:

- T*he value distribution of patents is skewed*. Many patents have no industrial application (hence, are of no value to society), whereas others are of substantial value: with such heterogeneity, patent counts that assume all patents to be of equal value actually tell us very little.
- Many inventions are *not patented*. The propensity to patent differs across countries and industries (there is evidence of a growing propensity to patent since the early 1980s, however). Non-patented inventions are either small ones, whose value does not warrant the costs of patenting, or inventions that are protected by other means (trade secrecy, lead-time on the market, reputation).

- *Differences in patent regulations across countries* make it difficult to compare counts of patents applied or granted in different countries – a Belgian patent cannot be compared with a Korean patent, for example. Moreover, it is difficult to draw comparisons between countries of invention based on patent applications filed in any given country: various biases (due to home advantage or trade flows) tend to bias the foreign country shares within any country.
- *Changes in patent law* over the years make it difficult to analyse trends over time. The protection afforded to patentees worldwide has been stepped up since the early 1980s, with the result that companies are more inclined to patent than before. The list of technologies covered has grown longer over time and in some countries now includes software and genetic sequences, which had been excluded until recently.

Patent counts should not be discarded as a statistical indicator just because of these limitations. Many statistical indicators, including the most widely utilised, such as GNP (gross national product) also have flaws, sometimes major ones. Secondly, appropriate statistical methods can do much to correct any flaws. The rest of this article addresses these methods.

III. WHERE AND WHEN? ATTRIBUTING A COUNTRY AND DATE TO PATENTS

Attributing a country: inventor, applicant or priority country

Depending on the indicators used, patents can be classed by the country of residence of the applicant or the inventor, or by country of priority application (country where the patent was first filed before being extended to other countries). These are all useful approaches and a comparative study of all three is informative. However, it is important to have a thorough grasp of these concepts before interpreting the indicators.

The applicant is the patentee at the date of the application. In most cases this is a firm, sometimes a government body or individual. Patent counts by applicant concentrate on "ownership" (*i.e.* the number of patents owned by residents of each country). Indicators of this type reflect the innovative performance of a given country's firms, regardless of where their research facilities are located. For measuring the innovative performance of laboratories and researchers in a given country, a count of resident inventors is more meaningful. Finally, a count by priority country tells us more about the attractiveness of that country's patenting process: quality of intellectual property regulations, reputation of the patent office (rules, cost of patenting) and general economic features (size of the market). The latter can be a decisive factor: it is well known, for instance, that large Canadian firms often patent directly in the United States before eventually filing an extension of their patent in Canada.

How does the choice of count criteria affect patent-based indicators? Table 1 reports OECD country shares in applications to the European Patent Office (EPO) using different count criteria. Depending on the criterion used to obtain a

Table 1. **Differences in patent counts depending on the reference date selected, 1990**[1]

Reference date	Number of patents				Shares in OECD			
	Grant		Application		Grant		Application	
	Priority	Grant	Priority	Applic.	Priority	Grant	Priority	Applic.
Australia	167	92	361	361	0.45	0.41	0.60	0.57
Austria	462	297	652	678	1.23	1.33	1.08	1.08
Belgium	314	224	512	627	0.84	1.00	0.85	1.00
Canada	324	173	550	628	0.86	0.77	0.91	1.00
Czech Republic	0	0	0	0	0.00	0.00	0.00	0.00
Denmark	242	109	325	321	0.64	0.49	0.54	0.51
Finland	287	81	429	401	0.76	0.36	0.71	0.64
France	3 379	2 345	4 916	5 107	9.00	10.48	8.17	8.13
Germany	7 866	5 756	11 490	12 810	20.96	25.73	19.10	20.39
Greece	8	0	27	25	0.02	0.00	0.04	0.04
Hungary	30	59	70	91	0.08	0.26	0.12	0.15
Iceland	3	0	9	5	0.01	0.00	0.01	0.01
Ireland	37	12	68	67	0.10	0.05	0.11	0.11
Italy	1 281	691	2 246	2 410	3.41	3.09	3.73	3.84
Japan	8 961	3 679	12 914	13 189	23.87	16.45	21.47	20.99
Korea	74	3	118	64	0.20	0.01	0.20	0.10
Luxembourg	25	19	41	26	0.07	0.08	0.07	0.04
Mexico	8	1	14	14	0.02	0.00	0.02	0.02
Netherlands	1 000	757	1 519	1 696	2.66	3.38	2.52	2.70
New Zealand	12	10	23	39	0.03	0.04	0.04	0.06
Norway	89	56	128	174	0.24	0.25	0.21	0.28
Poland	9	12	20	18	0.02	0.05	0.03	0.03
Portugal	3	2	8	5	0.01	0.01	0.01	0.01
Spain	118	55	256	255	0.32	0.24	0.43	0.41
Sweden	686	514	933	959	1.83	2.30	1.55	1.53
Switzerland	1 144	928	1 684	1 884	3.05	4.15	2.80	3.00
Turkey	1	0	4	5	0.00	0.00	0.01	0.01
United Kingdom	1 924	1 418	3 546	3 937	5.13	6.34	5.89	6.27
United States	9 081	5 079	17 298	17 035	24.19	22.70	28.75	27.11
OECD	37 534	22 371	60 160	62 831	100	100	100	100

1. Number of patent applications and patents granted, by inventor, fractional counts.

breakdown of patents by country, a country's share can differ (in relative terms) by more than 10% for large countries and more than 20% for smaller countries.

- The average discrepancy between counts by applicant and counts by inventor (in absolute value) was 10% in 1994 (when restricted to the 18 countries with more than 100 EPO applications). For counts by inventor, the United Kingdom's share was 5.7% in 1994, falling to 5.0% for applicant counts. For the Netherlands, the figures were 2.4% and 3.2% respectively. For the United States, they were 29.7% and 31.3%. In other words, some countries like the United States and the Netherlands have more applicants than inventors, while the reverse is true for countries like the United Kingdom. This asymmetry reflects the internationalisation of research (location of research facilities by multinational firms, see Guellec and van Pottelsberghe, 2001). These data can be used for analysing patterns of research internationalisation.
- The average discrepancy between counts by priority and counts by inventor (in absolute value) was 33% in 1994 (when restricted to the 18 countries with more than 100 applications). In the United States, the United Kingdom and to a lesser extent Germany, the total number of patents filed in the patent office is higher than the number of patents filed by resident inventors and applicants. The preference of some foreign firms for these countries is probably due to the reputation of their national offices and their market size. It is common for instance for Austrian firms to file a priority application in Germany and Canadian firms in the United States.

Attributing a date: priority date, application date, grant date

The problem in choosing the year to which a patent is attributed is that every patent document includes several dates, reflecting the patenting process and the strategy of the patentee (see Box 1): priority (date of first application in any country worldwide); PCT application (for an increasing proportion of patents, filed 12 months after priority application); application to national or regional agency (at most 12 months after the priority date for the traditional, direct procedure; 20 to 31 months after the priority date for the PCT procedure); publication (18 months at least after the priority date); and grant date (for the patents that are granted it takes three years on average at the USPTO and five years at the EPO, but can take up to ten years).

The only clearly meaningful date from a technological or economic point of view is the priority date. It is the closest to the date of invention. There is evidence that companies which choose to patent an innovation do so early in the process, so that they have the option of withdrawing their filing later if the invention turns out to be disappointing. For assessing a country's innovative performance at a particular point in time, it is therefore better to use the priority date.

Table 2. **Country shares in EPO applications with various criteria of attribution**
Inventor country, priority office or applicant country; by priority year; in %

	Priority country		Inventor country		Applicant country	
	1985	1994	1985	1994	1985	1994
Australia	0.00	0.01	1.13	0.71	1.07	0.65
Austria	1.23	0.89	1.37	1.10	1.21	0.96
Belgium	0.46	0.60	0.92	1.22	0.79	0.88
Canada	0.00	0.00	0.98	1.10	0.88	0.98
Czech Republic	0.00	0.00	0.00	0.04	0.00	0.03
Denmark	0.49	0.63	0.54	0.72	0.51	0.71
Finland	0.40	1.08	0.42	1.11	0.42	1.14
France	8.63	7.95	8.68	8.09	8.42	7.78
Germany	22.38	21.01	21.97	20.26	21.57	19.75
Greece	0.01	0.04	0.02	0.05	0.01	0.04
Hungary	0.00	0.00	0.27	0.07	0.27	0.05
Iceland	0.11	0.10	0.01	0.02	0.00	0.00
Ireland	0.07	0.09	0.09	0.13	0.07	0.15
Italy	3.33	3.53	3.44	3.78	3.28	3.40
Japan	15.54	16.81	15.57	16.58	15.45	16.33
Korea	0.26	0.27	0.04	0.57	0.04	0.56
Luxembourg	0.22	0.04	0.08	0.04	0.19	0.10
Mexico	0.11	0.05	0.00	0.02	0.00	0.01
Netherlands	2.30	1.33	2.73	2.41	3.42	3.18
New Zealand	0.50	0.26	0.10	0.10	0.10	0.10
Norway	1.07	0.68	0.30	0.29	0.29	0.31
Poland	0.01	0.01	0.05	0.03	0.04	0.02
Portugal	0.01	0.02	0.01	0.02	0.01	0.02
Spain	0.24	0.51	0.29	0.62	0.25	0.52
Sweden	2.19	2.12	2.25	2.14	2.20	2.20
Switzerland	3.09	2.40	3.54	2.77	4.06	3.44
Turkey	0.06	0.05	0.00	0.01	0.00	0.00
United Kingdom	8.69	6.51	7.58	5.72	7.15	4.99
United States	28.61	33.01	27.37	29.74	28.06	31.30
OECD	100	100	100	100	100	100

Source: OECD.

In many statistical publications the application or the grant date is used as these are the most readily available (published by national patent offices or the WIPO) and, ostensibly, the most recent statistics (although they in fact relate to inventions that go back some time). However, these dates are highly dependent on various administrative delays and the strategic behaviour of the patentee. The lapse of time between the date of invention and these various dates can differ widely from one patent to another. If one wants to measure the innovative performance of countries at a given point in time, it is clearly the priority date (the closest to the date of invention) which matters. Table 2 illustrates how the choice of date influences the indicators:

- The total number of patents granted to OECD countries in 1990 is 22 371, if the date of grant is taken as the reference date and 37 534 if the priority date is taken as the reference date.
- The average discrepancy between counts by priority date and counts by application date was 4% in 1994 (when restricted to the 18 countries with more than 100 patent applications). For grants (difference between counts taking 1990 as the priority date and 1990 as the grant date), the discrepancy was 25%.
- The statistics for patents granted by the EPO to inventors in the United States and Germany show the impact of the choice of date on cross-country comparisons. If computed with 1990 as the priority year, the United States has the largest share (24.2%). If computed taking 1990 as the year of grant, the United States falls into second position (22.7%) and is overtaken by Germany (25.7%).

The reason for these discrepancies is twofold: country shares by priority year fluctuate over time, and the delay between priority and application – or grant – dates differs across countries. While European countries are more likely to file their priority application with the EPO itself (making the priority and application dates the same), the United States and Australia make extensive use of the PCT procedure (giving a time lapse of 30 months between the priority application in the national office and the EPO application) whereas Japan does not. There is little doubt that the best choice for most purposes is the priority date. However, this raises the issue of timeliness in the availability of indicators.

IV. PATENT FAMILIES

National patent counts: statistical biases

Most national statistical directories publish counts of patents filed in the country concerned. Thus we compare the number of patents filed with the national industrial property agency in country "A" by inventors resident in country "A", country "B", and so on. The advantage of this approach is that it allows us to assess the relative share of various countries in innovation on a given national technology market, in this case country "A's" market. Since patents only protect an invention in the country of filing, any technology used or sold in country "A" must be patented there (at least in reasonably large countries) and national authorities are interested in this domestic aspect of technology competition. However, this approach is not sufficient for international comparisons of technology performance: the performance of countries is not fully reflected by their share of patents in any given country.

Nationals of country "A" will file more patents – proportionate to their innovative activity – in their home country than will nationals of other countries. When an inventor invents a new technique, he generally first patents it in his own country, which automatically protects it worldwide for one year. After one year, if he wishes to continue protecting it worldwide, he must file patent applications in the relevant countries (the process can be more complicated than this if he uses the PCT procedure, see Box 1). An inventor will only do so if the invention: *i*) has international commercial potential; and *ii*) is still commercially promising one year after first filing for a patent. Filing abroad therefore suggests that there are two criteria that will be met by only some of a country's national patent applications. Consequently, patent applications in country "A" by its own residents and by residents of other countries are not comparable, since the latter meet some criteria that some of the former group of applications does not meet. This is known as the "home advantage" and leads to over-representation of country "A" residents in that country's patent total. For instance, the share of United States residents in patents granted by the USPTO is between 55% and 60%, while the share of Japanese residents in patent applications filed with the Japanese Patent Office (JPO) is of the order of 85%.

A second source of bias in national statistics stems from the fact that patent protection is operative only on one market and that other countries may or may not be so interested in protecting their inventions on any given market. A key factor in patenting is commercial strategy: if one wants to sell the new product on a given market, then patent protection is needed. If not, protection is less important. Consequently, international patent filings are influenced by trade flows. Korean inventors have more of an incentive to seek protection in Japan (they accounted for 4.3% of patents filed with the JPO by non-residents in 1998) than in Germany (1.1%), for instance.

To avoid the biases of purely national statistics, we can turn to international applications. One approach to international comparisons is to look at the number of patents taken out abroad by different countries. This also raises a few problems. First of all, it means counting individual inventions several times, as many times as it is patented in any country. In other words, the count for an invention patented in 100 countries will be 50 times higher than for an invention patented in only two. Second, all of the countries concerned are treated in the same way, regardless of size.

The indicator we are looking for would ideally:

- Select patents of a certain quality standard.
- Count patents fairly whatever the country of innovation.

The indicator that comes closest to meeting the above criteria is "patent family" counting.

Family counts

A patent confers national property rights in that it protects an invention only in the country in which it was granted. Inventors seeking international rights therefore have to file applications in each country in which they want patent protection.

A "patent family" can be defined as all patent documents filed in different countries to protect the same invention. At its most basic, the family comprises a "priority patent application" and all "subsequent patent applications" that relate to it. The priority patent application is the first application filed to protect the invention, generally in the inventor's country. Subsequent patent applications are filed one year after the priority application in other countries in order to extend the geographical coverage of protection.

Advantages of the "patent family" for statistical purposes

- It improves the *international comparability* of patent-based indicators. Only patents applied for in the same set of countries are included in the "family", thus eliminating *home advantage* and the influence of geographical location.
- Patents in the family are *high-value patents* (the value of a patent can roughly be defined as the contribution of the invention it protects to the economy, either in technological terms or in economic terms). The patentee will take on the additional costs related to the extension of the protection to other countries only if he/she deems it worthwhile: *i.e.* if the expectation of having the patent granted and the expected return from protection (sales or licences in designated countries) are high enough.

Some methodological choices have to be made before conducting patent family counts:

- *Geographical coverage*: there are over 100 national industrial property agencies worldwide, not counting regional agencies (such as the EPO in Europe). Which agencies should be taken into account in constructing a patent family? In other words, with which agencies does a patent have to be filed in order to be considered part of a family? In the shorter term, we opted for the "triad". The "triad family" is a patent family that has one "member" in Europe, one in Japan and one in the United States.
- *Defining the family*: the relationships in the patent family as outlined above (a priority application, plus subsequent related applications) can sometimes be a little more complex in real life. First, a number of patent applications made in one country can be grouped together under a single patent in

another country. Applications citing multiple priority applications are particularly common for Japanese patents, which often cite between five and 30 priority applications for a single European or US patent. Then there are patents that have "common priorities", where a single patent is cited as the priority application for two or more subsequent applications. So, some patent families are related to each other by common priorities and the problem is then where to draw the line between them. The choice we made here was to define the family as all patents with one or more common priority.

