Catalogue no. 11F0027MIE — No. 032
ISSN: 1703-0404
ISBN: 0-662-40096-8

Research Paper

Economic Analysis (EA) Research Paper Series

Canada's Investments in Science and Innovation: Is the Existing Concept of Research and Development Sufficient?

by John R. Baldwin, Desmond Beckstead and Guy Gellatly

Micro-economic Analysis Division
18-F, R.H. Coats Building, Ottawa, K1A 0T6

Telephone: 1 800 263-1136

Statistics Canada Statistique Canada

Canada

Canada's Investments in Science and Innovation: Is the Existing Concept of Research and Development Sufficient?

by
John R. Baldwin, Desmond Beckstead and Guy Gellatly

11F0027MIE No. 032
ISSN: 1703-0404
ISBN: 0-662-40096-8

Micro-economic Analysis Division
18-F, R.H. Coats Building
Statistics Canada
Ottawa, ON K1A 0T6

How to obtain more information :
National inquiries line: 1 800 263-1136
E-Mail inquiries: infostats@statcan.ca

April 2005

The authors' names are listed alphabetically.

We acknowledge comments and suggestions by Erwin Diewert, Barbara Fraumeni, Fred Gault, and Mohammed Rafiquzzaman.

Published by authority of the Minister responsible for Statistics Canada

Aussi disponible en français

ECONOMIC ANALYSIS RESEARCH PAPER SERIES

The Economic Analysis Research Paper Series provides for the circulation of research conducted by the staff of National Accounts and Analytical Studies, visiting Fellows and academic associates. The research paper series is meant to stimulate discussion on a range of topics including the impact of the New Economy, productivity issues, firm profitability, technology usage, the effect of financing on firm growth, depreciation functions, the use of satellite accounts, savings rates, leasing, firm dynamics, hedonic estimations, diversification patterns, investment patterns, the differences in the performance of small and large, or domestic and multinational firms, and purchasing power parity estimates. Readers of the series are encouraged to contact the authors with comments, criticisms and suggestions.

The primary distribution medium for the papers is the Internet. These papers can be downloaded from the Internet at www.statcan.ca for free. Papers in the series are distributed to Statistics Canada Regional Offices and provincial statistical focal points.

All papers in the Economic Analysis Series go through institutional and peer review to ensure that they conform to Statistics Canada's mandate as a government statistical agency and adhere to generally accepted standards of good professional practice.

The papers in the series often include results derived from multivariate analysis or other statistical techniques. It should be recognized that the results of these analyses are subject to uncertainty in the reported estimates.

The level of uncertainty will depend on several factors: the nature of the functional form used in the multivariate analysis; the type of econometric technique employed; the appropriateness of the statistical assumptions embedded in the model or technique; the comprehensiveness of the variables included in the analysis; and the accuracy of the data that are utilized. The peer group review process is meant to ensure that the papers in the series have followed accepted standards to minimize problems in each of these areas.

Table of contents

Abstract

Estimates of GDP are sensitive to whether a business expenditure is treated as an investment or an intermediate input. Shifting an expenditure category from intermediate expenditures to investment expenditures increases GDP. While the international guide to measurement (the SNA (93)) recognizes that R&D has certain characteristics that make it more akin to an investment than an intermediate expenditure, it did not recommend that R&D be treated as an investment because of problems in finding a "clear criteria for delineating [R&D] from other activities".

This paper examines whether the use of the OECD Frascati definition is adequate for this purpose. It argues that it is too narrow and that attempts to modify the National Accounts would not be well served by its adoption. In particular, it argues that the appropriate concept of R&D that is required for the Accounts should incorporate a broad range of science-based innovation costs and that this broader R&D concept is amenable to measurement.

Finally, the paper argues that failing to move in the direction of an expanded definition of R&D capital will have consequences for comparisons of Canadian GDP to that of other countries—in particular, our largest trading partner, the United States. It would provide a biased estimate of Canada's GDP relative to the United States. If all science-based innovation expenditures are to be capitalized, GDP will increase. But it appears that Canada's innovation system is directed more towards non-R&D science-based expenditures than the innovation systems of many other countries. If Canada were to only capitalize the narrow Frascati definition of R&D expenditures and not a broader class of science-based innovation expenditures, we would significantly bias estimates of Canadian GDP relative to those for other countries, such as the United States, whose innovation systems concentrate more on traditional R&D expenditures.

Keywords: research and development, innovation costs, capitalization

Executive summary

As part of the current SNA (93) revision cycle, national accountants are contemplating making recommendations as to the desirability of capitalizing expenditures made on innovation capital that enhance production efficiency, much as software expenditures are currently treated. These expenditures are referred to in the SNA (93) as research and development expenditures.

The debate over the capitalization of R&D has focused on two issues—what the appropriate concept of R&D should be, and whether this R&D concept is amenable to measurement.

It is clear that there exists a widely-accepted definition of R&D, established by the OECD's Frascati manual. And statistics on R&D expenditures, collected in accordance with the Frascati manual, are published for a large number of countries as part of OECD's Main Science and Technology Indicators. At minimum, this generally-accepted definition provides a base from which cross-national comparisons of R&D performance can be undertaken.

But the existence of a set of estimates derived from the Frascati manual is not a sufficient condition for using this as an SNA (93) standard. To do so, we need to argue that the concept is reasonably exhaustive and that alternatives do not readily exist. In this paper, we argue that the R&D data collected in accordance with the Frascati definition will underestimate the total amount that domestic businesses spend on science-based innovation capital—especially in open economies, such as Canada's, where there is substantial trade in assets associated with the acquisition and use of intellectual property. There are two reasons why the Frascati definition may be insufficient for the purposes of the SNA (93). First, the data on R&D expenditures that are most commonly examined include only domestic intramural R&D expenditures, that is, expenditures resulting from transactions that occur entirely within the boundaries of a national economy. But Canada, in contrast to many other countries, buys a considerable amount of its R&D from abroad—as it does with much of its capital equipment. Second, the expenditures captured in official R&D data are relatively narrow for the purposes of the National Accounts. Economic statisticians have need of information on the set expenditures on science-based knowledge that contribute to the economy's stock of intellectual capital. Investments in R&D are an important subset of total expenditures on science-based innovation, but they are not the only means by which Canadian businesses invest in this type of intellectual capital.