Table 3. **Triad patent families (patents filed with the EPO, JPO and USPTO)**
By priority year and country of invention

	Number of families		Share in world total	
	1990	1995	1990	1995
Australia	135	148	0.43	0.46
Austria	159	194	0.51	0.60
Belgium	205	319	0.66	0.99
Canada	242	345	0.77	1.08
Czech Republic	7	3	0.02	0.01
Denmark	98	160	0.31	0.50
Finland	134	253	0.43	0.79
France	1 894	1 775	6.05	5.54
Germany	3 918	4 267	12.51	13.31
Greece	3	1	0.01	0.00
Hungary	29	15	0.09	0.05
Iceland	1	6	0.00	0.02
Ireland	27	20	0.09	0.06
Italy	622	557	1.99	1.74
Japan	9 699	8 601	30.97	26.83
Korea	62	313	0.20	0.98
Luxembourg	18	11	0.06	0.03
Mexico	7	11	0.02	0.03
Netherlands	687	719	2.19	2.24
New Zealand	8	13	0.03	0.04
Norway	41	79	0.13	0.25
Poland	4	3	0.01	0.01
Portugal	1	2	0.00	0.01
Slovak Republic	0	2	0.00	0.01
Spain	70	86	0.22	0.27
Sweden	383	649	1.22	2.03
Switzerland	769	693	2.46	2.16
Turkey	1	1	0.00	0.00
United Kingdom	1 355	1 303	4.33	4.06
United States	10 503	11 162	33.54	34.81
European Union	9 574	10 316	30.57	32.17
OECD Total	31 083	31 711	99.27	98.90
World	31 312	32 064	100.00	100.00

Source: OECD patent database.

> In other words, when two sets of patents are "inter-related", they are regarded as forming a single family (this is the method used for the INPADOC database maintained by the EPO). The family therefore consists of a set of priority applications and any subsequent related applications in the triad countries.

Table 3 gives the number of triad patent families by country of invention for priority years 1990 and 1995, constructed in accordance with the above rules.

V. CONCLUSION

Patent-based indicators are extremely useful for comparing and monitoring trends in the technology output of different countries. However, we have to follow some methodological rules in constructing them if we are to avoid certain statistical biases. The proposals on patent families, priority years and county of invention outlined in this article are a step in that direction. Work to further this approach is either currently in progress or is to begin shortly. It primarily involves: nowcasting families so as to have more up-to-date statistics (currently, with the PCT and USTPO procedures for granting applications, it can take around five years before information is made available); improving the correlation of patent-based indicators to the activity of firms (using a table correlating patent technology classifications with industrial activity classifications); and lastly, better reflecting patent value in the indicators, using supplementary information such as citations, claims or renewals.

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IMPROVING MEASURES OF GOVERNMENT SUPPORT TO INDUSTRIAL TECHNOLOGY

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I. INTRODUCTION

OECD countries increasingly seek wide-ranging and coherent policy reforms to enhance the contribution of technology to growth, productivity and jobs. In 1998, the OECD published a report entitled *Technology, Productivity and Job Creation: Best Policy Practices* (OECD, 1998*a*) which had two aims: *i*) to identify the appropriate roles of government in regard to the links between technology, productivity and job creation in a policy environment characterised by increasing globalisation, the move to a knowledge-based economy, the systemic nature of technological advances and the changing patterns of government funding and firms' innovative strategies; and *ii*) to assess innovation and technology innovation policies in OECD countries with a view to identifying "best practices" and to making recommendations to individual countries.

As part of this exercise, it was decided to assemble a new set of internationally comparable data on total government support to industrial technology in order both to reveal overall national strategies and to act as a framework for the analysis of best policy practice in selected areas. The aim was to obtain the broadest coverage possible, going beyond the focus in many national reports on recent measures assisting the development of new technologies in the small high-tech segment of the economy in order to include longer-established programmes and institutions and also policy areas with important secondary impacts on industrial technology. Similarly, an effort was made to include a full range of financial instruments, some of which are not included in current R&D data. The data set sought had three main components: financial incentives; mission-oriented contracts, procurement, etc., S&T infrastructure and diffusion.

The data required to analyse funding in this way were not readily available from standard OECD sources. Nevertheless, series were obtained via a pilot study for ten OECD countries: six from the G7 (the United States, Japan, Germany, the United Kingdom, France, Canada), plus four smaller ones (Australia, Finland, Mexico and the Netherlands) for the period 1989-95, updated to 1997 for the OECD *Science, Technology and Industry Scoreboard* (OECD, 1999). The later stages of this work were supported by Statistics Canada.

The present article presents the main results of the exercise, highlighting what can be learned from this new set of data compared with the traditional indicators.

II. CLASSIC MEASURES OF GOVERNMENT SUPPORT FOR INDUSTRIAL TECHNOLOGIES

Using data from the regular OECD R&D database, there are two ways of identifying and comparing government support to industrial technology:

- Government-financed R&D in the business enterprise sector.
- Government budget appropriations or outlays for R&D whose primary aim is development of industry.

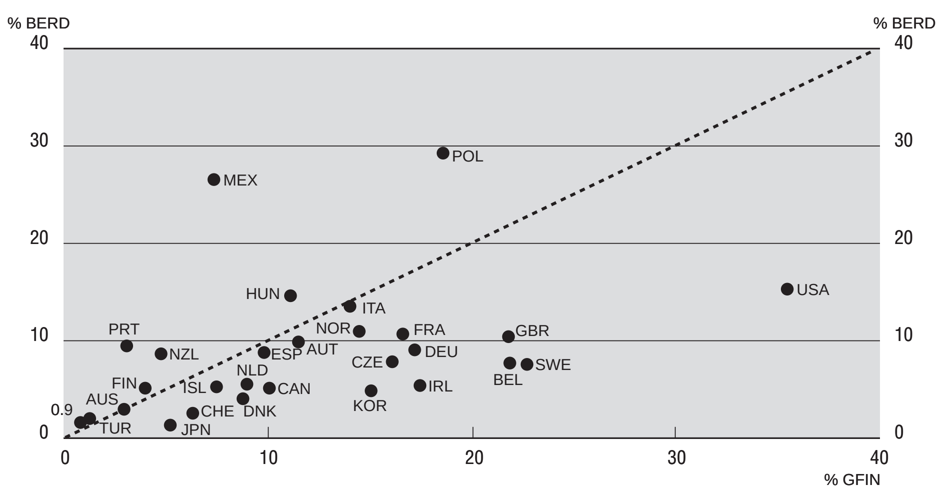
Each gives a different, but incomplete, picture of government support.

Government-financed R&D in the business enterprise sector

This first series measures how much of the R&D carried out in the business enterprise sector is financed by government. It is based on the amounts that industrial firms and commercial R&D institutes report as having been received from all levels of government and used for R&D.

The classic way of comparing across countries is to take these sums as a percentage of total R&D expenditures in the business enterprise sector (BERD). Figure 1 shows these shares of BERD mapped against the percentage of total government-financed R&D (GFIN) carried out in the business enterprise sector.

Figure 1. **Government-financed R&D in the business enterprise sector**



Source: Basic Science and Technology Statistics (BSTS) 2000 (OECD, annual).

The data are given in Table 1. In most OECD countries, 10% or under of all industrial R&D is financed by government. The shares are slightly higher in the United States, the United Kingdom, France, Italy, Norway and Hungary, and substantially higher in Mexico and Poland. The cost to government as a percentage of its total funding of R&D is highest in the United States (Figure 2).

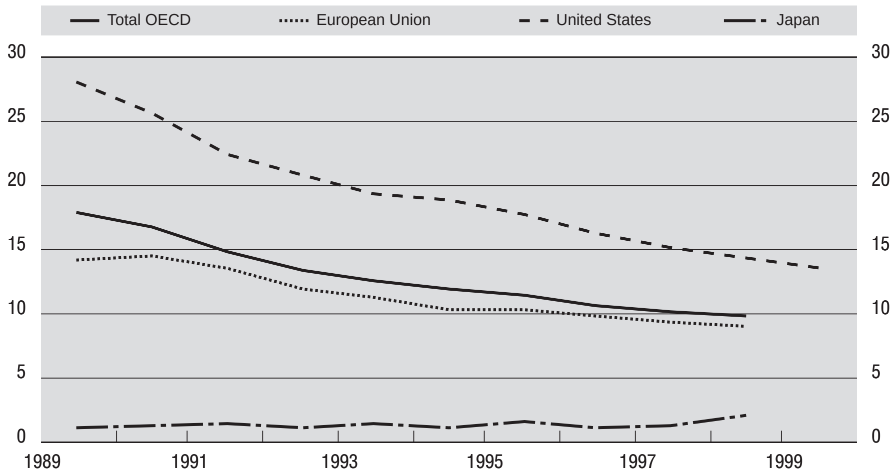
Table 1. **Government-financed R&D in the business enterprise sector**

	Million national currency	Million USD PPPs at fixed prices		Share of BERD		Share of government-financed R&D	
	1998	1989	1998	1989	1998	1989	1998
Australia	122.9	47.1	92.9	2.7	3.1	..	2.9
Austria	..	66.8	..	5.6		7.6	..
Belgium 1997	8 712.3	195.0	231.3	8.9	7.6	18.5	21.9
Canada	473.0	461.7	392.3	10.1	5.3	12.1	10.3
Czech Republic	1 207.8	..	86.2	..	8.2	..	14.3
Denmark	646.6	104.4	72.3	11.7	4.2	14.1	9.0
Finland	591.2	34.2	96.1	3.1	4.4	5.4	9.9
France	10 396.5	2 950.7	1 552.1	19.3	9.0	24.1	15.0
Germany	5 100.0	3 096.8	2 456.1	11.0	8.6	23.5	17.3
Greece 1997	769.4	9.0	3.3	8.6	1.8	2.8	0.9
Hungary	2 479.4	..	25.3	..	9.4	..	6.4
Iceland	215.9	1.2	2.6	10.9	5.0	3.2	3.3
Ireland 1997	28.3	15.3	41.7	6.9	5.3	11.8	17.5
Italy	1 503 371.0	1 257.8	876.0	16.3	13.3	19.4	14.0
Japan	223 274.0	647.3	1 325.1	1.2	2.1	4.7	7.6
Korea 1997	423 374.0	..	642.2	..	4.8	..	15.2
Mexico 1997	569.2	..	125.1	..	26.4	..	7.3
Netherlands	357.0	362.1	167.5	10.6	4.4	15.0	6.2
New Zealand 1997	27.1	9.9	18.0	6.5	8.7	3.2	4.7
Norway 1997	1 135.3	163.2	118.4	19.6	11.0	21.8	14.5
Poland	447.4	..	271.0	..	26.9	..	18.9
Portugal 1997	2 429.2	..	19.2	..	9.4	..	3.1
Spain	26 833.0	258.4	203.4	11.8	6.6	14.2	8.8
Sweden 1997	3 826.5	396.3	383.1	12.6	7.6	21.7	22.7
Switzerland (% 1996)	130.0	59.6	64.3	1.6	2.4	5.2	6.3
Turkey 1997	932 978.0	..	12.9	..	2.0	..	1.2
United Kingdom	1 190.0	2 561.1	1 662.3	17.2	11.6	32.5	24.6
United States	24 164.0	33 659.9	23 010.4	28.0	14.3	43.6	34.8

Source: BSTS 2000 (OECD, annual).

There was a rapid fall in the share of R&D in the business enterprise sector financed by government in the United States and in the European Union; while there was a slight rise in Japan from a very low level. In all three cases, the trends in the percentages reflect changes in the level of government-funded BERD at fixed prices. There was growth in a few other countries, including Australia and in

Figure 2. **Trends in the share of business enterprise R&D financed by government**



Source: Main Science and Technology Indicators (MSTI) 2000-2 (OECD, bi-annual).

Finland (Table 1). There was also a general decline in the cost of such transfers to government measured as a percentage of their total R&D finance. However, it was less marked and did not affect quite so many countries.

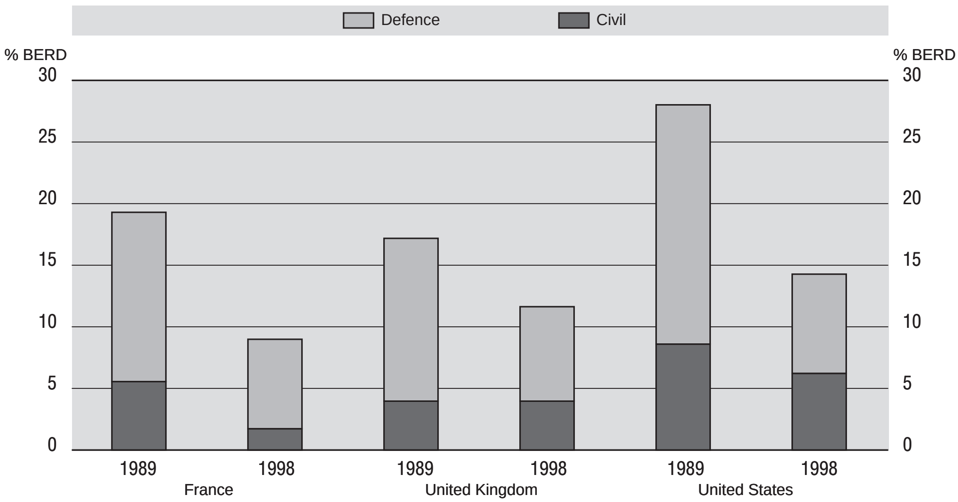
This indicator tells us that support has declined but does not tell us why. For selected countries, the OECD collects data on defence R&D expenditures broken down by sector of performance and source of funds. As can be seen from Figure 3, defence was a prime mover in the United States, France and the United Kingdom. However, civil government funds also declined compared with BERD and also, slightly, at fixed prices.

Government-funded R&D in the business enterprise sector falls short of the full coverage of government support for industrial technology because it does not include all the financial instruments available to government, notably fiscal incentives and some categories of loans, and also because it does not cover R&D carried out in other sectors which governments finance with the aim of supporting industry.

GBAORD for industrial development

Another way of measuring R&D expenditure is to approach the funders of the R&D. In the OECD/Eurostat system, this is only done for central (federal) government-funded R&D using data derived from budgets. The sum of total government funds

Figure 3. **Government-funded R&D in the business enterprise sector as a percentage of BERD: defence and civil**



Source: OECD R&D database, February 2001; NSF (annual).

thus measured is referred to as government budget appropriations or outlays for R&D – GBAORD. These series are less accurate than the performance-based data described in the previous section but they are more timely and, as they are derived from the budget, they can be linked to policy issues by means of a classification of goals or objectives. The OECD system distinguishes 12 such objectives, of which one is the furthering of industrial development as defined in Box 1.

GBAORD for industrial development covers not only R&D programmes carried out by industry but also by government, higher education and PNP institutes and any payments to abroad. The OECD has attempted to collect data on GBAORD by sector of first destination but the response rate from countries is very low.

Governments in the G7 countries devote a low share of their R&D budgets to this objective and the sums are very small compared with those spent on R&D by industry, especially in the United Kingdom, the United States and Japan (Figure 4). The shares of GBAORD for this objective are highest in Ireland and Finland and the sums are worth the most (compared to R&D financed by industry) in Portugal, Greece, Spain and New Zealand.

Box 1. **Promotion of industrial development (category of GBAORD)**

This group includes R&D programmes whose primary objective is to support the development of industry. The core of this class will consist of R&D programmes in favour of manufacturing industry (ISIC Rev.3, Divisions 15-37). However, it also contains R&D for the construction industry (ISIC Rev.3, Division 45); wholesale and retail trade, restaurants, and hotels (ISIC Rev.3, Divisions 50-52 and 55); banking, insurance, and other commercial services (ISIC Rev.3, Divisions 65-67 and 70-74); or industry in general. It does not include R&D performed by industry (principally financed from public funds) in support of other objectives – for example, in the fields of space, defence, transportation and telecommunications – although these obviously have an important secondary effect on the development of the industries concerned. If R&D is supported for a communal project, it should be excluded from this class and included under the relevant objective. For example, the development of a new type of rolling stock as part of a reorganisation of the nation's railways should be classified under "transport". Redevelopment of similar rolling stock in view of export sales belongs under the present heading. Similarly, R&D in support of tourism as a cultural activity should be included under the objective described in Section 8.7.4.7, but R&D mainly intended to improve the commercial prospects of the hotel and tourism industry should be included here.

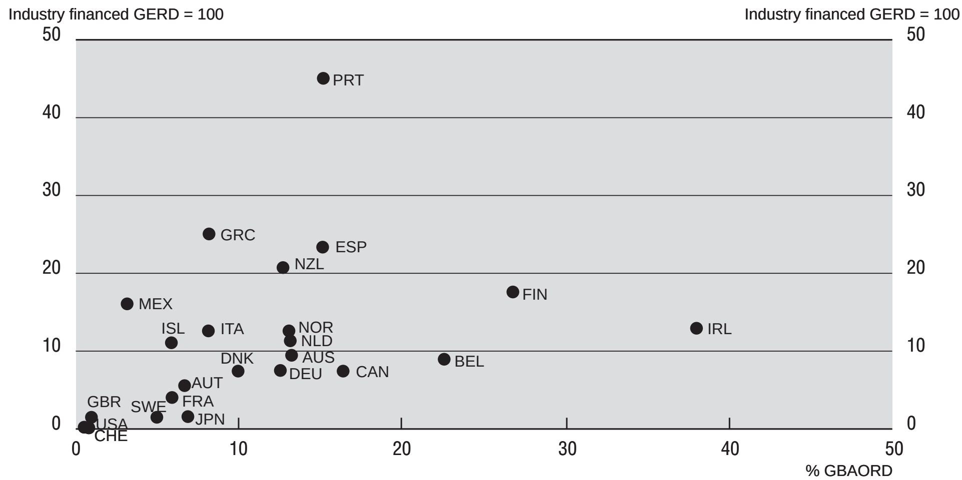
Source: OECD (1994).

The role of this objective declined in the European Union during the early 1990s but rose very slightly in the United States. In Japan, there was a sudden rise in 1997. These trends reflect those in funding at fixed prices. The decline in the share was marked in France, Italy and the United Kingdom but not in Germany where funding of the objective rose slightly at fixed prices. Both funding and shares rose in a number of countries including Finland (Table 2).

GBAORD for industrial development gives a policy-oriented measure of how much central government money is committed to R&D with the primary aim of supporting industry whether paid to firms or carried out in other sectors (Figure 5). The picture is incomplete because GBAORD data are generally only collected for federal/central government and, like government-financed BERD, they do not cover all types of financial instrument. Furthermore, this particular series only covers programmes with industrial development as their primary objective. The pilot study revealed a number of programmes included under other objectives which also aimed to assist industry.

Figure 4. **Funding of R&D with industrial development as a primary objective, 1998 or nearest year**

Percentage of GBAORD and compared with total R&D financed by business



Source: BSTS 2000 (OECD, annual).

III. THE PILOT STUDY

Specifications and sources of data for the pilot study

The pilot study identified three main categories of support for industrial technology. The first included all programmes designed to encourage industrial firms to carry out R&D (or other innovation activities) by reducing the cost through grants, loans, fiscal incentives, etc. The second covered government payments to industrial firms to carry out R&D to meet government needs, notably for defence or space objectives. The third covered ways in which governments can assist firms without giving them R&D money: by financing R&D activities specifically aimed at industrial development in institutes and universities; by supporting technological research in a more general way in academic and similar units; and by funding non-R&D programmes either supporting post-R&D stages of the innovation process or diffusion and extension programmes. Each main category was further sub-divided as shown in Box 2.

Table 2. **Industrial development as a principal objective of GBAORD**

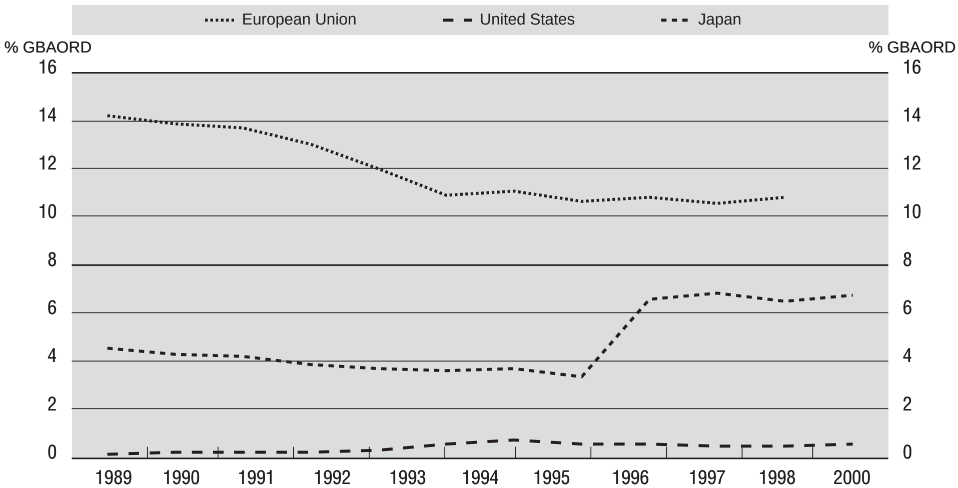
	Million national currency	Million USD PPPs at fixed prices		Share of GBAORD		R&D financed by business = 100	
	1999	1989	1999	1989	1999	1989	1998
Australia (1998)	434.1	208.5	328.1	12.2	13.1	..	11
Austria	924.7	71.9	64.5	8.4	5.5	7	6
Belgium	13 215.7	207.7	342.2	18.9	23.6	10	9
Canada (1998)	523.0	394.2	433.7	11.3	16.3	11	7
Czech Republic	..	..	..	..	..	..	..
Denmark	843.5	129.6	91.8	15.5	9.6	17	7
Finland	2 387.9	209.2	385.5	28.2	31.5	19	16
France	5 234.0	1 964.2	778.5	13.3	6.2	18	5
Germany	4 052.0	1 846.9	1 934.3	12.8	12.7	7	7
Greece	8 752.0	39.7	34.8	12.3	8.0	44	25
Hungary	..	..	..	..	..	..	..
Iceland	449.3	..	5.1	..	6.8	..	10
Ireland	60.1	43.2	80.7	30.0	29.8	20	13
Italy (1998)	963 849.0	1 178.4	561.6	15.2	8.1	19	10
Japan	205 485.0	523.4	1230.3	4.6	6.5	1	2
Korea	..	..	..	..	..	..	..
Mexico (1998)	274.9	..	52.3	..	3.1	..	16
Netherlands	906.8	529.3	420.0	19.3	14.1	17	11
New Zealand (1997)	70.8	38.0	47.1	13.0	12.6	24	21
Norway	1 113.2	118.7	109.7	16.4	12.4	18	13
Poland	..	..	..	..	..	..	..
Portugal	22 240.4	60.5	164.5	17.7	17.2	..	45
Spain	101 955.1	446.8	749.2	17.7	18.4	24	19
Sweden	612.0	79.6	60.2	4.1	4.0	3	2
Switzerland (1998)	15.0	28.6	7.4	4.9	0.6	1	0
Turkey	..	..	..	..	..	..	..
United Kingdom	87.5	881.5	119.3	9.7	1.5	8	1
United States	401.0	150.9	376.4	0.2	0.5	0	0
European Commission	826.4	776.5	868.8	47.3	33.8	..	..

Source: BSTS 2000 (OECD, annual).

Preparing this pilot study involved close co-operation between the OECD Secretariat and national experts in order to combine industry-related series from tables supplied via the regular OECD R&D survey, data on RDI (research development and innovation) programmes from the (now defunct) OECD database on public support to manufacturing industry (PSI) (Box 3), and other relevant data from national sources (the guidelines to countries are shown as Annex 1).

Five countries (Australia, Canada, Finland, Mexico and the Netherlands) provided full responses which were used after some discussion and adjustments. The Secretariat prepared tables for France, Germany, Japan, the United Kingdom and the United States, with some assistance from the countries concerned.

Figure 5. **Trends in the share of GBAORD with industrial development as primary aim**



Source: BSTS 2000 (OECD, annual); OECD R&D database.

Despite these efforts, the results in the pilot study were still only broadly comparable between countries and over time. There are several reasons for this. First, the guidelines, which drew on both the *Frascati Manual* (OECD, 1994) and the specifications for measuring public support to industry (OECD, 1995) categories and definitions, were not entirely coherent (Pretschker and Young, 1998) and thus

Box 2. **Main categories of government support for industrial technology**

A. Financial incentives	**B. Contracts and procurement**	**C. Support via the S&T infrastructure**
1. Fiscal incentives	1. Defence	1. Institutes
2. Grants, etc.	2. Space	2. Academic
3. Other financial incentives	3. Other contracts and procurement	3. Diffusion, etc.

Box 3. RDI data in the OECD database on public support to industry (PSI)

This database was set up as a tool to make the industrial support policies of OECD governments transparent and information concerning them more internationally comparable. The underlying methodology is given in *Industrial Subsidies: A Reporting Manual* (OECD, 1995). The work was undertaken under the aegis of the Working Party on Support to Industry of the Industry Committee whose members supplied the data, and the base was managed by the Industry Division of the OECD's Directorate for Science Technology and Industry. The main aim was to examine industrial subsidies defined as: "specific direct and indirect financial support measures of central or sub-central governments in favour of manufacturing industry resulting in a net cost to government."

The essential was for governments to supply a set of information, including net and gross funding data for each programme (covering an extensive list of financial instruments) which they designated as subsidy measures, of which a certain number had RDI as a primary or secondary policy objective or as a means of support. After discussion with the Working Party (so-called "confrontation meetings"), they might agree to add other programmes which could be considered as subsidies or to supply information "for the sake of transparency" without agreeing to inclusion in the database. In order to obtain a fuller picture of funding of R&D, governments were also requested to supply funding of defence and space RDI contracts and procurement and also support to applied R&D centres serving the enterprise sector, known as intermediary R&D institutions. The data for individual subsidy programmes were confidential, as was the additional information on support via contracts and procurement and institutes.

Data were collected for the period 1989-93. The Working Party agreed to make a special update of the RDI series to 1995 for use in the Technology, Productivity and Job Creation exercise. The data were analysed in a special issue of the present journal (Pretschker, 1998) and in an OECD publication (OECD, 1998*b*). The Working Party was disbanded at the end of 1998 and the database closed.

sometimes proved difficult to apply.[1] For example, the PSI base covered only support to manufacturing whereas the *Frascati* definition of industrial development also covers the services. On the other hand, the *Frascati* data cover only R&D whereas the PSI also included support for innovation. Second, there are important national specificities in R&D institutions and R&D funding mechanisms which sometimes do not fit easily within the proposed statistical framework. Third, however clearly RDI support is defined in theory, actually selecting the programmes concerned always involves an element of political judgement which may vary among countries, experts and over time. A comparison between the coverage desired for the pilot study and the main sources used is given in Box 4.

Box 4. **Coverage of four measures of government support for industrial R&D**

	Funding of industrial technology	R&D in PSI base	GBAORD for industrial development	Government-financed BERD
Reported	Funder	Funder	Funder	Performer
R&D/RDI	RDI	RDI	R&D	R&D
Industry	Manufacturing + market services	Manufacturing	Manufacturing + some services	Agriculture + mining + manufacturing + services
Government	Federal + state	Federal + state	Federal State (MO)	All levels
Components				
Financial incentives				
Fiscal incentives	Rep sep	Rep sep	MO	
Grants, etc.	Rep sep	Rep sep	Inc	Inc
Regular loan, etc.	Rep sep	Rep sep		
Contracts				
Defence	Rep sep	Rep sep		Some Rep sep
Nat. Space	Rep sep	Rep sep		Inc
ESA	Rep sep	Rep sep		
Other	Rep sep		Small part Inc.	Inc
S&T *infrastructure*				
Industrial R&D institutes	Rep sep	Rep sep	Inc	Small part Inc. Some Rep sep
Academic engineering	Rep sep		**	
Other	Rep sep			

Key: Rep sep = reported separately; Inc. = included but not separated out; MO = option in *Frascati Manual* but not collected by OECD.
** Can be derived from Eurostat (Advancement of Knowledge) MO.
Source: Eurostat, 1994; OECD, 1994; OECD, 1995.

Summary of results of the pilot study

The pattern of support varied considerably across countries (Table 3). In the United States, federal support for industrial technology was almost all paid to

Table 3. **Estimated total support for industrial technology by type: percentage distribution**

	Australia	Canada	Finland	France	Germany	Japan	Mexico	Nether-lands	United Kingdom	United States
	1996	1995	1997	1995	1997	1995	1996	1997	1996	1996
Fiscal	15	45	0	9	0	3	0	23	0	3
Grants	14	10	43	15	25	2	4	8	4	16
Other	0	0	2	0	0	2	5	0	0	0
Total financial	29	55	45	24	25	7	9	32	4	19
Defence	13	4	0	36	24	13	..	6	58	63
Space	0	9	7	20	9	12	..	12	6	8
Other	0	14	0	3	2	17	..	7	10	7
Total contracts	14	28	7	59	35	42	..	25	73	79
Institutes	48	9	36	1	14	19	12	10	2	1
Academic	11	8	13	17	25	32	79	33	15	2
Other	0	0	0	0	1	0	..	1	5	0
Total S&T infrastructure	59	17	49	18	40	51	91	43	23	2
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Source: Pilot study.

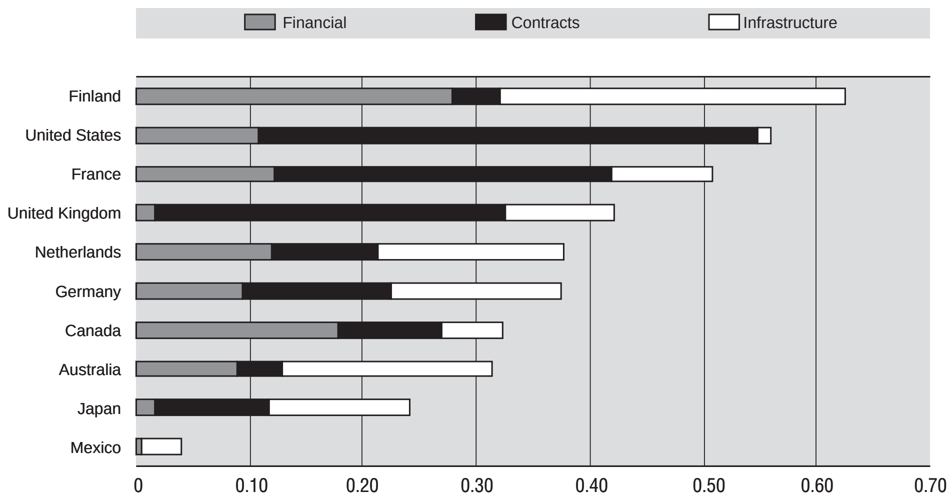
firms, with the largest share in the form of mission-oriented contracts and procurement. The pattern was similar in France and the United Kingdom. The Finnish Government spent on financial incentives and on S&T infrastructure, with very little contracts and procurement. In Canada, financial incentives were the largest category, followed by mission-oriented contracts and procurement. Funding in Germany and the Netherlands was distributed fairly evenly across the categories. In Australia, Japan and Mexico, support via the S&T infrastructure was the largest category.

Comparing the sums involved with industrial GDP allows them to be viewed in a national context without making precise comparisons which are not justified by the quality of the data. Figure 6 shows Finland as spending relatively the most on support for industrial technology, followed by the United States and France. The smallest effort was in Mexico, far below the second lowest, Japan.