More importantly, this paper also notes that extending the concept of R&D capital beyond its present Frascati-based definition is practical because data on many types of investments in science and innovation are already collected by official statistical agencies—not under the rubric of science and technology divisions, but rather by balance of payments collection programs and from population censuses that measure the wages of scientists. At present, balance of payments divisions collect substantial data on foreign payments for patents and other forms of intellectual property—with all the attendant definitions and collection experience. And population censuses collect data on the payments that are made to scientists outside of traditional R&D jobs. The evidence provided in this paper is that these payments are about twice the size of R&D expenditures.

While data exist that suggest the standard definition of R&D can be expanded, there is nevertheless need for further work before definitive estimates of the size of these science-based expenditures can be made. The balance of payments program collects data on the payments that domestic firms make to foreigners for intellectual capital. Estimates need to be developed for the payments that domestic firms make to other domestic firms for similar intellectual services. And if we are to use data on wages paid to all scientists, not just R&D scientists, to proxy investments in science and innovation capital, work needs to be done on defining the limits of who should be included in this group. The concept of expenditures on scientific activity outside of the traditional R&D area is in need of development. The National Accounts already makes use of these data to capitalize in-house software. While moving to a broader concept—from R&D personnel to a larger class of science workers—may challenge the Accounts, it is conceptually no different than what is presently being done in the area of software.

Finally, the paper argues that failing to move in the direction of an expanded definition of innovation capital would provide a biased estimate of Canada's GDP. If science-based expenditures are to be capitalized, GDP will increase. But it appears that Canada's innovation system is directed more towards non-R&D science-based expenditures than the innovation systems of many other countries. If Canada were to only capitalize R&D expenditures and not science-based innovation expenditures, we would significantly bias estimates of Canadian GDP relative to those for other countries, such as the United States, whose innovation systems concentrate more on traditional R&D expenditures.

1. Introduction

As part of the current SNA (93) revision cycle, national accountants are contemplating making recommendations as to the desirability of capitalizing expenditures that are made on knowledge capital that enhances production efficiency.

The 1993 System of National Accounts framework (SNA (93)), which provides guidelines for the measurement of GDP, wrestled with the appropriate treatment of a number of intermediate expenditures that provide long-lived benefits. National accountants had to make decisions on which expenditures should be considered as investments. Decisions on how to treat expenditures on machinery and equipment as investments were relatively easy to reach. But decisions were more difficult on the treatment of other expenditures, such as petroleum drilling, or software, or research and development (R&D). The SNA (93) recommended that the first two categories should be capitalized, but that R&D not be.

R&D expenditures develop new knowledge. R&D expenditures encompass "work directed towards the innovation, introduction, and improvement of products and processes" (Canadian Oxford Dictionary, 2001). They are an essential part of the process by which new products, services and processes are developed and commercialized. As such, R&D expenditures have long-lasting value within the economic system.

While the SNA (93) framework recognizes that R&D expenditures provide future benefits, and therefore constitute a type of investment, it raises several issues that need to be resolved before implementing a regime that treats R&D expenditures as investment rather than as intermediate inputs. The first is the establishment of clearly-definable criteria outlining what expenditures should be classed as R&D; the second is the specification of assets to be included according to these criteria; the third is to provide R&D valuations that are economically meaningful; and the fourth is the determination of the rate of depreciation to be applied to R&D investments.

This paper focuses primarily on the first issue—what boundaries should be used in defining R&D expenditures.

2. The issues

The debate over the capitalization of R&D has focused on two issues—what the appropriate concept of R&D should be, and whether this R&D concept is amenable to measurement.

It is clear that there exists a widely-accepted definition of R&D, established by the OECD's Frascati manual. According to the manual, "Research and experimental development comprise 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" (2002, p. 30). The OECD publishes R&D-to-GDP ratios in its Main Science and Technology Indicators as part of a 'scorecard' that is used to compare national innovation systems.[1] At minimum, this generally-accepted definition provides a base from which cross-national comparisons of R&D performance can be undertaken.

Central to this OECD exercise has been the development of international standards, codified in the OECD's Frascati manual, that allow for the harmonization of research and development statistics across different countries. As a result, a set of comparable estimates of R&D expenditures is available for a broad cross-section of countries (OECD, 2003).

But the existence of a set of estimates derived from the Frascati manual is not a sufficient condition for accepting this as the standard to be used in the SNA (93). To do so, we need to argue that the concept is reasonably exhaustive. This paper argues that it is not sufficiently exhaustive to be adopted for the purposes of the National Accounts.

While the Frascati manual provides an international R&D standard, the definition that is used to collect these statistics is relatively narrow and does not exhaust all the investment expenditures that support industrial innovation. There are two types of omissions.

First, it should be stressed that the expenditures considered by Frascati are basically those which are aimed at 'scientific' investigation. Other expenditures on education and training, administration and other supporting activities are excluded. This means that a substantial set of innovation-related expenditures, such as those made on marketing or improving worker skill sets, are excluded.

Second, the Frascati definition excludes many expenditures on scientific activities that have a long-lasting effect—primarily in the applied engineering area. The Statistics Canada definition of research and development, which has been adopted to meet the Frascati standard, includes all expenditures that support the systematic investigation in natural and engineering sciences undertaken to achieve scientific or commercial advances that are likely to be patentable (Statistics Canada, 1991, 2005). Frascati outlines the basic criteria for distinguishing R&D from other innovation expenditures as "an appreciable element of novelty and the resolution of scientific and/or technological uncertainty" (OECD, 2002: 34). A difference is drawn between what some refer to as early-stage expenditures on basic new knowledge and later-stage expenditures that facilitate the integration of innovations into working production systems.

In contrast, the SNA (1993, 6: 163) took a much broader view of what should be included in R&D. SNA (93) took the position that "research and development are undertaken with the objective of improving efficiency or productivity."[2] The OECD concept is narrower because it is restricted to activities that involve considerable uncertainty and have a degree of novelty that allows them to be 'patentable'. As Baldwin and Hanel (2003) point out, a relatively small percentage of all innovations fall into the patentable category, and thus the use of the Frascati definition will ignore part of the investment process related to scientific activity that generates productivity and efficiency improvements. The Frascati definition excludes a wide range of science-related expenditures that are needed to bring a new product or process to market.

1. Canada has set a national goal of improving its international R&D-to-GDP ranking (Canada, 2002).
2. It should be noted that the SNA (93) also recognized that there were productivity-enhancing expenditures outside the scientific area, but left a discussion of what might be done in this area to another time.

Efficiency gains result from both the early-stage expenditures that involve considerable uncertainty and the later-stage development expenditures, excluded by Frascati, that involve less uncertainty. Moreover, the effect of both lasts for several years and this qualifies them as investments and not intermediate expenditures.

The point that there are considerable scientific expenditures required for innovation that are outside of R&D has been made by others who have studied the innovation process. Mowery and Rosenberg (1989) stress that inventions are often the result of discoveries that are made in production and engineering departments. These discoveries are then turned over to research departments for a better understanding of the phenomenon so that they can be commercialized—in particular, so that products resulting from these discoveries can be mass produced. Once the research department has more fully investigated the science behind the invention, production and engineering departments are called upon to transform inventions into viable commercial products and processes. The contribution of production and engineering departments is critical to the overall success of the innovation process—and in many cases, involves path-breaking work.

Rosenberg (1976) has also emphasized the importance of engineering departments in innovations associated with the evolution of production processes—especially in industries producing standard materials or durable consumer goods. In these industries, operating conditions are difficult and economies of scale depend on maintenance of capacity in each part of an integrated system of processes. The breakdown of any segment threatens the integrity of the whole. As Rosenberg demonstrates, production-engineering facilities are used to identify technical imbalances and resolve bottlenecks that, in turn, allow for improvements in productivity.

It is clear that the Frascati manual provides clearly-definable criteria that are amenable to measurement, but it is narrow in concept for SNA (93) purposes. The issue, then, is whether the omissions are empirically important, and whether Frascati-based estimates can be extended in a meaningful way.

In what follows, we argue that these omissions are important. In the spirit of Frascati, we restrict ourselves just to expenditures on scientific effort and still argue that traditional R&D measures are too narrow for SNA (93) purposes in that they ignore substantial scientific expenditures outside the R&D process that are essential to the knowledge required for innovation. These expenditures include payments for technologies through licence agreements, payments for patents, and applied development work. While these expenditures may be at the tail end of the innovation process, in that they follow the early stage discovery process, they still account for a good portion of total innovation expenditures. And if the System of National Accounts is to properly treat ‘scientific expenditures’, then these engineering and technology expenditures need to be captured.

The paper also argues that the omitted categories are amenable to measurement. It argues that there are several routes that need to be explored for this purpose. The first is by making use of concepts that are already being successfully employed in innovation surveys. The second is by using measures and definitions employed in the balance of payments program that are currently used to measure the international trade in services. The third is by using population censuses to measure the expenditures on scientists outside of traditional R&D jobs.

The paper proceeds as follows. In the third section, we present evidence from innovation surveys on the size of scientific expenditures on the innovation process that are outside the normal measures of R&D. This section shows that these expenditures are at least twice as large as those on R&D. Section 4 examines a separate source of data that also shows that innovation expenditures are larger than those normally reported by those using just domestic R&D expenditures. This section reports on the increasingly international character of Canada's economy, and examines the expenditures that Canadian firms make to non-residents for a range of intellectual services. R&D-styled measures of innovation performance that form the basis for our empirical analysis are also discussed. We argue that the R&D data, as normally reported, will underestimate the total amount that domestic businesses spend on science-based innovation capital—especially in open economies, such as Canada's, where there is substantial trade in assets associated with the acquisition and use of intellectual property. Cross-national estimates of R&D performance that incorporate foreign sources of intellectual capital are presented. Section 5 provides a third set of data that can be used to assess the importance of scientific innovation expenditures outside of R&D. It examines the embodied contribution that specialized scientific workers make to the development of innovation capital, and includes basic tabulations on the stock of scientific workers in Canada and the United States. This section also discusses other specialized workforces that may warrant consideration in national accounting strategies designed to capitalize intangible investments. Concluding remarks are found in Section 6.

Several comments regarding our research design, and our accompanying use of terminology, are warranted. The first two methods of gauging the size of non-R&D investments focus on expenditure flows—expenditures that occur within some narrow time frame that effectively add to the existing stock of scientific and technical knowledge. Information on technology expenditures from innovation surveys—our first method—are generally measured over a two-to-three year time horizon, a window that innovation surveys use to develop cross-sectional representations of the innovation process. We refer to these expenditures interchangeably as both "scientific expenditures on innovation" or "non-R&D expenditures on innovation and technology". Similarly, the payments made to foreigners for a variety of specialized services—our second method—are annual expenditure flows collected by balance of payments programs. These are payments for intellectual capital that has already been created, and provide some measure of the value of these foreign-produced assets to domestic production processes. We generally refer to these as payments for "intellectual services". Our last method, estimates of scientific labour from population censes, differs from the first two in that it essentially captures a stock of scientific capital at a point in time, a cumulative measure of the embodied contribution that specialized, science-based workers make to national innovation systems. This stock of human capital is one general proxy for the level of "creative technology capacity" at work within the economy—one that encompasses both R&D and non-R&D activities. Accordingly, wage payments to this pool of specialized workers capture the flow of services that derive from scientific services. We use these labour and wage data to estimate the share of economic activity accounted for by "scientific innovation expenditures".

The point worth emphasizing is that these three methods are complementary—in that all reinforce the importance of investments in science, technology and innovation beyond what is traditionally regarded as R&D. And all are germane to the "efficiency and productivity gains" criterion set out by the SNA as a litmus test for identifying R&D activity. In our view, each lends credence to a more comprehensive R&D definition, one that is more conceptually suited to the National Accounts.

3. Expenditures on innovation and technology

If we are going to argue that the definition provided by the Frascati manual on R&D knowledge creation expenditures is not as comprehensive as that envisioned by the SNA (93), evidence of the size of the science-based expenditures that are omitted is required. This section examines one source of evidence: data from innovation surveys.

3.1 Survey-based information

Innovation surveys have been recently developed in order to investigate many aspects of the process that brings new inventions to market.[3] Amongst those is the importance of expenditures outside of R&D that are needed to bring an innovation to market. Many of these are traditional investments in machinery and equipment, while others pertain to expenditures that improve the technological capabilities of the firm but that not are captured by either machinery or equipment or by R&D. It is primarily this latter class of expenditures that is our focus here.