As might be expected, the reason for the major difference in the level of mission-oriented R&D in France, the United Kingdom and the United States, on the one hand, and the other countries, on the other, is the amount of defence R&D.[2] Space R&D in the model of support to industrial technology covered both direct contracts to industry and contracts from the European Space Agency (usually with payments to the ESA as a proxy). Together, these funds are most important in France. The "other contracts" category proved difficult to identify from

Figure 6. **Estimated government support for industrial technology as a percentage of Domestic Product of Industry (DPI)**

1997 or nearest year available



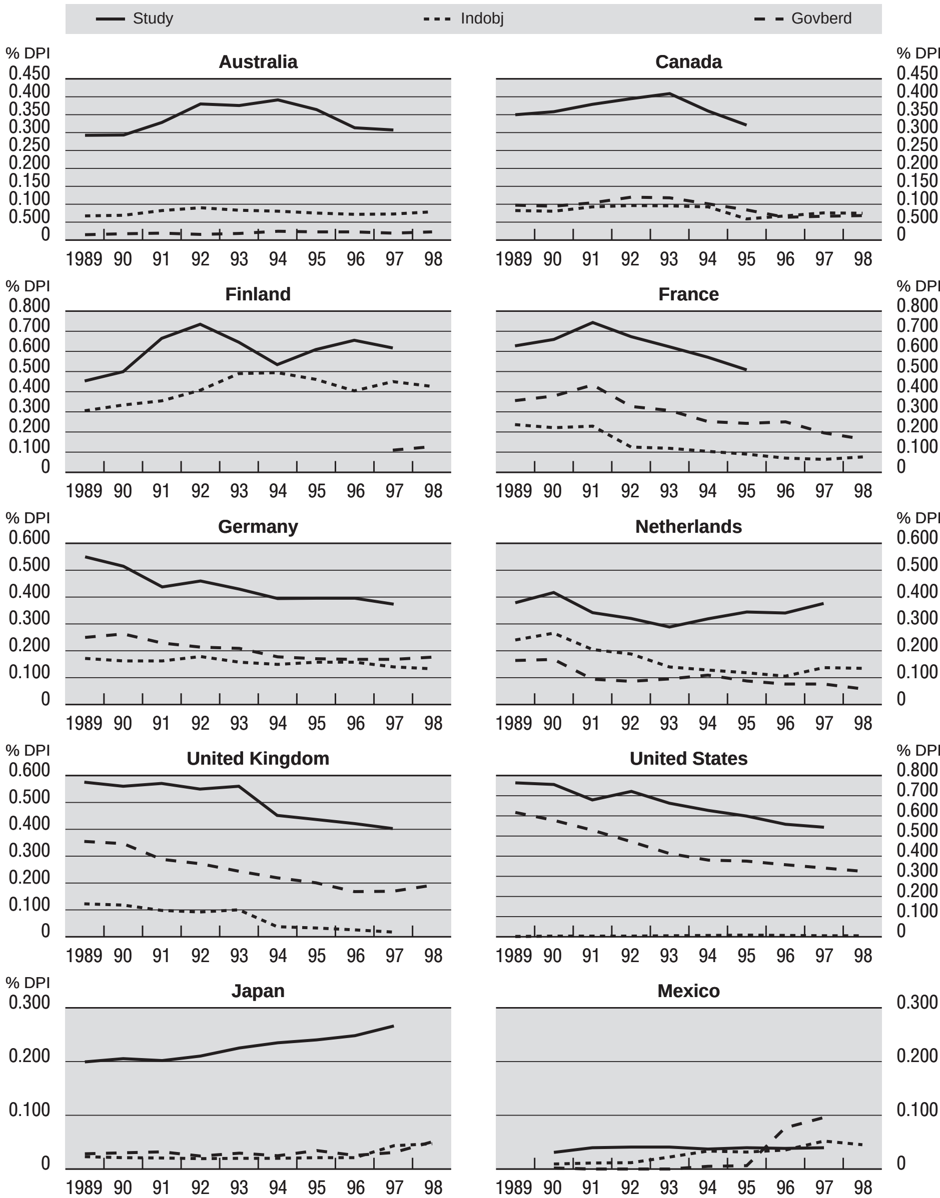
Source: Pilot study.

existing sources. In the United States as in several other countries, this sub-category was represented by government extramural R&D expenditure to the business enterprise sector less payments to firms for financial incentives and for defence and civil space contracts and procurement. It was most important compared to industrial GDP in the United States and in Canada.

Of the four countries which spent the largest share of the funds on the S&T infrastructure, the Mexican funds were mainly for academic engineering and this sub-category got about one-third of the funds in Japan and the Netherlands. R&D in industrial R&D institutes was particularly important in Australia and Finland.

Examination of trends in total support from the pilot study (Figure 7) shows that it generally moved in the same direction as the two classic measures of government support for industrial technology: government budget appropriations or outlays (GBAORD) for industrial development as a socio-economic objective, and government-financed R&D in the business enterprise sector. One exception is the Netherlands, where the government shifted R&D support from grants (included in GBAORD and government-financed BERD) to fiscal incentives (excluded from GBAORD and government-financed BERD). There is no similar explanation for the differing trends in Finland.

Figure 7. **Trends in various measures of support for industrial technology**



Source: Pilot study.

IV. IMPACT OF A WIDER COVERAGE OF FINANCIAL INCENTIVES

The pilot study defined financial incentives in terms of a list of eight financial instruments derived from the PSI exercise. For the purposes of the pilot study, they were grouped as follows:

1. Fiscal incentives/tax credits.
2. Grants and forgiven loans (regular grants, reimbursable grants, conditional loans).
3. Other financial incentives (regular loans, interest rate subsidies, loan guarantee equity capital).

Box 5. ***Frascati Manual*: direct and indirect transfers of funds**

General

Resources may be transferred in a number of ways, not all of which may be direct (para. 370). Contracts and grants paid for the performance of current or future R&D are clearly identifiable as a transfer of funds (para. 371).

In some cases, a firm's R&D project may be financed by loans from a financial institution, an affiliated company, or a government. Loans which are to be repaid are not to be considered transfers; loans which may be forgiven are to be considered transfers (by convention) (para. 375). There are also a variety of other government incentives for R&D in the business enterprise sector. Examples are the remission of income taxes for industrial R&D, the payment by a government, on demand and after audit, of a certain portion of some or all of a firm's R&D expenditures, bonuses added to R&D contracts to encourage a firm in its own R&D, remission of trades and tariffs on R&D equipment, and the reimbursement of part of a firm's costs if it hires more R&D staff. For the present, even where these transfers can be separately identified, they should not be counted as (*Frascati*) "direct support" for R&D (para. 376).

GBAORD

"When such indirect support programmes are undertaken as part of an integrated R&D policy (for example, when the sources are documented and are included in interministerial discussions of a science budget), they may be included in GBAORD. However, indirect funding should always be declared separately so that it can be excluded when making certain international comparisons" (para. 440).

Source: OECD, 1994.

Only incentives in the second category are credited to government in the regular R&D statistics examined above so this set of data gives a wider picture of government support than is usually available.

The *Frascati Manual* basically prefers R&D data reported by performers to that reported by funders because the former are best placed to assess the amount of R&D activity carried out and, thus, the resources concerned. The guidelines for measuring flows of funds were essentially designed to be appropriate for performer reporting, and were then extended to funder reporting (extramural expenditure and GBAORD) for reasons of comparability. The principles are that there must be a direct transfer of resources and that this transfer must be both intended and used for the performance of R&D (OECD, 1994, para. 368). The *Manual* is a little more flexible for GBAORD (Box 5).

Effect of including fiscal incentives

The main advance was the inclusion of fiscal incentives, mainly tax credit programmes.[3] In the mid-1990s, such programmes contributed almost half of total funding of industrial technology in Canada, one-third in Australia, and one-quarter in the Netherlands (Table 3 above). There was a smaller impact in France, the United States and Japan and, according to the PSI data, in Belgium and Denmark.

In most of the countries included in the *ad hoc* exercise, data on the cost of tax incentives were quoted on a regular basis in national S&T budgets or indicator reports, although usually separately from the regular R&D funding series. They are, for example, given in the US biennial *Science and Engineering Indicator* reports (National Science Board) and in the annual French science budgets (Imprimerie Nationale, annual).

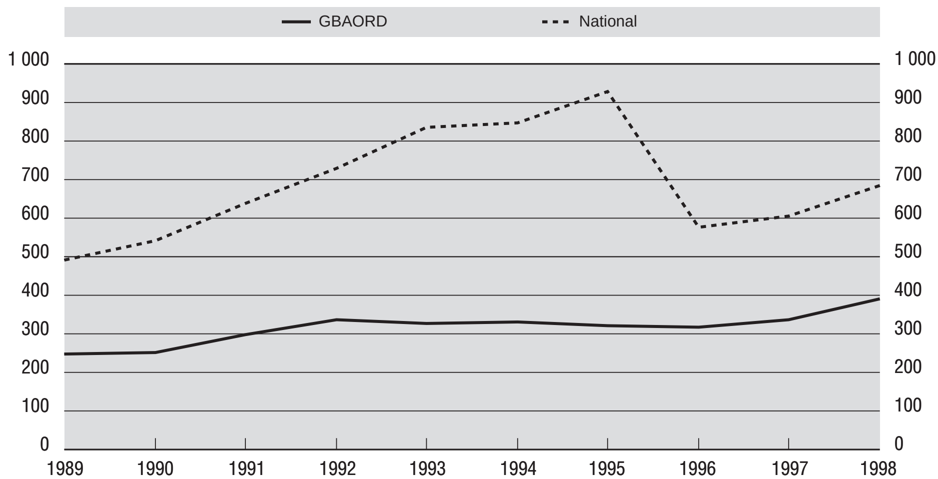
In Australia, the sums involved are actually included in the national version of GBAORD by socio-economic objective (SEO). The difference for industrial development as an SEO is shown in Figure 8. The downturn in 1996 marks a change in the rate of the concession.

Effect of including other financial instruments

Relatively few countries make major use of the third group of financial instrument (regular loans, guarantees and equity holdings), although, according to PSI data, they are the main forms of support in Austria and Hungary and are also in applied in Italy, Japan, Mexico Norway and Turkey. Funding for such schemes appears to fluctuate from year to year.

Figure 8. **Australia – funding of GBAORD for industrial development with and without fiscal incentives**

AUD million at 1990 GDP prices



Source: Minister for Science and Technology (annual); BSTS (OECD, annual).

Problem of net and gross if one includes funds with repayment

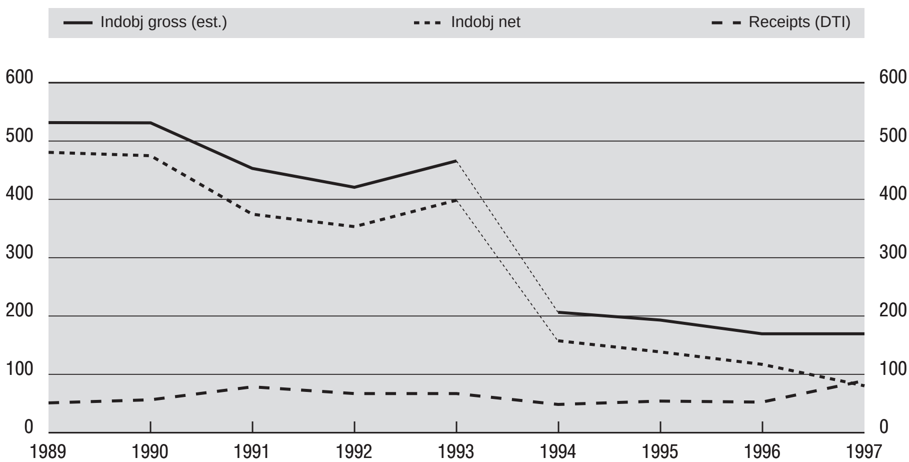
The *Frascati Manual* recommends that for performer-based reporting of transfer, statistical units should report gross R&D expenditures as incurred, even when their actual costs may be reduced because of remissions, rebates or post-performance grants from government (OECD, 1994, para. 376). GBAORD clearly includes all outlays to be met from taxation and excludes contracts and grants from other sectors for the performance of R&D by government establishments. No guidelines are given on the treatment of other extra-budgetary funds such as the retained receipts of government R&D laboratories, receipts from levies, etc. Net reporting provides information on the cost to government in a given year, while gross reporting indicates the amount of funds committed to the various programmes and objectives.

Most countries report GBAORD and government-financed GERD gross. Some, notably the United Kingdom, traditionally report GBAORD net. Where repayments are substantial, one can arrive at negative flows for individual industries (for example, from the aircraft industry), which can pose problems both for GBAORD and for performer-based reporting.

Figure 9 shows the effect of net and gross reporting for GBAORD for industrial development as an SEO in the United Kingdom. The difference is largely repayments for the aircraft Launch Aid programmes.

Figure 9. **United Kingdom – net and gross funding of GBAORD for industrial development**

GBP million at 1990 GDP prices



Source: Office of Science and Technology, 1998.

Since 1992, France reports government-financed BERD to the OECD on a net basis.[4] The break can be seen in Figure 7. In fact, half the decline in civil government-financed BERD in Figure 3 can be attributed to the change in reporting practice.[5] Note that the type of R&D funding of the aircraft programmes involved is scheduled to pick up again in both France and the United Kingdom in 2001.

V. IDENTIFYING THE TWO MAIN SUB-CATEGORIES OF FUNDING IN BUSINESS ENTERPRISE

The guidelines for the pilot study made a clear distinction between "financial incentives" for RDI and "contracts and procurement". This was of obvious interest for reviews of industrial policy and for studies of the economic impact of different types of support for technology. However, it proved difficult to apply in practice.

The *Frascati Manual* (OECD, 1994) currently recommends that government funds in the business enterprise sector should be broken down into the two categories defined in Box 6.

Box 6. **Categories of government support to industrial firms**

a) Those which are specifically for the procurement of R&D, *i.e.* the results of the R&D belong to the recipient of the output or the product of the R&D, who is not necessarily the funder of the R&D.

b) Those which are provided to the performer of the R&D in the form of grants or subsidies,* with the results of the R&D becoming the property of the R&D performer.

* Despite this use in the *Frascati Manual*, the term "R&D subsidies" was deliberately avoided during the pilot study as it has a specific meaning in the guidelines of the World Trade Organisation (Pretschker and Young, 1998).

Source: OECD, 1994.

As efforts to collect the *Frascati* breakdown via an experimental table in the regular OECD R&D survey had failed, this new data set was extremely eagerly awaited. However, as noted above, establishing the break proved difficult. The *Frascati* text suggests that the main criterion should be the ownership of results. This break can also be made on the basis of the intentions of the funder or on the financial instrument involved. Of the countries included, only the United Kingdom had a classification of the first kind (Annex 2) and only Canada had one of the second kind (Box 7).

The break by financial instruments

A breakdown by financial instrument, notably between contracts and other financial instruments, might be an alternative to that between subsidies and procurement. Such a break is not currently mentioned in either the *Frascati* or the *Oslo Manuals*. It is collected systematically in Canada for federal extramural R&D funding as described in Box 7 below.

Figure 10 shows trends in payments to industry for R&D contracts and grants (including fellowships). The ratio between the two varied over the period 1989-98.[6]

In practice, in the pilot study the distinction was based on a mixture of intentions and types of financial instruments. For most countries, the approach used was to take the sum of funding of the designated programmes in the PSI as "financial

Box 7. **Canadian breakdown of extramural funding by financial instrument**

The federal government uses three methods of funding extramurally performed S&T activities:

- A ***contract*** is a legal agreement between two or more parties which will usually specify the nature and general objective of the S&T activity to be performed and the provision of the service according to an agreed schedule and cost.
- A ***grant*** is an unconditional payment for which service is not necessarily expected (information, goods, etc.). It is to be noted, however, that prospective recipients may have to satisfy certain eligibility requirements.
- A ***contribution*** is an agreement between the government and the recipient which specifies the terms and conditions under which funds will be paid. The payments are conditional upon performance or achievement and the recipient's use of the funds is subject to audit.

Data sub-divided by type of funding are collected for R&D only. In national data publications, the term "grants" encompasses both grants and contributions but an additional category is given for ***Research Fellowships***.

Source: Statistics Canada, 1998*a*.

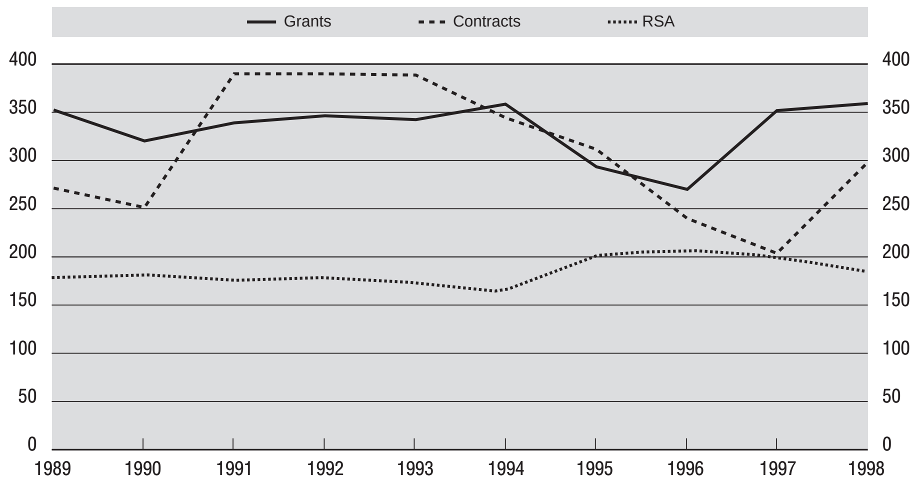
support" and residual (*Frascati* direct) extramural R&D expenditure to the business enterprise sector as "contracts and procurement".

Primary and secondary objectives

The break between financial incentives and contracts and procurement is also blurred by programmes with primary and secondary objectives, particularly those touching the aerospace industry. Several countries have financial incentives for the aerospace industry, both for space and civil aircraft and, in countries which procure most of their defence equipment abroad, financial incentives to keep national defence industries capable of participating in international schemes.

The situation is even more complicated in the United States where there is neither a ministry of industry nor of technology and, indeed, no specific category for industrial development in the national classification by objective. When reporting to the OECD, the category "Commerce and Housing Credit" is quoted as industrial development. It covers the small amount of funds committed to such R&D by the Department of Commerce. Support for the aircraft industry funded by

Figure 10. **Canada – federal extramural payments to industry: contracts and grants**



Source: Statistics Canada, 1998*a*.