What are the types of investment categories covered in innovation surveys that fall into this latter technological category that we feel need to be considered to make the Frascati definitional framework more complete for SNA (93) purposes?

A first investment category includes those expenditures made on technological know-how that is embedded in process innovations. Process innovations require not only expenditures on plant and equipment but they also often require the purchase of technological know-how from third parties.

Statistics Canada’s 1993 Survey of Innovation and Advanced Technology determined that almost a third of large firms that reported a major innovation acquired new technology at the same time through a licensing agreement or other technology transfer agreements (Baldwin and Hanel, 2003, 353). These expenditures are outside of those made to acquire machinery and equipment. They entail development of the knowledge of systems.

Second, firms invest in the intellectual property of others through the purchase of patents and trademarks. Third, firms purchase specialist consulting services in order to adapt technologies to their production systems. Each of these constitutes an investment.

While it has not been the norm to collect comprehensive data on all of these expenditures on intellectual capital, empirical evidence exists for Canada that sheds light on the importance of non-R&D based investments.

3. For a description of the results from the 1993 Canadian innovation survey, see Baldwin and Hanel (2003).

Table 1. Importance of R&D versus technology (per cent of total investment)

	Science-based industries	Other industries
R&D	27	3
Technology	13	9
Market development	13	5
Training	8	3

Source: STC Survey of Operating and Financing Practices.

The first comes from a special survey of entrants conducted by Statistics Canada—the 1996 Survey of Operating and Financing Practices.[4] This was a survey that focused on all firms that entered goods or service industries in the early 1980s, and that survived through the early 1990s. Firms were asked to report the size of their investments in nine categories—R&D, technology acquisition and licences, market development, training, machinery and equipment, land and buildings, upgrades to land or machinery and equipment, acquiring other businesses, and other expenditures.

The results of the survey indicated that while substantial investments were made in R&D, even more substantial investments occurred elsewhere (Table 1). At least twice as many firms indicated that they invested in technology as indicated that they invested in R&D. The percentage of total investment that occurred in the first four 'non-traditional' categories is reported in Table 1 for two different groups of industries—those that are heavily R&D- intensive (in science-based industries) and those that are not.[5] In the majority of industries (i.e., non-science based industries), technology expenditures outside of machinery investments are twice as important as expenditures on R&D. Even in science-based industries, technology expenditures are half as large as R&D expenditures.

A second source of Canadian information on innovation expenditures comes from the 1993 Survey of Innovation and Advanced Technology.[6] In this survey, manufacturing firms were asked to report on their expenditures for their most important innovation. Innovation expenditures were broken down into basic research, applied research, acquisition of technology, development, manufacturing start-up and marketing start-up. The Frascati definition of R&D would include basic research and applied research, but only part of development because the latter includes a large portion that is not sufficiently novel or does not involve enough uncertainty to satisfy the Frascati definition. The distribution of innovation expenses for major innovations is reported in Table 2. These results are similar to those reported for science-based industries in Table 1 where expenditures on technology acquisition are about half as large as those for research and development. Of course, the results for new firms that were presented in Table 1 also indicate that technology investments are substantially more important outside of R&D-intensive industries, and hence, relatively more important in the economy as a whole.

4. See Johnson, Baldwin and Hinchley (1997).
5. For a discussion of this classification, see Baldwin and Johnson (1999).
6. More information on this survey can be found in Baldwin and Hanel (2003).

Table 2. Distribution of innovation costs (percent of total)

Basic research	8
Applied research	9
Acquisition of technology (e.g., patents, trademarks, licenses, specialist consulting services, disclosure of know-how)	10
Development (e.g., engineering, layout, design, prototype construction, pilot plant, acquisition of equipment)	30
Manufacturing start-up (e.g., engineering, tooling, plant arrangement, construction, equipment)	34
Marketing start-up	9

Source: STC Survey of Innovation and Advanced Technology.

This information demonstrates the importance to the innovation process of a range of technological expenditures outside of R&D. After expenditures are made at the level of basic and applied research, a considerable amount of 'engineering' is required to prepare inventions for commercialization. Some of this is included in R&D, but a substantial part is not. And, after development expenditures, other investments are required to start-up the production line.

An earlier pilot innovation survey, conducted for five Canadian industries,[7] finds broadly the same results (De Melto et al., 1980, p. 26). The expense categories used are basically the same, with the exception that technology acquisition is not a separate category and is therefore implicitly included in development. In the earlier Canadian innovation survey, basic and applied research accounted for about 10 percent of total expenditures, development for 32 percent and manufacturing start-up for about 55 percent. The development component is a little less important in the five industries that formed the basis for the earlier survey than in the more comprehensive sample that made up the 1993 innovation and technology survey. Nevertheless, the important point is that most development expenditures fall outside the categories of basic and applied research, where uncertainty is the operative definitional criterion, and into the development stage, which is partially an uncertain activity and partially just an applied implementation process.

Others have also examined the relative importance of the various expenditure components of the innovation process. Kamin et al. (1982) examine the Israeli case, comparing their results to earlier studies for the United States and Canada. They divide the process of technological innovation into four phases.[8] These are:

> Phase 1: Research and Development including laboratory prototype and basic pilot procedures or bench scale, but excluding any scale-up activities.

7. Telecommunications equipment, electrical industrial equipment, plastic compounds, nonferrous smelting, and petroleum refining.
8. For an alternate, six-phase description of the innovation process, see Mansfield (1988).

> Phase 2: Transition to industrial product or process including preparations of industrial production, industrial prototype, full scale pilot plant and scale-up activity.
>
> Phase 3: Design, construction and start-up of industrial production (excluding investment in production line equipment but including the alteration of existing product lines and tooling).
>
> Phase 4: Market penetration and establishing marketing infrastructure for the new product within or in addition to the firms' marketing establishment.

In a cross-country comparison of different studies, the authors note two difficulties. First, some studies include 'transition' stage expenditures in phase 2 that should legitimately be classified as R&D. Research includes expenditures of both a basic and applied nature. Basic research involves original investigations for the advancement of scientific knowledge not having specific commercial applications. But applied research has specific commercial applications and what is sometimes included in the transition stage is more appropriately put back one stage into the earlier R&D stage. Research and development involve expenditures on 1) very basic research 2) on applied research and 3) that part of the development stage that still involve substantial uncertainties. In phase 2—the transition—development expenditures, in contrast, include technical activities of a more routine nature concerned with translating research findings into new products and processes. This transition stage is not part of R&D.[9] Distinguishing between the R&D stage and the subsequent development phase or the transition to industrial production phase involves distinctions that are often grey. Use of the criterion that the expenditure must involve uncertainty does not resolve the problem. This classification problem serves to hamper comparability across studies. For example, a basic pilot plant that is built when considerable uncertainty still exists falls under the development phase and should be included as R&D, but scale-up models do not. It is noteworthy that many industrial processes do not lend themselves to clear conceptual distinctions as to where uncertainty stops and therefore clear distinctions between what innovation expenditures are included in R&D expenditures and what are not included is sometimes vague.

The second difference in the studies that the authors considered occurs with respect to the amount of investment expenditures in plant and equipment that are included as part of start-up costs. Some studies include all investments in plant and equipment that are required for production; others focus only on investments that are made as a result of innovation, and discount those that would have been made in any case.

After making corrections for differences in approaches, Kamin et al. (1982) provide evidence that non-R&D expenditures outside of capital investments are large for all three countries studied—accounting for about half of total innovation expenditures (excluding capital investments) (Table 3).

9. See National Science Foundation (1972) and OECD, 1994 (Frascati Manual, 1993).

Table 3. Distribution of innovation costs (%)

	Israel	U.S. (Mansfield)	Canada
R&D	41	46	46
Transition to industrial production	43	43	50
Marketing	16	16	4

Source: Kamin et al. (1982).

Additional information on the importance of non-R&D costs in the innovation process is available from innovation surveys that were conducted in the early 1990s for the European Commission. Not all countries that conducted the survey asked for information on innovation costs in the original round of surveys that were conducted in the early 1990s, but data are available for a large collection of European countries, and individually for Germany, Italy, Denmark and the Netherlands (Evangelista et al., 1997a). In Table 4, innovation costs taken from the European surveys are broken down into three major categories—investment in plant, machinery and equipment, R&D and non-R&D. The latter include trial production, product design, market analysis, and licences/patents. In keeping with the findings reported above, the non-R&D investments are generally at least as large as R&D. R&D captures only about half of the investments that are required for innovation outside of machinery and equipment.[10]

Table 4. Distribution of innovation costs (%)

	All[1]	Germany	Italy	Denmark	Netherlands
Investment[2]	50	42	55	35	52
R&D	20	20	20	27	22
Non-R&D	30	38	25	38	26

[1] Belgium, Denmark, Germany, Ireland, Italy, Luxembourg, Norway, Spain, and the Netherlands.

[2] Total capital expenditures on plant, machinery and equipment in 1992 linked to new product innovation.

Source: Evangelista, Sandven, Sirilli and Smith (1997a).

A large number of other studies have found that non-R&D technology expenditures are important.[11] Corrado, Hulten and Sichel (2004) examine the size of intangibles. Their set of intangibles includes "computerized information, scientific and creative property and economic competencies". The second category includes a component which they term "nonscientific R&D" that incorporates "the scientific knowledge embedded in patents, licenses and general know-how (not patented) and the innovative and artistic content in commercial copyrights, licenses, and designs" (p.18). The authors conclude that spending on "scientific and creative/innovative property"…"was at least as large as scientific R&D spending in the 1990s".

All of these studies suggest that if we are going to measure the importance of a more general class of knowledge-based expenditures, we will need to look beyond the limits of the Frascati definition. We either require more data on the innovation expenditure process from the Innovation Surveys that are being done, or we must look for other sources that already exist. One existing source that yields some insights into the issues being investigated here is the Balance of Payments programs of most statistical agencies. It is to this data source that we now turn.

10. Italian innovation expenditures are well documented—Evangelista et al. (1997b), Archibugi et al. (1995).

11. The composition of innovation costs has also been the focus of detailed case studies—Mansfield (1988), Mansfield (1989).

4. Purchases of foreign intellectual services

While there are no comprehensive Canadian data on total business expenditures for intellectual capital that are created by investments in scientific knowledge, data on the expenditures of Canadian firms that flow to other countries are available from the Canadian balance of payments.[12] These data once more emphasize that innovation expenditures consist of more than just R&D.

Canada has an open economy. It not only imports goods and services but it also trades in services that are critical to innovation and growth. By examining the importance of these flows, and by comparing them to the size of the expenditures made on foreign and domestic R&D (as defined by the Frascati manual), we can determine the extent to which these other categories are marginal, and therefore might be ignored when revising the SNA (93) guidelines for capitalizing R&D-type expenditures.

In what follows, we focus specifically on the payments that Canadian firms made to foreign businesses for a range of intellectual services during the 1990s—years during which cross-border transactions assumed an increasingly important role in the Canadian economy following the Free Trade Agreement between Canada and the United States and the North American Free Trade Agreement between Canada, Mexico and the United States. We incorporate these foreign payments for intellectual capital into standard, cross-national comparisons of R&D-intensity, of the sort often used by policy makers to evaluate differences in the efficacy of national innovation systems. The basic question that guides our analysis is:

How do the payments that Canadian firms make abroad for non-R&D expenditures on intellectual services compare with their domestic expenditures on research and development?

To answer this question, we evaluate the degree to which standard indicators of innovation intensity, such as domestic R&D-to-GDP ratios, understate the amount of intellectual capital utilized (purchased or developed) by Canadian firms. We offer an investment profile that brings together the payments that Canadian businesses made to foreigners for different intellectual services—research and development services, royalties and license fees, computer services and information services. This illustrates the direct role that foreign-produced intellectual assets play in Canada's national innovation system.

4.1 Internationalization of Canada's economy

There are number of reasons why payments made abroad for intellectual services represent important inputs into Canada's innovation system. The Canadian economy is relatively open. Exports and imports are large relative to the Gross Domestic Product (GDP). And since the implementation of the Canada-U.S. Free Trade Agreement and the North American Free Trade Agreement, Canada's economy has become more outwardly oriented—as evidenced by sharp gains in the volume of total trade.

12. The R&D program also provides data on the technological balance of payments—but it is less comprehensive than the data provided by the Balance of Payments Division with National Accounts.