NASA is included in the transport objective in the national objectives breakdown and when reporting to the OECD. There are also a number of other programmes which support industrial development as a secondary objective with much of the funds contributed by the Department of Defense, NASA and the Department of Energy, notably the Small Business Innovation Research Programme, and the Independent Research and Development Programme (see National Science Board, 2000, pp. 216-219). In the pilot study, these schemes were included under financial incentives, bringing the indicator of such funding as a percentage of industrial value added to "normal" levels in Figure 6.

VI. MATCHING PAYMENTS TO RECEIPTS

Government-financed industrial R&D can be measured in two ways: how much governments say they have paid to industrial firms for R&D (extramural payments) during the period concerned; and how much firms report they have spent on carrying out government-financed R&D (government-financed BERD). The latter series are the most appropriate when trying to model the impact of government programmes in industrial R&D expenditures. However, the breakdown by type of support is usually only available for the government-reported extramural funding. Because of differences in survey coverage, reporting dates, etc., there are often minor differences between these two series, with receipts generally lower than extramural payments. In the years covered by the pilot study, however, they clearly grew apart, even moving in different directions, notably in countries with major defence/aerospace RDI programmes. In the past, this was thought to be mainly because ministries of defence had a more generous view than firms of the R&D content of development contracts. A more recent view is that a significant share of government defence R&D funds are losing their "government" label during subcontracting which is becoming more widespread and complex and now includes movements between different countries. Furthermore, during the later years covered by the pilot study, the defence industries were going through a period of rapid consolidation and the newly merged multinational firms were taking time to assemble a complete picture of all their R&D efforts and who is financing them.

VII. FUNDING OF INDUSTRIAL TECHNOLOGY VIA THE S&T INFRASTRUCTURE

S&T infrastructure covers government funding of R&D and related activities which are intended to support industrial technology but are not carried out by industrial firms.

Industrial R&D institutes

The initial idea was identified in the PSI guidelines (Box 8).

Box 8. **Definition of intermediary R&D institutions (PSI guidelines)**

"Organisations in which the main purpose is to make equipment, research personnel or research results available to manufacturing enterprises by the means of direct co-operation or transactions with manufacturing firms." Be they autonomous or established within the basic or university research system, such organisations are relevant to this project when they reduce R&D costs which would otherwise have to be borne by the enterprises themselves by supplying R&D resources (equipment and personnel) and research results (technologies and patents) to manufacturing firms at prices below economic costs. This occurs when such institutions are partly or entirely financed by public sources such as central or sub-central governments or other intermediary institutions.

Source: OECD, 1995.

These activities may be in the business enterprise sector (co-operative R&D institutes) but are more often in the government or private non-profit sectors. Such R&D activities were particularly important in Australia and Finland and were also significant in Germany, Japan, and the Netherlands (Figure 7). Three of these countries have major institutions whose function is to fund and/or perform industrial R&D. Australia (the Commonwealth Scientific Industrial Research Organisation: CSIRO); Finland (TEKES) and the Netherlands (Organisation for Applied Scientific Research TNO). Where such agencies exist, it should be relatively easy to identify funding for the industrial R&D institutes concerned. However, opinions may vary on which units/programmes to include, as happened for Finland during the pilot study. In the United Kingdom, the corresponding institution, the Department for Scientific and Industrial Research (DSIR), has long been broken up and most of the institutes concerned have been privatised and thus have dropped out of this category. In France, only co-operative R&D in the business enterprise sector could be identified, although, according to the annual R&D budget, a significant amount of government-financed R&D for industrial development goes on in major government establishments such as the Atomic Energy Commission (CEA).

Support for academic technology R&D

When the framework for the pilot study was first proposed to the OECD's National Experts on Science and Technology Indicators (NESTI) group, delegates pointed out that for some governments, notably of smaller OECD countries, general R&D funding for "academic" technology was a significant component of their overall strategy for supporting industrial technology.

Because a special set of data on this topic could not be designed and obtained in time, a series based on GBAORD was used as a proxy, *i.e.* funding of engineering research via the objective "advancement of knowledge", which includes non-oriented R&D in general and public support to R&D in the higher education sector via block grants (known as general university funds – GUF). Engineering is broken out from other fields of science in Eurostat and some Nordic GBAORD series but not, although recommended in the *Frascati Manual*, in the OECD R&D database. A number of estimates had to be made to obtain the data behind this row in Table 2.

The following table, based on more recent data, shows that including engineering has less effect in Finland than in Germany and the Netherlands. In the United Kingdom, funding via engineering is 85% of the wider total in 1998. Indeed the obvious break in series in the earlier graphs for the United Kingdom marks a major reclassification of funds from industrial development to advancement of knowledge, most of which reappeared under engineering. Some, however, was transferred to the mathematics and computing field, illustrating that the engineering series is only a proxy.

Table 4. **GBAORD: effect of adding funding of engineering via the advancement of knowledge to industrial development**
Selected EU countries, 1998

	Industrial development	Advancement of knowledge	Total
Finland	82	18	100
Germany	59	41	100
Netherlands	54	46	100
United Kingdom	15	85	100

Source: BSTS 2000 (OECD annual); NewChronos database; Office of Science and Technology (annual).

VIII. EFFECT OF INCLUDING RELATED S&T ACTIVITIES

At the time of the last revision of the *Frascati Manual*, there was much discussion of the need to look beyond R&D and to take a wider view of S&T and innovation activities in order to have data which could make the link to social and economic performance. Rather than expanding the coverage of the *Frascati Manual*, it was decided to prepare a separate set of guidelines for measuring technological innovation: the *Oslo Manual* (OECD, 1992; OECD and Eurostat, 1997). In consequence, the STI activities of the business enterprise sector are now well covered, mainly from performer-based surveys. The public sector is less well served both as performer and funder.

An attempt was made to deal with this lack during the pilot study by trying to include:

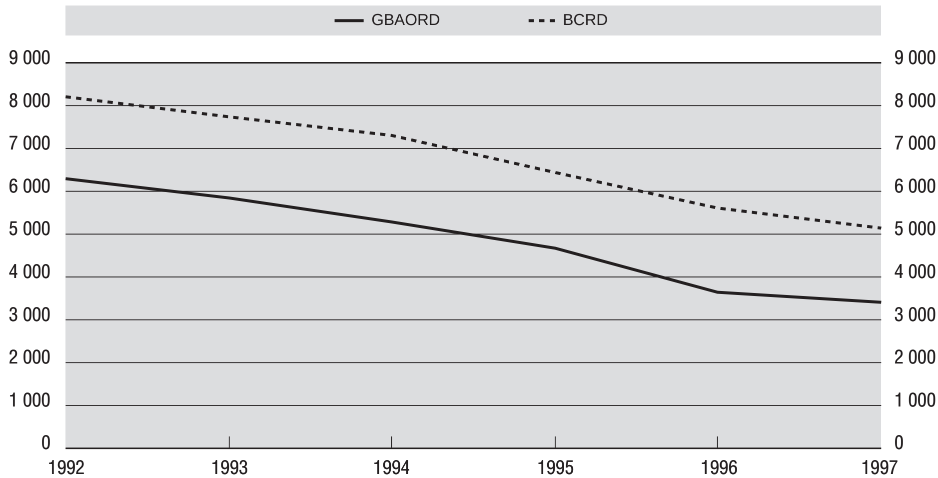
- Post-R&D activities leading to technological innovation.
- Related scientific activities, especially technical diffusion.

Including the post-R&D stages of innovation

From a government funding point of view, the main components will be programmes specifically aimed at the post-R&D stages of innovation (for example, support for training connected with the introduction of new products and processes) and the residual funding of innovation grants and contracts once the R&D component has been separated out (mainly defence and space).

The *ad hoc* study did not reveal any obvious cases of the former. National S&T budgets do sometimes include the latter. For example, in France the national table corresponding broadly to civil GBAORD (the BCRD) includes some post R&D funds. The effect on industrial development as a socio-economic objective is significant (Figure 11).

Figure 11. **France – Industrial development in the BCRD and in GBAORD, 1992-97**
FRF million, at 1990 GDP prices



Source: Imprimerie nationale (1998); OECD (annual).

In the end, innovation activities were only included in the pilot study where these were already in the PSI data.

Including other S&T activities

The *Frascati Manual* deals only with other S&T activities in order to identify and exclude them from R&D, including from GBAORD. However, a fuller picture of government strategies for support of industrial innovation systems would include and identify such related activities. Insofar as GBAORD is compiled in many countries by estimating the R&D content of government programmes, giving space to report other *bona fide* S&T activities might also increase international comparability.

Of the ten Member countries included in the second phase of the Technology, Productivity and Job Creation exercise, three, Canada, Mexico and the United Kingdom collected data on total government expenditure (intramural and extramural) on the full range of scientific and technological activities. For the Canadian federal government, these data cover R&D and the related scientific activities (RSA) listed in Box 9. Trends in payments to Canadian industry for RSA are shown in Figure 10. In 1997, they were at the same level as contracts.

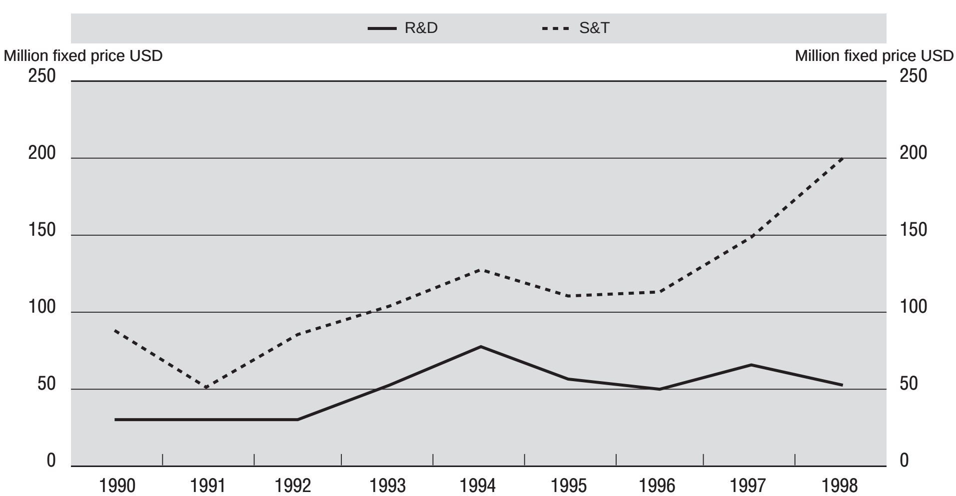
Box 9. **Canada – federally funded related scientific activities**

Natural sciences and engineering	*Social sciences*
Scientific data collection	General purpose data collection
Information services	Information services
Testing and standardisation	Economic and feasibility studies
Feasibility studies	Operations and policy studies
Education support	Education support
Museum services	Museum services

Source: Statistics Canada (1998*a*).

Mexico publishes its own annual S&T budget which includes R&D, education activities and other S&T activities broken down by objective. Figure 12 shows the comparison with the R&D series reported to OECD. The two curves give different impressions of the government policy in this area.

Figure 12. **Mexico – Government budgets for industrial development: R&D and S&T**

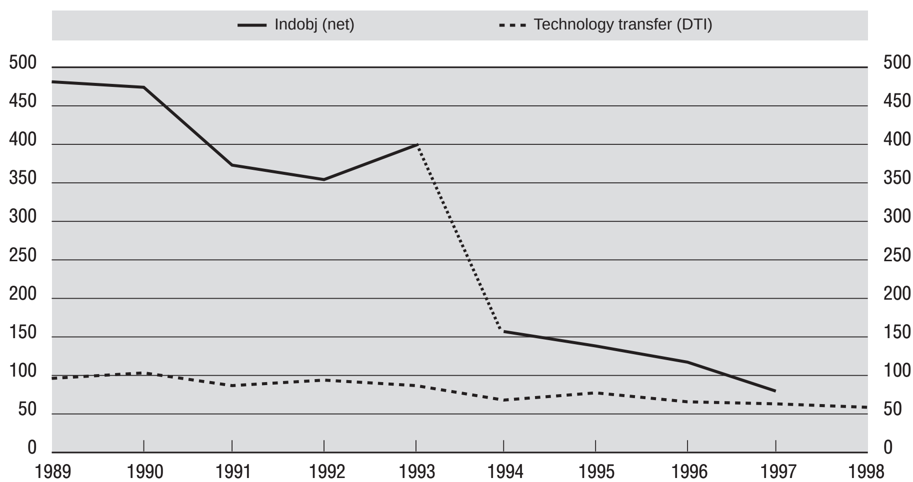


Source: BSTS (OECD annual); Conacyt (1999).

For a number of years, the information compiled for the annual report on government-funded S&T activities in the United Kingdom requested details on R&D expenditures and personnel but also provided space for departments to report on "non-*Frascati* R&D" programmes and funding. Information is now collected systematically on two RSA: "technology transfer" (activities that encourage the exploitation of knowledge in a different place to its origins) and "other SET expenditures" (Annex 2). Funding of technology transfer by the Department of Trade and Industry was at about the same level as GBAORD for industrial development in the late 1990s (Figure 13).

Figure 13. **United Kingdom – GBAORD for industrial development and Department of Trade and Industry funding of technology transfer**

GBP million at 1990 GDP prices



Source: OECD (annual); Office of Science and Technology (1998).

IX. ROLE OF PROVINCIAL GOVERNMENT IN FUNDING INDUSTRIAL TECHNOLOGY

Although provincial and local governments are taking an increasing interest in encouraging industrial technology in their regions as a means of attracting or generating jobs, their financial contributions are not yet very important in the majority of Member countries. For example, in Canada provincial governments spent about CAD 250 million on industrial technology (about 10%-15% of the total) (Statistics Canada, 1997*b*). Such schemes more often involve co-operation between the different levels of government, as in the United States where the states provide about 10%-15% of co-operative technology support (Berglund and Coburn, 1995). The share seemed slightly lower (5%-10%) in Australia where state governments spent about AUD 30 million per year on support for industrial technology. Efforts to obtain better data on state and provincial government support for R&D have continued since the pilot study (Jankowski, 1999; Statistics Canada, 2000).

There was also increased interest from sub-central government in knowing the distribution of central government R&D funds and/or all R&D spending. This has long been a concern of DGResearch/Eurostat (European Commission, 1997) but reporting is also developing in other Member countries (NSF, 1998).

X. NEXT STEPS

The results of the pilot study could feed into the design and development of new S&T indicators for a knowledge-based economy in a number of ways. How many are followed through to regular collection and/or calculation will depend on the level of future demand for the indicators concerned, the views of experts, notably NESTI, of their technical viability and last, but not least, on the availability of resources in national capitals and at OECD to do the work concerned.

The guidelines for this data set might be further developed and improved, leading to regular data collection.

Demand for such data can be of three kinds: to give a general picture of the level and structure of government support for technology (as for the original report); to improve the "transparency" of government aid to industry; and to have data which can be used to model the impact of such programmes on R&D funded by industry. The first type of interest certainly continues. For example, the data set in the pilot study was mined for an OECD E*conomic* R*eview* of France and the topic is still on the agenda of the Working Party on Technology and Innovation Policy. The second type, "transparency", is now the responsibility of the World Trade Organisation with the agreement on subsidies and countervailing measures (Pretschker and Young, 1998) and the publication in March 1998 of the associated reporting requirements for R&D programmes. This may make governments less willing to report detailed data to the OECD. Interest in modelling continues (Bentzen and Smith, 1999), but the difference between payments and receipts would have to be solved for the data to be really useful for this purpose.

Table 5. **Estimated total support for industrial technology by type**
Percentage of Domestic Product of Industry

	Australia	Canada	Finland	France	Germany	Japan	Mexico	Nether-lands	United Kingdom	United States
	1996	1995	1997	1995	1997	1995	1996	1997	1996	1996
Fiscal	0.05	0.15	0.00	0.05	0.00	0.01	0.00	0.09	0.00	0.02
Grants	0.04	0.03	0.27	0.08	0.09	0.00	0.00	0.03	0.02	0.09
Other	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Total financial	0.09	0.18	0.28	0.12	0.09	0.02	0.00	0.12	0.02	0.11
Defence	0.04	0.01	0.00	0.18	0.09	0.03	0.00	0.02	0.24	0.35
Space	0.00	0.03	0.04	0.10	0.04	0.03	0.00	0.04	0.02	0.04
Other	0.00	0.05	0.00	0.01	0.01	0.04	0.00	0.03	0.04	0.04
Total contracts	0.04	0.09	0.04	0.30	0.13	0.10	0.00	0.09	0.31	0.44
Institutes	0.15	0.03	0.23	0.00	0.05	0.05	0.00	0.04	0.01	0.00
Academic	0.03	0.03	0.08	0.08	0.09	0.08	0.03	0.12	0.06	0.01
other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00
Total S&T infrastructure	0.18	0.05	0.31	0.09	0.15	0.12	0.04	0.16	0.09	0.01
Total	**0.31**	**0.32**	**0.63**	**0.51**	**0.37**	**0.24**	**0.04**	**0.38**	**0.42**	**0.56**

Source: Pilot study.

The definition of industry would need to be reviewed, as the old study was probably too centred on manufacturing/engineering. For example, the exclusion of agriculture is no longer justified in the age of biotechnology.

On the supply side, further work would be needed to test the guidelines on a wider range of countries and indeed by more in-depth study of the national institutional specificities of the countries already included. The main problem is how to replace the data derived from the PSI database. Although these were often revised, extended or updated during the exercise, they provided the starting point for nearly all countries in the pilot study.

This might lead to a supplement to a future edition of the *Frascati Manual*. A supplement would be appropriate because the categories described above cut across those in the current manual and surveys and because this measure covers programmes and institutions with industrial technology as both a primary and secondary focus whereas units in the overall *Frascati* system are usually attributed wholly to their primary activity or goal.

Nevertheless, the pilot study revealed a number of sections of the *Frascati Manual* (1994 edition) where the current text could be improved, notably that on the distinction between financial incentives and contracts and procurement already cited above. The list of financial instruments from the PSI might usefully be incorporated, as might the explanation of the difference between net and gross funding.

NOTES

1. A particular complication was that the terms "direct" and "indirect" support have quite different meanings in the two statistical frameworks.
2. The defence R&D data for Japan are higher than in standard sources as the national authorities supplied information on the R&D content of defence procurement which is not included in regular Japanese R&D data.
3. At this stage, no distinction was made between the different types of fiscal incentives described in the article by Warda in this issue of the STI R*eview*.
4. The PSI series also showed significant differences between net and gross R&D funding in Japan (OECD, 1998*b*).
5. A comparison between the two approaches for civil government-financed BERD in 1997 gives 3.3% gross and 2.4% net (Bonneau and Weisenburger, 2000).
6. The RSA curve will be examined later.

Annex 1

GUIDELINES TO COUNTRIES PARTICIPATING IN THE PILOT STUDY OF GOVERNMENT FUNDING OF INDUSTRIAL TECHNOLOGY

Table A.1. **Main specifications of data sought for the pilot study**

1. R&D and industrial innovation
These are as defined in the *Frascati* and *Oslo Manuals*. Financial incentives for innovation should be included (Category A) but not funding of the post-R&D stages of innovation for contracts and procurement (Category C).

2. Whose point of view?
Government strategies should be identified from the funding point of view using a combination of GBAORD and PSI data and national sources.

3. The level of government as a source of funds
Separate returns should be made for central/federal government and for all or selected sub-central governments.

4. Time period covered
The base year for comparisons is 1995. The core period for the study of government strategies is 1989 to latest year available.

5. Which industries should be included
As an aim or objective (Categories A + C), the industrial coverage is in "Industrial development" as an objective for GBAORD. As a sector of destination/performance (Categories A + B), it covers all industries (except agriculture).

6. Primary and secondary objectives
Financial incentives should cover programmes involving payments to firms which either have RDI as a primary or secondary objective (or as a supporting activity) in the PSI or are included in R&D for industrial development in GBAORD.

7. Distinguishing between firms and other units
For section A, it is essential to only include funding of firms as institutes serving enterprises are treated in section C1. For section B, the business enterprise sector may be treated as a proxy for industrial firms unless it includes a significant institutes sub-sector.

8. Main categories of support for R&D and innovation
- Financial incentives, by financial instrument
- Defence space and other civil contracts and procurement.
- RDI outside firms

9. Net and gross funding
Fiscal incentives are measured net, other forms, derived from R&D sources, are measured gross.

10. Currency units
Please report in million national currency.

11. National territory
In principle, only include payments to firms and other units on national territory. Please note if payments are made to foreign subsidiaries of national firms.

Table A.2. **Suggested sources for establishing sets of national data for the pilot study of government funding of industrial technology**

	PSI	GBAORD	GBERD	National sources
A. Financial incentives to business R&D (firms)				
A.1. Fiscal incentives	MS			CS
A.2. Grants or forgiven loans				
Funding of R&D and innovation: primary aim industrial development	CS	MS		AD
Funding of R&D and innovation: secondary aim industrial development	MS	CS		AD
A.3. Other financial incentives	MS			AD
B. Mission-oriented R&D contracts and procurement (firms)				
B.1. Defence	CS	MS	CS	CS
B.2. Space	MS	CS		CS
B.3. Other objectives	CS	MS		AD
C. S&T infrastructure and diffusion.(other than firms)				
C.1. Government-financed R&D for industry outside firms	CS	MS	CS	CS
C2. Engineering via advancement of knowledge		MS		
C.3. Government-financed diffusion and other S&T activities				MS

Key: MS = Main source; CS = Check or secondary source; AD = Additional detail.

Annex 2

UNITED KINGDOM: THE PRIMARY PURPOSES OF GOVERNMENT SET FUNDING

"Unlike the F*rascati* categories (basic, applied and experimental development) which deal with the nature of the R&D, the primary purpose (pp) is concerned with why the R&D is being funded by government. The primary purposes of R&D financed by government are:

- *pp*A *general support for research* – all basic and applied research which advances knowledge; support for postgraduate research studentships.
- *pp*B *government services* (*broken down between defence and civil*) – R&D relevant to any aspect of government service provision (all defence included here).
- *pp*C *policy support* – R&D which government decides to fund to inform policy (excluding ppB and ppD) and for monitoring developments of significance for the welfare of the population.
- *pp*D *technology support* – applied R&D that advances technology underpinning the UK economy (but excluding defence). The category includes strategic as well as applied research and pre-competitive research under schemes such as LINK.
- *pp*E *technology transfer* – activities that encourage the exploitation of knowledge in a different place to its origins.
- *pp*F *other* SET *expenditures* – includes items such as postgraduate taught courses, etc."

Source: Office of Science and Technology (1998).

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MEASURING THE VALUE OF R&D TAX TREATMENT IN OECD COUNTRIES

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This article was written by Jacek Warda of The Conference Board of Canada. The views expressed in this article are those of the author and do not necessarily reflect those of The Conference Board of Canada.

I. INTRODUCTION

In many countries, research and development (R&D) tax incentives to stimulate private sector research spending are a significant element of technology and innovation policy. The purpose of this article is to present a model for calculating the relative attractiveness of these tax incentives and to update previous estimates for the selected OECD countries.

A "B-index methodology" is used to compare the relative importance of R&D tax support across tax jurisdictions. The model has had quite a following since its initial elaboration.[1] In this model, the value of the index measuring the relative attractiveness of R&D tax treatment – the B-index – depends on the tax treatment of R&D in a given tax jurisdiction and is based on the before-tax income required to break even on one dollar of R&D outlay. The more favourable the tax treatment of R&D, the lower the required break-even rate of return and thus the lower the country's B-index. However, although the B-index is a useful analytical and comparative tool, it is based on a number of methodological assumptions. In addition, it does not consider the full range of taxes in a country or the effects of other types of technology policy on research spending.

This article measures only differences in the tax treatment of R&D; it thus ignores factors such as subsidies, as well as taxes that do not pertain to corporate income. Although important, non-fiscal factors that affect the decision to invest in R&D, such as the availability of a skilled workforce and the presence of science and technology infrastructure, are beyond the scope of this work. Hence, while the comparison can inform the policy discussion, it cannot replace the detailed examination of alternatives for any particular private sector decision.

II. WHY TAX INCENTIVES?

Generally, governments are involved in the support of R&D because net spin-offs from R&D are of benefit for society at large but the returns cannot be perfectly appropriated by the performers of R&D – private sector firms. Research indicates that the social rates of return on R&D are several times higher than the private rates.[2] Thus the private sector tends to under-invest in R&D simply because it has less incentive to produce R&D beyond that portion that is already appropriable as a private good. This leads to so-called "market failure" since the market cannot fully ascertain the accrual of all benefits to the private R&D performer, thus leaving no choice but to allocate less resources to R&D than the socially desirable optimum. This under-production of R&D is the justification for government intervention in this area.

Tax incentives are granted by governments to offset market failure in allocating resources to long-term and risky investment such as R&D. They are part of the arsenal of tools that governments have at their disposal to directly stimulate R&D in the private sector. Unlike the other more direct measures, tax incentives are delivered indirectly through market decisions of the private sector. In the case of tax incentives, the decision to use them and how to use them remains with the company. Companies investing in R&D are eligible to claim tax incentives against their payable tax. Unlike the other tools, broadbased tax incentives do not target specific industry sectors, firms or fields of R&D investment. They can be accessed on the simple condition of R&D funds being expended and taxpayers' compliance with the rules and regulations pertaining to the claiming process. Government support can take different forms: direct grants, subsidies, loans and contracts. These do not work through the tax system but are delivered direct to business through the various programmes. They too can be modelled using the B-index approach. However, this requires even more assumptions, thus making the estimates even more distant from reality (see Appendix 1).

What are tax incentives?

Tax incentives take a number of different forms:[3]

- *Exemptions*: income or expenditures that are excluded from the tax base.
- *Allowances*: extra amounts over current business expenses deducted from gross income to arrive at taxable income.
- *Credits*: amounts deducted from the tax liability.
- *Tax deferrals*: a relief in the form of a delay in payment of a tax (*e.g.* accelerated depreciation allowance, current deduction).
- *Rate reliefs*: a reduced rate of corporate income tax applied to certain taxpayers or activities.

Tax incentives for R&D usually take three forms: tax credits, allowances from taxable income and tax deferrals (depreciation allowances and current deduction). Although tax credit and allowances from taxable income are an obvious type of tax incentive, depreciation allowances are only a tax incentive if they are allowed at a rate that is greater than the rate of economic depreciation.

Current deduction for R&D expenses is a particular form of tax deferral. General accounting practice defines current deduction as expenses incurred on regular day-to-day income-generating activities. R&D expenditures do not generate income today; they represent investment which generates income in the future. Thus they should be expensed proportionally to income generated in a given year. This means that treatment of the R&D expenses (wages, salaries and materials) as a current expense represents a tax subsidy, a kind of accelerated depreciation. As Bronwyn Hall (1995) has noted: "100% would be the economic depreciation rate only if the returns to R&D spending dissipated within one year, which is not a very realistic picture of most R&D." Current deduction represents a substantial loss of revenue for the governments offering it: close to 90% of each R&D dollar is spent on "current" expenses, the remainder representing fixed assets.

III. PARAMETERS OF THE R&D TAX ENVIRONMENT

Current and capital expenditures

For accounting purposes, R&D expenditures are separated into current expenditures, which include wages and salaries of research personnel and the cost of materials used, and capital expenditures, which include the cost of equipment and facilities. The countries examined in this article allow for current expenditures on R&D to be deducted from income in the year they are incurred. The countries differ, however, in that some allow capital expenditures for R&D purposes to be written off in the year they are incurred, while others require that capital expenditures be depreciated over their economic life (or some fraction thereof). Other things being equal, the net-of-tax cost of R&D will be lower in those countries that allow an immediate or accelerated write-off of expenditures on R&D facilities and equipment.

Capital expenditures are typically depreciated over the useful life of an asset according to two methods: declining balance or straight line. Some countries (*e.g.* the United States) allow a switchover from the declining balance to the straight line method at the point in time when the latter becomes more beneficial to the taxpayer in present value terms. The table below presents the formulas used for calculating the present value of the accelerated depreciation, *z*, according to each of these methods. The formulas assume that assets are depreciated at the beginning of the period.

Depreciation formulas

Declining balance: $z = d(1 + r)/(d + r)$

Straight line: $z = 1/T(1 - (1/(1 + r)\ )^T)(1 + r)/r$

Where: d = rate of depreciation
r = discount rate or rate of interest
T = the number of years over which the asset is to be written off.

Owing to the fact that current and capital R&D expenditures incur different tax treatments in different tax jurisdictions, the R&D expenditures were split into current expenses and capital expenses, using an average proportion of 90% and 10%, respectively. Capital expenses were then divided equally between machinery and equipment (5%), and buildings (5%). Furthermore, wages and salaries (a component of current costs) are assumed to represent 60% of total R&D expenditures. These proportions have been applied uniformly to all the tax jurisdictions examined.

Special allowances on R&D expenditures

A number of the countries examined in this study (Australia, Austria, Belgium, Denmark, Ireland and the United Kingdom) have special allowances on R&D expenditures that allow firms conducting R&D to deduct more from their taxable income than they actually spend on R&D. These special R&D allowances come in two forms. The first allows a firm spending one dollar on R&D to deduct $\$(1 + w)$ (where $w > 0$) from its taxable income for the year in which the expenditure occurs. This implies a tax saving of $\$(1 + w)u$ and an after-tax R&D cost of $\$(1 - (1 + w)u)$, where u is the corporate income tax rate. The greater the amount of the special allowance, w, the lower will be the after-tax cost of R&D.

A second type of special allowance is based on the increase in R&D expenditures over some prior base period (that is, an incremental allowance). In this case, a firm is allowed to deduct both its R&D expenditures and some fraction, w, of the increase, if any, in its R&D expenditures over a specified base period. For example, for a one-dollar expenditure that also involves a one-dollar increase over the base period, there is a tax saving of $\$(1 + w)u$ and an after-tax R&D cost of $\$(1 - (1 + w)u)$. The incremental allowance is discussed in greater detail in Appendix 2, which details the B-index model equations.

Investment tax credits

Investment tax credits for R&D are used by ten OECD countries (Canada, France, Italy, Japan, Korea, Mexico, the Netherlands, Portugal, Spain and the United States). Tax credits, like special allowances, reduce the after-tax cost of R&D. However, unlike allowances, tax credits are applied against income tax payable. Similar to allowances, there are two types of tax credits: a level-based tax credit and an increment-based tax credit. These credits can be either non-taxable or taxable. A level-based tax credit is less prevalent in the OECD countries – only Canada, Italy and the Netherlands have pure level-based tax credits in place. The other countries use increment-based R&D tax credits. In addition, the majority of the OECD countries give the taxpayer the full value of the tax credit. Only two countries – Canada and the United States – tax their tax credits.

The level-based tax credit is a direct reduction of a firm's tax liability equal to some fraction, c, of its annual R&D spending. A non-taxable tax credit does not reduce the amount of R&D spending that may be deducted from taxable income. If, for example, R&D were fully deductible, the tax saving on one dollar of R&D spending would be $\$(u + c)$ and the after-tax cost of R&D would be $\$(1 - u - c)$. With a 10% tax credit and a 50% tax rate, the tax saving would be 0.60 dollars and the after-tax cost of one dollar of R&D would be 0.40 dollars.

A taxable tax credit also involves a reduction of the firm's tax liability by some fraction, c, of its R&D spending but requires that the amount of R&D written off against taxable income be reduced by the amount of the credit. In the terms used above, the tax saving on one dollar of R&D spending would be $\$(c + t(1 - c))$. The after-tax cost of R&D would be $\$(1 - c)(1 - u)$. For the numerical values assumed above, the tax saving would be 0.55 dollars and the after-tax cost of R&D would be 0.45 dollars.

The increment-based tax credit is based on the nominal change in a firm's R&D spending over some base period. It may, or may not, reduce the R&D deductions the firm could otherwise claim. This credit may also be taxable or non-taxable. The typical incremental tax credit is discussed in more detail in Appendix 2.

Corporate income tax rate

The rate at which corporate income is taxed is another important factor in R&D tax treatment. The tax rate directly affects the after-tax cost of R&D, which is the conventional method of measuring the impact of R&D tax incentives.

Developing a model to measure the value of R&D *tax incentives*

It was important to choose a model that was capable of including the above parameters and measuring their impact on an R&D investment. The model discussed below is based on the marginal effective tax rate approach (METR). The marginal model is designed specifically to look at the tax burden on income generated by an "additional dollar" invested in R&D, and to construct an overall measure of the corporate tax burden on marginal R&D investments in different countries. In its simplest form, the model represents a ratio of the present value of taxes incurred as a result of an additional investment to the present value of income generated by that investment. The model discussed in this article follows this form, although it has been slightly modified. It aims to answer, for a given tax system, how much before-tax income the taxpayer/investor must derive to make the "additional investment" break even.