From 1992 to 1999, goods exports, measured as a percentage of GDP, increased by 7.0% annually; service exports, by 5.9%. Imports-to-GDP ratios also rose significantly, averaging 6.1% for goods and 2.0% for services. Increasing globalization is also apparent from patterns of cross-border investment. While Canada's domestic investment-to-GDP ratio[13] increased only modestly during the 1992-97 period, foreign direct investment (FDI) in the Canadian economy, a measure of the monetary flows generated through the acquisition and control of Canadian assets, increased dramatically. From 1992 to 1999, FDI, as a percentage of GDP, grew by 3.9% annually.[14]

This era of trade liberalization has witnessed considerable plant-level restructuring within traditional manufacturing industries. Using establishment-level panel data, Baldwin, Beckstead and Caves (2001) found that Canadian manufacturing plants that increased their export intensity in the post-FTA period also placed more emphasis on specializing their product lines. Export-orientated firms reacted to new competitive pressures by concentrating on their core business activities. This process of competitive restructuring was particularly apparent in foreign-owned plants. The openness of the Canadian economy to foreign direct investment led to distinct productivity gains in the foreign sector—partially as a result of the importation of foreign technology and business methods. Baldwin and Brown (2003) also found that the move towards freer trade has affected the structure of Canada's regional economies. Regions with a strong export orientation tend to be more specialized, and increases in export intensity have generally been associated with further specialization.

Globalization has also played a major part in the process of high-tech growth that, in many ways, defined the domestic business climate in the 1990s. Long-run annual growth rates in investments in technological assets (computers, software and telecommunications equipment) have been dramatic, averaging 16.2% per annum over the 1981-2000 period (Armstrong et al., 2003). The technological restructuring and efficiency gains that result from these investments are one important factor contributing to the Canadian economy's productivity resurgence in the post-1995 period.

What is notable is the extent to which inflows of foreign technological products have contributed to high-tech growth within Canada's business sector. Information and communications industries benefited substantially from trade liberalization. In the late 1980s, Canadian ICT manufacturers exported less than 50% of their total output. By the late 1990s, their export-to-output ratio rose to 75% (Beckstead and Gellatly, 2003). But the Canadian economy, on balance, relies extensively on foreign technology inflows—evidenced by a growing trade deficit in technology and science-based goods during the 1990s (Beckstead and Gellatly, 2003). This contrasts with more traditional industries in which Canada enjoys a large trade surplus.

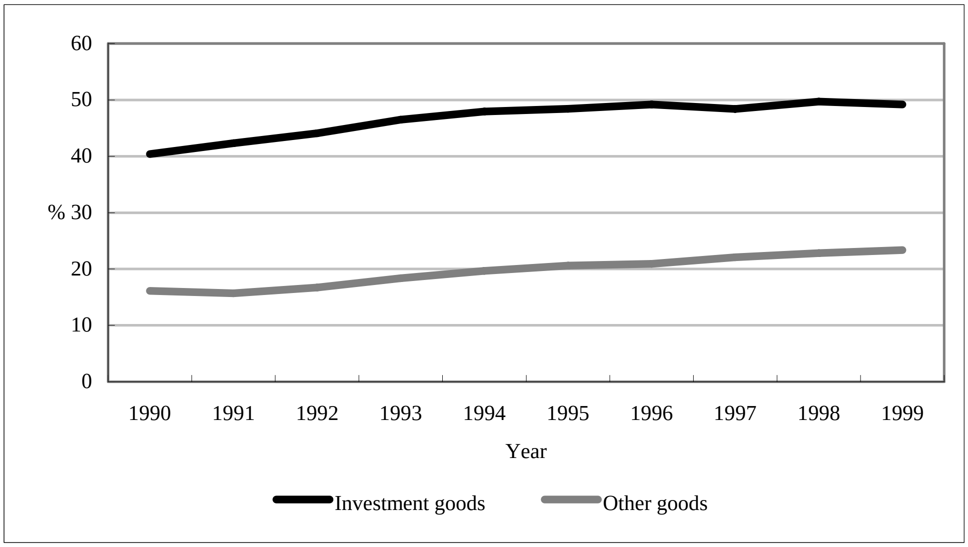
Canada's trade is specialized in different areas. High-tech goods are not the only area in which imports play a significant role. Investment in machinery and equipment is also made up of a substantial proportion of imports. Between 1990 and 1999, the import ratio for investment

13. These reflect domestic expenditures on machinery and equipment and structures.

14. Note that during this period the direct investments that Canadian businesses made abroad increased at an even faster pace (9.2% annually).

goods[15] increased from 40% to 49%.[16] In contrast, imports were much less important for non-investment goods, with the import ratio increasing from 16% to 23% over the same period (Figure 1).

Figure 1. Import share of final demand



All this underscores the fact that international transactions are an important aspect of Canada's economic system. Moreover, Canada tends to buy a large percentage of its capital goods from abroad. Despite the importance of imports of high-tech equipment, the debate on the importance of R&D generally ignores the international dimension of trade in R&D—and how much scientific knowledge capital is acquired in Canada through imports.

The following section examines the important role that international trade plays in Canada's use of intellectual services. It demonstrates that, in a climate of increasing openness and specialization, payments for these technological services are important inputs into Canada's domestic innovation system.

4.2 R&D, technology and competitiveness: some conceptual issues

National R&D statistics are widely used to evaluate the propensity of major economies to develop and commercialize scientific and technological knowledge. Statistical indicators of R&D intensity, such as the GERD-to-GDP ratio and the BERD-to-GDP ratio, are closely bound to perceptions of national competitiveness. GERD denotes gross domestic expenditure on research and experimental development, and "covers all R&D carried out on national territory in the year concerned" (OECD, 2002: 3). The BERD is a more restrictive measure, and includes

15. Investment goods are defined as furniture, agricultural machinery, industrial machinery, office machines, automobiles, trucks, other transportation equipment, telecommunication equipment and other machinery and equipment.
16. The import ratio is defined as machinery and equipment imports divided by the final domestic demand for machinery and equipment (the sum of consumption, investment, government expenditures and imports, less exports and re-exports).

only the subset of domestic R&D expenditures that occur in the Business Enterprise Sector. These are ratios that inform industrial policies and the ratios used for this purpose rarely take into account the international trade in R&D.[17]

The contribution of domestic R&D expenditures to firm performance is well established. Recent studies from Canadian business surveys have found that SMEs that make significant investments in R&D are more likely to outperform their competitors across a range of performance categories, including growth in market share, productivity and profitability (see Baldwin and Gellatly, 2003). Among Canadian manufacturing firms, R&D expenditures are highly correlated with the rate at which firms commercialize new products and services.

While traditional R&D statistics are useful barometers of innovation performance, they are not without limitations.[18] Two issues of direct relevance to the current analysis are noted below.

First, in this era of integrated global markets, R&D strategies are becoming increasingly international in scope. Many multinational firms are locating their R&D activities outside of their home countries. Consequently, “foreign funded” and “foreign-performed” R&D now represent important elements of “national” innovation systems. As Niosi (1999) notes, new research in academic circles and in statistical agencies has begun to explore the factors that are associated with the internationalization of R&D systems.[19] To focus solely on the R&D performed within national borders, as the GERD/GDP ratio does, is to discount the benefits that firms derive from foreign-based R&D strategies.

Second, many official R&D statistics center on intramural R&D expenditures—expenditures that derive from the “in-house” R&D activities that firms perform. As we argue herein, firms invest in knowledge creation in numerous ways, many of which are well beyond the boundaries of traditional R&D programs. Even when focusing specifically on R&D inputs, research has examined why many firms eschew just internal R&D activities in favour of extramural strategies wherein firms purchase R&D services from other firms.[20]

Some discussion of this literature is warranted here to bring the importance of external R&D expenditures into focus. There exist several factors that, in theory, can be expected to influence a firm’s choice of R&D mode. These include (1) the transaction costs associated with different R&D strategies, and (2) the array of business-specific capabilities (technological and organizational) that determine a firm’s ability to commercialize new knowledge.[21] Transaction costs have received much attention in the literature (e.g., Mowery, 1983) and center on “the costs involved in managing internal R&D versus those incurred in engaging in contractual research agreements with other parties” (Love and Roper, 2002: 243). Mowery and Rosenberg (1989)

17. Canada’s recent experience in this regard is discussed in Lonmo and Anderson (2003).
18. A full treatment of these limitations is beyond our scope here—for background discussion, see Mowery and Rosenberg (1989), Kleinknecht (1987, 1989), Baldwin and Hanel (2003), and Baldwin and Gellatly (2003).
19. For an overview of the state of current research on foreign-based R&D strategies, see Niosi (1999).
20. Love and Roper (2002) argue that extramural expenditures should not be regarded as “a trivial issue”. Based on 1993 statistics for U.K. manufacturing, the authors note that 12% of R&D expenditures were extramural.
21. Useful summaries of both theoretical perspectives are found in Odagiri (2003).

have stressed that it is codifiable research whose results can more easily be transferred back inside the firm from the outside R&D-performing entity.

Central to the evaluation of whether external R&D strategies will be adopted are the appropriability problems that arise when firms share knowledge of new innovations with outside partners.[22] Accordingly, contractual arrangements for R&D are often difficult to establish—a reflection of the complexities and uncertainties that characterize R&D outcomes. As Odagiri (2003) notes, the choice of R&D mode thus derives from an "appropriate organizational design": firms are more likely to opt for external procurement strategies in situations where "incentives can be enhanced with market competition" (p.190).

Capability theory provides an alternative vantage point for evaluating R&D decisions. This theory stresses the heterogeneous nature of competing firms—competitors will exhibit markedly different competencies when it comes to developing and nurturing intangible assets such as R&D.[23] Firms with fewer innovative capabilities[24] may choose to outsource their R&D function to more capable firms, providing that the transaction costs that characterize inter-firm collaboration do not overshadow the expected benefits to the contracting firm (Odagiri, 2003). Baldwin and Hanel (2003) stress the fact that the population of Canadian firms has varying innovative competencies—with some developing internal capabilities—and others making more use of outside resources—but that almost all firms combine both internal and outside sources of information for innovation.

The point worth stressing in the current context is that there are well established reasons behind a firm's decision to opt for external R&D and technology strategies over in-house programs—and there are many situations where the former constitute sizable contributions to the innovation process.[25] Audretsch, Menkveld and Thurik (1996) and Love and Roper (2002) have investigated factors that, in practice, condition the choice between internal and external R&D. Love and Roper found that, among UK manufacturing plants, R&D choice is influenced by variables related to market structure (e.g., industry concentration and minimum efficient scale), and, in general, depends less on plant-level characteristics (e.g., skill of workforce, type of production). Audretsch, Menkveld and Thurik found a stronger association between firm-level factors and R&D choice. The authors demonstrate that external R&D activities are more common among firms that possess relatively low levels of skilled labour. Accordingly, businesses with a high incidence of human capital may benefit less from external R&D arrangements—which appears consistent with the basic tenets of capability theory. The authors also found that firms with

22. These issues are discussed in Audretsch, Menkveld and Thurik (1996) and Odagiri (2003).
23. Data from recent large-scale business surveys have provided a much clearer picture of the extent to which business models are heterogeneous and give rise to different market outcomes; for an examination of Canadian evidence, see Baldwin and Gellatly (2003).
24. Notions of "less capable" need not focus around the set of firm competencies that are essential for R&D (e.g., skilled labour). As Love and Roper (2002) note, basic scale issues also come to the fore, as external strategies allow firms to overcome "the limitations of in-house R&D budgets (and gain) access to the economies of scale and scope available to specialist research organizations" (p. 240). See also Odagiri (2003).
25. Some have reported evidence to this effect: Jones (2000) noted that the ratio of external to internal R&D expenditures in the UK increased from 5% in 1989 to 16% in 1995. Love and Roper (2002) report that 12% of UK R&D spending was extramural, and that the relative importance of extramural expenditures varied substantially from sector-to-sector.

higher capital intensities—and hence larger scale, more standardized production systems—are more likely to engage in external R&D. Accordingly, these capital intensive environments may serve to reduce the risks of appropriation that characterize shared R&D arrangements. For Canada, Baldwin and Hanel (2003) found that firms that were larger, foreign controlled, and in the most innovative industries were likely to combine internal with external R&D sources to support their innovation activities.