The marginal model chosen here provides a useful summary of the main features of business taxation and is effective in making international comparisons. The trade-off for its utility, however, is that its modeling is quite conceptual, largely requiring significant external development of microeconomic analysis such as the adaptation of an equation for the user cost of capital. These requirements must be understood by the user in order for the model to provide an effective policy analysis tool.

Although the METR model is more abstract and static than the cash-flow model, which is based on average tax rates, it appears to be more relevant to specific business decisions, such as the commitment of additional resources to particular types of business investments. Thus the marginal model provides an approach to answering the question: "What is the likely consequence, in terms of taxes to be paid, of a specific R&D activity which I am considering undertaking within my firm?" This is precisely the question that the B-index model attempts to answer.

IV. GENESIS OF THE B-INDEX

While at the Department of Economics, Carleton University, the author and his professor, Don McFetridge, were involved in the evaluation of government support programmes for R&D. In 1983, a great deal of discussion took place in Canada about the need to invest more in R&D and the respective roles of the government and the private sector. It was felt that Canada had a fairly generous support programme delivered through its tax incentives scheme, but no-one knew how generous it was relative to our foreign competitors. There was a need for a model that would synthetically capture all the tax incentives and compare them with those in other countries. In order to measure the relative attractiveness of different R&D tax treatments, the model needed to meet the following conditions:

- It should be able to isolate the impact of the incentives on the rate of return to one unit of R&D performed.
- It should be based on well-founded economic theory.
- It should be simple to calculate and understand.
- It should serve as a policy analysis tool.

We found the underlying theoretical framework in the approach chosen by Hall and Jorgenson (1967) to measure the user price of capital. Later, King and Fullerton (1984), expanded the model with the aim of deriving marginal effective tax rates on various types of investment.

The B-index model and its theoretical framework were originally published in 1983 by the Canadian Tax Foundation, an internationally recognised independent tax research organisation (McFetridge and Warda, 1983). A series of studies followed during the period 1990-99, published under the auspices of The Conference Board of Canada and the OECD.

About the B-index model

The origin of the name "B-index" captures the fact that the model describes the minimum benefit-cost ratio at which an R&D investment becomes profitable given a jurisdiction's income tax treatment for firms performing this work. The name is rather cryptic, however, for many of the organisations and researchers using the index. Thus, other names for the B-index or its transformations have evolved. Among the most popular names which perhaps better reflect the nature of the index, are:

- Tax-subsidy ratio (*i.e.* the B-index subtracted from unity).
- Tax price of R&D.
- Tax component of the user price of R&D.
- Rate of return on the marginal R&D investment, before tax.

In all of these applications, the B-index remains a measure that reveals the relative support for private sector investment in R&D delivered through a tax system. Put differently, the B-index shows the impact of a tax system on private sector decisions to invest in R&D. Specifically, the B-index is calculated as the present value of before-tax income that a firm needs to generate in order to cover the cost of an initial R&D investment and to pay the applicable income taxes. The lower the index, the greater the incentive for a firm to invest in R&D.

The important feature of the B-index model is that it makes it possible to benchmark the relative attractiveness of R&D tax systems among jurisdictions. Within any single region, a firm's R&D opportunities can be regarded as a series of projects, each of which will have a benefit–cost ratio. The firm will find it profitable to undertake all projects with benefit–cost ratios in excess of B. Thus, the lower the B-index, the greater the amount of R&D that a firm will undertake.

Across jurisdictions, interest focuses on the effect of differences in countries' or regions' tax systems on identical projects. The value of the B-index depends on the income tax treatment of R&D. The more favourable the tax treatment of R&D, the lower a jurisdiction's B-index and, other things being equal, the greater the amount of R&D that will be conducted by its corporate residents.

Technically speaking, the B-index formula is simple; it represents a ratio of the after-tax cost (ATC) of one dollar of expenditure on R&D divided by 1 less the corporate income tax rate. The ATC enters the numerator of the B-index equation. It is defined as the net cost to the company of investing in R&D, taking account of all available tax incentives for R&D.[4] Tax incentives lower the ATC of an R&D project. Corporate income tax rates influence the level of ATC, as well. The higher the tax rate, the lower the ATC of R&D, and *vice versa* . As can be seen, using ATC as a measure of the relative attractiveness of R&D tax incentives can yield a distorted result, complicated by the size of the corporate income tax rate that enters the

ATC equation. To isolate the impact of tax incentives from the impact of the corporate income tax rate, the study applies the measure of the B-index. Since the B-index is expressed as a before-tax ratio, it reduces the impact of tax rates and makes international comparisons possible.

The elements that are typically included in the model estimate pertain to the corporate income tax system:

- The time period over which both current and capital expenditures on scientific research may be written off against taxable income.
- The existence of any deductions, including accelerated and bonus deductions, from taxable income that are based on the level or the change in the level of R&D spending.
- The availability of any tax credits (reductions in taxes payable) that are based on the level or the change in the level of R&D spending.
- The rate at which corporate income is taxed, including the impact of major provincial or state tax systems.
- The time factor: the B-index model is expressed in present value terms (net return over time). It is assumed that for all the countries compared, the discount rate is constant and holds at 10%.[5]

A number of tax system features that relate to R&D decisions as well as to other investment decisions are outside the scope of the model. Important factors involved in corporate decisions to invest in R&D, such as personal income taxes, commodity taxes, property taxes, payroll taxes and taxes on capital, and grants and subsidies for R&D are also excluded. A limitation to the corporate income tax regime is a particular weakness of the model. However, further extensions are possible, as many of the measures other than tax incentives affect corporate income (see Appendix 1). This will be particularly relevant to tax jurisdictions that rely on capital, property and commodity taxes as main sources of their revenues rather than on corporate income tax.

The B-index model measures the potential generosity (maximum full value) of the tax system. Thus, it operates under additional assumptions, one of which is the existence of no tax exhaustion. In this respect, the index makes no difference between non-refundability and refundability provisions of tax incentives. Firms have sufficient taxable income to claim the full amount of R&D tax incentives in the current year, and, therefore, certain dynamic aspects of R&D tax incentives, particularly the use of carry-forward/carry-back provisions, do not alter B-index values. This aspect can be included in the model – but at the cost of additional assumptions on how the firm uses the carry-over provisions. To incorporate them would require restrictive assumptions regarding the distribution of income over time. To comply with the assumption of no tax exhaustion, the model also assumes the income tax rate and the rate of the tax incentive to be available on top eligible income.

Yet another important assumption that allows us to show the potential generosity of the tax system is a limitless ability of the firm to claim the tax incentive. In this model, firms are not bound by ceilings or floors on claiming tax incentives. Everything that has been earned is claimed and is paid in full within the fiscal year. In practice, the situation is very different in many countries. Limits are imposed and the process of compliance with the tax authorities' rules and regulations is costly and can take a slice out of the tax incentive pie. This is not, however, the problem dealt with in the model.

Relationship between the B-index and the marginal effective tax rate

It can be shown that, qualitatively, the B-index gives the same results as the METR (Jung, 1989).[6] Marginal effective tax rates are calculated as the difference between the before-tax real rate of net return of economic depreciation required on a marginal project and the real rate of return after taxes required by the investor. Dividing the difference by the before-tax rate of return yields the METR.

Real after-tax rates of return are easily calculated using readily available data – often they are determined exogenously by international financial markets. Thus, these rates can be treated as a constant. A problem emerges when determining the before-tax real rate of return which cannot be measured directly. However, it can be estimated indirectly using the concept of user cost of R&D capital. According to this theory, a profit-maximizing firm will invest until, at the margin, the expected rate of return on capital is equal to the user cost of capital. This can be expressed as a rental rate of capital equation (gross economic depreciation):

$$Rg = (r - p + d)(1 - c)(1 - uz)/(1 - u) \qquad [1]$$

Where:

Rg = gross of tax real marginal rate of return
r = discount rate
p = inflation rate
d = economic depreciation rate
c = tax credit
z = present value of depreciation allowances
u = corporate income tax rate.

Equation 1 shows the case where tax credits are taxable while equation 2 shows a case where tax credits are not taxable.[7] It is clear that the equation can be written as:

$$Rg = (r - p + d)(\text{B-index}).$$

The B-index is calculated as the present value of before-tax income that a firm needs to generate in order to cover the cost of an initial R&D investment and to pay the applicable income taxes. It represents a tax component of the before-tax rate of return or tax component of the user price of capital.

It is also clear that:

$$METR = ((r - p + d)(B\text{-index}) - Const)/(r - p + d)(B\text{-index}) \quad [2]$$

Where *Const* represents the real after-tax rate of return, which is determined exogenously.

In other words, METR is also a function of the B-index. Thus, the B-index represents the tax component of METR. By the same token, the B-index also represents the tax component of the user cost of R&D capital. (For a discussion of the B-index under various R&D tax treatment provisions, see Appendix 2.)

V. THE B-INDEX AS A POLICY ANALYSIS TOOL: BENEFITS AND DRAWBACKS

Overall, we believe that the B-index is a good benchmarking measure for international comparisons. It demonstrates the potential of the national tax (and innovation) system to attract investment in R&D. It is widely used to monitor changes in the level of attractiveness of R&D tax treatment in OECD countries and is increasingly used as an instrument in cross-country and cross-time evaluations of policy tools with respect to their impact on incremental private sector R&D spending.

The B-index methodology has multiple benefits:

- By measuring the relative generosity of R&D tax treatment, it makes international comparisons possible.
- As a synthetic measure, it allows tracking of tax trends and policy changes over time.
- The index can be applied in econometric analysis to inform policy makers' decisions.
- It can be used as a dependent variable in analysis of tax effectiveness.
- The index can be extended to include direct support instruments such as grants and contracts in order to produce a comprehensive picture of the overall level of generosity of government support to private sector R&D.
- Using macro data on business-funded R&D, it can be used to estimate the value of taxes foregone due to R&D tax incentives (Warda, 1998).

Of course, the B-index also has its drawbacks, a major one being the fact that it is limited to factors affecting corporate income taxation. Today, with the ever-accelerating pace of globalisation and investment in knowledge, governments provide incentives via different fiscal mechanisms. These include, for example, VAT exemptions, sales and use tax deductions, R&D employment credits and capital gains deductions. These incentives are used to promote the entire innovation chain – not just R&D. Work on possible extensions to the B-index model in these areas is ongoing.

A 1999-2000 overview of OECD countries' R&D tax treatment

A comprehensive review of national systems of R&D tax incentives, setting out their nuances and implications for private sector investment decisions, was elaborated by Lhuillery (1995). This analysis is still relevant and serves as a useful complement to the discussion of recent work on R&D tax incentives presented below. For greater detail, the reader can refer to Exhibit 1 and Exhibit 2, which present country-by-country details of the parameters of the R&D tax treatment included in the calculation of the 1999-2000 B-indexes.

The number of countries offering at least one tax incentive for R&D (either in form of a tax credit or an allowance from taxable income) has significantly increased over the 1996-99 period. In 1999, 16 countries (66.7% of the 24 countries examined) offered a tax incentive for R&D, compared with only 12 countries in 1996 (50%).

The countries that offered an R&D tax credit or tax allowance in 1999 are Australia, Austria, Belgium, Canada, Denmark, France, Ireland, Italy, Japan, Korea, Mexico, the Netherlands, Portugal, Spain and the United States. The comparison includes the United Kingdom which began offering an R&D tax incentive on 1 April 2000.

Since the 1996 comparison, the following countries have joined the tax incentive providers: Ireland (1996), Mexico (1998), Portugal (1998) and the United Kingdom (2000). Two countries – Austria (1999) and Japan (1999) – have radically improved their R&D tax incentive system. One – Australia (1996) – has radically scaled down the generosity of its R&D tax incentive system.

Of the 16 countries that offer R&D tax credits, five offer an R&D tax credit of the incremental type, four offer level- or volume-based R&D tax credits, and two countries offer a combination of the two (Table 1). Korea offers both a level-based and an incremental R&D tax credit, but these two credits are mutually exclusive – the firm can claim only one of these credits.

An increasing number of countries are offering R&D allowances on taxable income. Four countries provide level-based allowances, one offers an incremental allowance and one gives a combination of both types of allowances (Table 2).

Table 1. **Countries that offer R&D tax credits, 1999**

	Level of R&D	Increment of R&D	Combination of both
Canada	Yes		
France		Yes	
Italy	Yes		
Japan		Yes	
Korea	Yes	Yes	
Mexico		Yes	
Netherlands	Yes		
Portugal			Yes
Spain			Yes
United States		Yes	
Total	**4 countries**	**5 countries**	**2 countries**

Table 2. **Countries that offer R&D allowances from taxable income, 1999**

	Level of R&D	Increment of R&D	Combination of both
Australia	Yes		
Austria			Yes
Belgium	Yes		
Denmark	Yes		
Ireland		Yes	
United Kingdom	Yes		
Total	**4 countries**	**1 country**	**1 country**

A relatively small number of countries provide R&D tax incentives for small firms. Only seven (29.2%) countries have been identified (Table 3). Two countries offer R&D tax incentives targeted at basic technology research, one stimulates collaborative research and another provides a credit for investment in R&D facilities (Table 3).

Two countries with federal political systems provide R&D tax incentives through their local jurisdictions (provinces in Canada and states in the United States), on top of federal R&D tax incentives (Table 3).

It should be noted, however, that there are limits to the generosity of those countries that provide tax incentives – these limits, due to B-index model assumptions, are by-passed in the calculation of the country B-indexes. Of the 16 countries which offer R&D tax credits or R&D allowances on taxable income, 12 impose limits on the annual amounts that can be claimed by the firm (see Exhibit 2). There

Table 3. **Countries that offer R&D tax credits or R&D allowances from taxable income targeted by specific area or activity, 1999**

	Company size	Research or technology	Activity	Region
Belgium	SME			
Canada	SME			Provinces
Denmark		Basic research		
Italy	SME			
Japan	SME	Basic research	Collaboration	
Korea	SME		R&D facilities	
Netherlands	SME			
United Kingdom	SME			
United States				States
Total	**7 countries**	**2 countries**	**2 countries**	**2 countries**

are two types of limits: a cap (floor or ceiling) on the absolute amount of R&D that can be claimed; or a cap on the maximum amount of the tax incentive that can be deducted. This cap is equivalent to the percentage of tax liability or a percentage of taxable income, depending on the type of the incentive.

Finally, ten countries provide special accelerated depreciation for machinery and equipment used for R&D. However, only four – Canada, Spain and the United Kingdom (and Denmark for basic research only) – are truly generous, providing an immediate (100%) write-off (Table 4).

An even smaller number of countries provides special tax depreciation for buildings used for R&D. There are only four such countries, of which two grant 100% write-off for buildings (Table 4).

Table 4. **Countries that offer special accelerated depreciation for R&D capital assets, 1999**

	Machinery and equipment	Buildings
Australia	3 years	
Belgium	3 years	
Canada	100%	
Denmark -basic research	100%	100%
Greece	3 years	12.5 years
Korea	5 years	5 years
Mexico	35% slm	
Portugal	4 years	
Spain	100%	
United Kingdom	100%	100%
Total	**10 countries**	**4 countries**

Rating the generosity of R&D tax incentives

The B-index values are presented in Table 5. Based on this table, three groups of countries can be distinguished.

Table 5. **Values of B-indexes ranked from lowest to highest, by country, 1999-2000**

	Large company	Small company
Spain	0.687	0.687
Canada	0.827	0.678
Portugal	0.850	0.850
Denmark – basic research	0.871	0.871
Austria	0.878	0.878
Australia	0.890	0.890
Netherlands	0.904	0.642
France	0.915	0.915
Korea	0.918	0.837
United States	0.934	0.934
Ireland	0.937	0.937
Mexico	0.969	0.969
Japan	0.981	0.937
United Kingdom	1.0	0.888
Finland	1.009	1.009
Switzerland	1.011	1.011
Greece	1.015	1.015
Sweden	1.015	1.015
Norway	1.018	1.018
Italy	1.027	0.552
Iceland	1.028	1.028
Germany	1.041	1.041
New Zealand[1]	1.131 (1.023)	1.131 (1.023)

1. New Zealand may now allow full deduction of current expenses.

***For all (large and small) companies*:**

- Generous incentive providers – defined by B-indexes of less than 0.9 [Australia, Austria, Canada, Denmark (basic research only), Portugal and Spain].
- Moderate incentive providers – defined by B-indexes greater than 0.9 and less than 1.0 (France, Ireland, Japan, Korea, Mexico, Netherlands, United Kingdom and the United States).
- Low incentive providers or non-incentive providers – countries with B-indexes greater than 1.0 (Belgium, Finland, Germany, Greece, Iceland, Italy, New Zealand, Norway, Sweden, Switzerland and the United Kingdom). The

distinguishing feature of this group is that none of the countries provide a tax credit or tax allowance for R&D.[8]

Seven countries provide generous R&D tax incentives targeted specifically to small companies (see Table 3). Of these, two – Italy and the United Kingdom – have tax incentive programmes that are available only to small businesses. Thus, the composition of the groups is significantly different. It is noteworthy that the group of "generous incentive providers" has grown from six to ten countries.

F*or small companies*:

- Generous incentive providers – defined by B-indexes of less than 0.9 [Australia, Austria, Canada, Denmark (for basic research only), Italy, Korea, the Netherlands, Portugal, Spain and the United Kingdom].
- Moderate incentive providers – defined by B-indexes greater than 0.9 and less than 1.0 (France, Ireland, Japan, Mexico and the United States).
- Low incentive providers or non-incentive providers – countries with B-indexes greater than 1.0 (Belgium, Finland, Germany, Greece, Iceland, New Zealand, Norway, Sweden and Switzerland).

VI. CONCLUSION: WHAT DOES IT ALL MEAN?

Based on the above analysis, it can be noted that after the "lean" period of the early to mid-1990s, tax incentives for R&D are back in favour among governments. The number of countries applying tax credits or taxable income allowances has grown from 12 in 1996 to 16 in 1999-2000. Radically more countries are opting for allowances on taxable income as a way of providing tax incentives for R&D. In 1996, only Australia and, to a certain extent, Belgium and Denmark, had implemented such a mechanism. By 1999-2000, these countries were joined by Austria, Ireland and the United Kingdom.

Targeted support for small firms is also on the rise, as shown by the fact that the United Kingdom has initiated an R&D tax incentive for small businesses. This leads to the conclusion that competition among countries and regions for knowledge-based investment is – and will continue to be – fierce. National governments will need to carefully monitor international developments in order to be able to respond to changes in incentive packages in other countries.

It does not appear, however, that countries are selectively targeting specific industries or technology activities with their R&D tax incentives.[9] Thus, R&D tax incentives will probably continue to play the role of a market-based instrument rather than a direct subsidy.

Finally, in addition to national tax incentives, Canada and the United States both provide R&D tax incentives at the provincial/state level, with a growing number of provinces and states introducing their own R&D tax incentives.[10] It is expected that, in these and other countries, and particularly those with federal systems, the sharing of R&D tax incentives among the various tiers of government may increase in the future. This is, once again, a reflection of increasing competition among regions to attract knowledge-based investment.

Appendix 1

POSSIBLE EXTENSIONS TO THE B-INDEX: GRANTS, SUBSIDIES AND GOVERNMENT CONTRACTS

The B-index study covers indirect support of R&D through the tax system. However, other important incentives outside the tax system also need attention. The most common arrangements include subsidy and procurement systems that, together with the tax incentives, create an overall national R&D tax-subsidy system. R&D subsidies and tax incentives tend to complement each other: the former is a direct measure of government support, while the latter is an indirect measure working through the market mechanism. The evidence shows that countries with generous subsidy-procurement programmes tend to have less generous R&D tax incentive programmes (examples include the United States, Germany, Italy). Countries that provide a very attractive R&D tax treatment (Australia, Canada, the Netherlands), tend to complement it with a seemingly less generous R&D subsidy-procurement system (Lhuillery, 1995).

A subsidy is a payment for which government expects nothing directly in return. The B-index methodology can be extended to cover government R&D subsidies. Overall, subsidies will lower the B-index, thus making a subsidised R&D project relatively more attractive to the firm. The replacement of one dollar of private R&D expenditure with one dollar of subsidy reduces the after-tax cost of a one-dollar R&D project to zero. Since the B-index is expressed as the before-tax income required to cover a one-dollar R&D investment, a 100% cost subsidy will reduce the B-index to zero. In the case of a 50% subsidy, the R&D project's after-tax cost will be reduced by a half, thus allowing the B-index to fall by a half of its before-subsidy value.

In general, subsidies can be included in the B-index in a relatively straightforward manner. The generic formula for incorporating subsidies is as follows:

$$B^S = B(1 - P^S)$$

Where:

B^S = the B-index adjusted for the subsidy component

B = the unadjusted B-index (incorporating only the impact of R&D tax treatment)

P^S = the proportion of industrial R&D in a country covered by subsidies.

The B-index methodology works well for both R&D tax incentives and R&D subsidies. However, it is first necessary to obtain a reliable estimate of the proportion of industry-performed R&D covered by subsidies.

Because subsidies usually target specific industries, the use of an average measure of subsidy for the whole economy may be distorting. Taxability of subsidies is another issue, as some countries may treat some R&D subsidies as taxable income. Similarly, subsidies may be excluded from the base for R&D tax credits or related incentives. Therefore, a review of the appropriate tax laws applying in the OECD countries would be required in order to derive appropriate national B-indexes.

In addition to direct subsidies, many governments offer procurement contracts. A contract is not a direct subsidy; it represents a purchase by the government of R&D from the firm. The purchase price reflects the cost of conducting the R&D in terms of wages, materials and overheads. This does not constitute support in the same sense as an R&D subsidy. Contracts, however, may have a subsidy component to the extent that the R&D paid for by the government can generate income for the contractor. In other words, a subsidy will exist to the extent that there are spin-off benefits available to the contractor. The exact magnitude of the subsidy in the R&D contract remains an empirical question and is difficult to estimate. A review of the relevant literature on such estimates. followed by a sensitivity analysis of the impact of various estimates of the subsidy component on the country's B-index may be required. Once the appropriate estimates are obtained, the B-index methodology is fully applicable to measuring the impact of the R&D subsidy component of contracts.

Appendix 2

DEVELOPING THE B-INDEX FORMULAS

The first step in calculating the B-index is to determine the numerator – the present value of the after-tax cost (ATC) of a one-dollar expenditure on R&D. The next step is to determine the present value of the before-tax income required to cover the present value of a one-dollar outlay on R&D expenditures and to pay the applicable taxes. Thus, the generic formula for the B-index is as follows:

$B = (1 - uz)/(1 - u)$

Where:

$(1 - uz)$ = after-tax cost per dollar of R&D expenditure
z = present value of deductible R&D expenditures
u = corporate income tax rate.

In a world in which there are no taxes ($u = 0$), the value of the B-index will be 1. A firm would never find it profitable to undertake a project for which the present value of project-related income was less than the present value of project costs. No project with a benefit–cost ratio of less than 1 would be undertaken. In a world where taxes exist, however, the value of the B-index can still be 1, provided that all R&D expenditures are fully deductible in a current year ($z = 1$) and are taxed at the same rate. For example, if $u = 50\%$, then $B = (1 - 0.5)/(1 - 0.5)) = 1$.

The B-index will vary from 1 only when R&D expenditures are not fully deductible ($z<1$) or are more than fully deductible ($z > 1$), and/or where there exist allowances or tax credits for R&D that reduce the after-tax cost of an R&D project (that is, the after-tax cost of one dollar of expenditure on R&D). Below are some examples of allowances and credits applicable to this study.

R&D expenditures are partially deductible

If R&D expenditures are only partially deductible in the year incurred, then:

$B = (1 - uz)/(1 - u)$

Where: $z < 1$.

As a result, the present value of the before-tax income required to cover the cost of one dollar of R&D expenditures will be greater than 1; hence, the B-index is greater than 1 ($B > 1$). This result indicates the lower attractiveness of an R&D tax treatment compared with a full deductibility case.

When allowable deductions exceed expenditures and the excess deductions are not taxable, the B-index is a decreasing function of the tax rate; that is, the lower the tax rate, the higher the B-index. A lower tax rate makes R&D appear less rather than more attractive. This is because R&D expenditures are not only fully deductible but they also serve to reduce taxes that would have been paid on other income. The lower the corporate tax rate, the smaller the before-tax value of this tax saving. If, for example, a firm is allowed to deduct 125% of R&D costs when these costs are incurred and if the corporate tax rate is reduced from 50% to 40%, the B-index rises from .75 to (1 – 1.25(.4))/(1 – .4), or .83.

R&D tax credits

A tax credit will decrease the B-index and will usually result in a B-index that is less than 1. Tax credits can be applied on the level of a firm's R&D investment or on an increase in R&D expenditures over a specified R&D expenditure base.

Tax credits on the level of an R&D investment

If a tax credit equal to 10% of R&D expenditures is allowed in addition to a 100% write-off and if the corporate tax rate is 50%, the B-index is $(1 - z - .10)/(1 - u)$, or .80. Again, the B-index is a decreasing function of the tax rate. If the corporate tax rate were 40%, for example, the B-index would be .83. If, however, the amount of R&D expenditures that may be deducted is reduced by the amount of the credit (the credit is taxable), the B-index takes on a value of $(1 - u)(1 - .10)/(1 - u)$, or .90, regardless of the corporate tax rate. The lowering of the corporate tax rate reduces the marginal effect of a tax credit on the B-index, provided that the credit itself is not taxable. If the credit is taxable (deductions allowed are reduced by the amount of the credit), its marginal effect on the B-index will be independent of the corporate tax rate.

The generalised B-index formulas are:

Non-taxable tax credit:

$B = (1 - u - c)/(1 - u)$.

Where c = rate of tax credit.

Taxable tax credit:

$B = (1 - u - c(1 - u))/(1 - u)$.

Tax credits on increases in R&D nominal expenditures

Tax credits or special allowances based on increases in R&D spending over the same base year also reduce the B-index.

In order to obtain a more general measure of the impact of this type of incentive on the B-index, it is assumed that R&D expenditures will be maintained over time at a constant level in real terms. Under these circumstances, tax credits based on increases in nominal R&D spending over the previous period will represent the tax saving resulting from investing one dollar in R&D in year m less the present value of the tax saving foregone over the next n years as a consequence of investing in year m. The present value of the tax saving foregone will be smaller and the net value of the incentive will be greater, the longer the base period m and the greater the nominal discount rate r.

The formula for the incremental non-taxable tax credit is: $c(1/n)\ (1 - (1 + r) - n)$ and that for the tax credit which is taxable: $c(1 - u)((1/n)\ (1 - (1 + r)\text{-}n))$, where c = rate of tax credit.

The same formulas hold for calculating special allowances from the taxable income of a taxpayer.

Exhibit 1. **R&D tax treatment in OECD countries: major parameters, 1999-2000**

	B-index Large/SME	CIT rate %	Current deduction %	Depreciation – ME	Depreciation – B	Treatment of SME
Australia	0.890	36	100	3 years	40 years	
Austria	0.878	34	100	5 years	25 years	
Belgium	1.012/1.008	40.17	100	3 years	20 years	
Canada – fed.	0.827/0.678	32.12	100	100%	4%	CITR 23.1%
Denmark						
Ordinary	1.018			30%	20 years	
Basic research	0.871	34	100	100%	100%	
Finland	1.009	28	100	25%	20%	
France	0.915	40	100	40%	20 years	
Germany	1.041	51.5	100	30%	4%	
Greece	1.015	35	100	3 years	12.5 years	
Iceland	1.028	33	100	8.5 years	50 years	
Ireland	0.937	10	100	7 years	4%	
Italy	1.027/0.552	3	100	10 years	33 years	
Japan	0.981/0.937	48	100	18%	50 years	CITR 35%
Korea	0.918/0.837	30.	100	5 years	5 years	CITR 17.6%
Mexico	0.969	35	100	35% slm	20 years	
Netherlands	0.904/0.613	35	100	5 years	25 years	
New Zealand	1.131-1.023	33	22-100	22%	4%	
Norway	1.018	33	100	20%	5%	
Portugal	0.850	37.4	100	4 years	20 years	
Spain	0.687	35	100	100%	33 years	
Sweden	1.015	28	100	30%	25 years	
Switzerland (Zurich)	1.011	25.1	100	40%	8%	
United Kingdom	1.0/0.888	30	100	100%	100%	CITR 20%
United States Fed	0.934	35	100	5-year MACRS property	39-year property	

Exhibit 2. **R&D tax credits and R&D allowances in OECD countries: major characteristics, 1999-2000**

Country[1]	Rate on level %	Rate on increment	Base for increment[2]	Expense base[3]	Deducted from TI or CIT[4]	Taxable	Carryover (years)	Limits	Special treatment of SMEs
Australia	125			C, ME	TI	Yes	10	Floor AUD 20 thousand	
Austria	125	35	3 yrs	C	TI	Yes	5	No limit	
Inv. deduction	9			ME, B	TI	Yes			
Belgium	13.5			ME, B	TI	Yes	5	?	18.5%
Inv. deduction									
Canada	2			C, ME	CIT	Yes	No limit	Cap CAD 2 million SME R&D	35%; refund
Fed									
Denmark (Basic research)	125			C, ME, B	TI	Yes	5	none	
France		50	2 yrs	C, AME B	CIT	No	5	Cap FRF 40 million	Refund
Ireland		40	3 yrs	C	TI	Yes	?	IEP 25 000 - IEP 175 000	
Italy	30			C, ME, B	CIT	No	?	Cap ITL 500 million	Yes
SME									
Japan									
Regular		20	3 yrs	C, AMEB	CIT	No	5	10% of CIT	
Small business	6			C, ME	CIT	No	?	15% of CIT	Alternative to regular
Basic technology				ME	CIT	No	?	13% of CIT	
Co-op. R&D	6			C, ME, B	CIT	No	?	10% of CIT	
Korea									
Dev. of techn. and HR				C	CIT	No	?	none	15% applies
Alternative		50	2 yrs	C	CIT	No	?	none	
Facilities	5			ME	CIT	No	?	none	

Exhibit 2. **R&D tax credits and R&D allowances in OECD countries: major characteristics, 1999-2000** (*cont.*)

Country[1]	Rate on level %	Rate on increment	Base for increment[2]	Expense base[3]	Deducted from TI or CIT[4]	Taxable	Carryover (years)	Limits	Special treatment of SMEs
Mexico		20	3 yrs	C	CIT	No	yes	?	
Netherlands	12.5			Salaries	CIT	No	8	Cap NLG 10 million	40%
Inv. deduction	2			ME, B	TI	Yes			18%
Portugal	8	30	2 yrs	C	CIT	No	3	Cap PTE 50 million	
Spain	20	40	2 yrs	C, ME	CIT	No	3	35% of CIT	
United Kingdom SME	150			C	TI	Yes	?	Floor GBP 25 000	Available in 2000
United States Federal		20	Max. 50% of C	C	CIT	Yes	15	Amount of tax liability	Start-up credit base

1. Other OECD countries do not have tax credits or taxable income allowances.
2. Average over specified number of years.
3. C = current; ME = machinery and equipment; B = buildings; AMEB = amortisation of ME and B.
4. CIT = corporate income tax; TI = taxable income.

NOTES

1. The model is elaborated in Warda (1996). Most recently, the model has been used by Guellec and Van Pottelsberghe (2000), while a similar model was recently presented in Hall and Van Reenen (2000).
2. For a brief summary of research results in this area, see Salter *et al.* (2000), pp. 20-21.
3. For succinct overview of the different types of tax incentive, refer to Whitehouse (1996), pp. 67-69.
4. For more detailed information on the model, see McFetridge and Warda (1983) and Warda (1990), as well as more recent publications by Guellec and van Pottelsberghe, (2000) and Hall and Van Reenen (2000).
5. This is a standard hurdle rate used in other studies (Hall and Van Reenen, 2000, p. 468). The rate has been kept unchanged to ensure comparability over time of the B-index with previous B-index studies.
6. The author would like to express his gratitude to Gordon Lenjosek of the Department of Finance Canada, for his comments on this section.
7. The equation $Rg = (r - p + d)(1 - c)(1 - uz)/(1 - u)$ was chosen as the basic equation since investment tax credits (and grants) generally reduce the amount of expenditure available for capital cost allowance – the "stacking" of benefits is thereby avoided. If the tax credit is not taxable, the formula becomes $Rg = (r - i + d)(1 - uz - c)/(1 - u)$.
8. The exception is Belgium, which provides an allowance for investment in R&D but only on capital equipment. Thus the size of the incentive is small.
9. Japan and Denmark are minor exceptions.
10. In Canada, eight out of ten provinces and one territory (Yukon) provide their own R&D tax incentives. In the United States, most states offer some form of R&D tax incentive.

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