A major finding to emerge from empirical research on R&D modes is that, in practice, internal and external R&D activities are often complementary—especially in knowledge-based environments. Audretsch, Menkveld and Thurick (1996) found that internal and external R&D strategies serve as complements (substitutes) in high-technology (low-technology) industries. Veugelers (1997) observed in a cross-section of R&D-based firms that external R&D strategies (collaboration and outsourcing) can actually serve to bolster internal efforts in companies that possess R&D competencies. Kaiser (2002) found similar results for German service firms. Nicholls-Nixon and Woo (2003) find that, among U.S. biotechnology ventures, the choice of R&D mode has implications for the types of business competencies that are developed. Ventures that make more use of licenses and R&D contracts tend to develop stronger reputations for biotechnology expertise. Baldwin and Hanel (2003) note that firms with internal R&D capabilities are more likely to make use of external R&D sources as well.

Applied research on the choice of R&D mode informs the scope of activities that should be included when developing statistical indicators of R&D performance. Ignoring external programs biases summary statistics on R&D intensity. Extramural R&D practices are recognized as an important mechanism by which firms acquire knowledge-based capital. In terms of innovation accounting, these acquisition strategies should not be regarded ex ante as peripheral activities. And as R&D systems become increasingly international in character, many of these acquisition strategies can be expected to take the form of cross-border transactions. Baldwin and Hanel (2003) point out that while multinational firms operating in Canada perform R&D as often as domestic firms do, they also make considerable use of information that is supplied by affiliated companies abroad.

Extramural strategies also bring other issues to the fore—if one accepts the basic proposition that acquired R&D are legitimate inputs into innovation systems. There is a close relationship between the payments made for R&D services and expenditures on technology acquisition. As Guellec and van Pottelsberghe de la Potterie (2001) note: "(f)oreign business R&D is partly paid for by domestic users, in the form of international payments for technology transfers (patents, licences and know-how contracts)." Technology purchases represent, in effect, one form of procured R&D (Odagiri, 2003). And these transactions often deliver more certain outcomes to the contracting party than do other R&D-based transactions.[26] Technology strategies are often multidimensional—as firms tend to rely on both internal and external sources. An industry-level analysis of the relationship between foreign technology inflows and R&D in the Canadian manufacturing sector by Mohnen and Lépine (1991) concluded that, in the main, payments for foreign technology and domestic R&D are complementary. Using Community Innovation

26. As Odagiri (2003, p. 191) notes, in the case of technology acquisition "(t)he technology to be traded has been already invented and patented before the contract is made for the transaction: hence the object of the contract can be clearly defined."

Survey (CIS) data on Belgian manufacturing companies, Veugelers and Cassiman (1999) found that make and buy technology strategies are complementary, particularly among large firms. In their study, firms purchased technology through a variety of methods—including licensing agreements, R&D contracts, business acquisition, consultancy agreements, and hiring skilled employees.

4.3 Balance of payments data on trade in intellectual property services

In this section, we concentrate on quantifying several major foreign inputs to Canada's innovation system. We examine the extent to which Canadian firms purchase R&D services from abroad, along with other types of (foreign-based) intellectual services.

Four basic categories of knowledge-based services that are captured in the Canadian balance-of-payments accounts are examined.[27] These are:

1) R&D services, which covers payments for basic and applied research and experimental development of new products and processes;
2) royalties and license fees, which cover payments for the use of intangible, non-produced, non-financial assets and proprietary rights (such as patents, copyrights, trademarks, industrial processes, franchises, etc.) and with the use, through licensing agreements, of produced originals or prototypes (such as manuscripts and films);
3) computer services, which include payments for hardware and software consultancy; provision of advice and assistance on matters related to the management of computer resources; analysis, design and programming of systems ready to use; technical consultancy related to software; development, supply and documentation of customized software; maintenance of other support services such as training; and
4) information services, which include payments for database services; database conception; data storage and data dissemination on-line and on magnetic media; news agency services.

Each of these services involves expenditures that have an investment component. The reason that expenditures on research and development as well as royalties and license fees fall into this category is self-evident. Payments for the majority of computer and information services can also be regarded as investment, though there may be some payments (news agency services) that are more in the vein of expenditures on intermediate services. These categories, starting with R&D, consist of a set of progressively broader spectrum of intellectual services. They all possess an investment component. They are not meant to be exhaustive of all such payments but they do capture a variety of intangible investments that are (quantitatively and conceptually) important to the innovation process and amenable to measurement. We examine all four components in turn, without issuing any opinions on whether some of the categories are more worthy for inclusion than others.

27. For full definitions and/or discussion of these service categories, beyond that reproduced here, consult OECD/Eurostat (2003).

In what follows, we adjust a standard proxy for (domestic) R&D intensity, the BERD-to-GDP ratio, to include the payments that domestic firms make abroad for these intellectual services. In doing so, we are implicitly treating both as flows of investments that can be combined together.[28] Our empirical results are based on two OECD public datafiles: the OECD Statistics on International Trade in Services (TIS) database and the Main Science and Technology Indicators (MSTI) database. We make use of the BERD-to-GDP framework despite its limitations, not because we are trying to rank Canada's performance relative to other countries—rather, we are trying to ascertain what percentage of GDP is presently being spent on activities related to knowledge creation that might be classed as investments rather than as intermediate inputs.

The payments that Canadian firms made for intellectual services during the 1990s are reported in Table 5. From 1992 to 1999, annual expenditures on intellectual services grew by 13.9%, compared to an average of 7.1% for all services. Payments for intellectual services accounted for 8.4% of total service payments in 1992; by 1999, they represented 13.0% of service payments.

The majority of these payments are for royalties and license fees (63.3% of intellectual services in 1999) and R&D services (20.2% in 1999). Both of these categories experienced strong growth in the 1990s. From 1992 to 1999, payments for royalties and license fees, bolstered by sharp gains in the acquisition of patents and industrial designs, increased by 13.3%. Expenditures on R&D services purchased from abroad grew by 16.3%.

These payments for intellectual services have an appreciable impact on the volume of knowledge capital services utilized by domestic firms. In 1999, domestic expenditures on business sector R&D stood at $10.2 billion. But firms in Canada spent another $1.6 billion on foreign R&D services. An autarchic emphasis on only domestic expenditures would underestimate the importance of R&D available to the domestic economy by some 14%. Taking into account payments for other intellectual services increases total investment in this area by over $7.8 billion—some 76% more than if just domestic expenditures on R&D were regarded as investment.

To put this differently, domestic R&D-to-GDP ratios underestimate the importance of the services of knowledge capital being used in Canada. In 1999, Canadian businesses recorded a BERD-to-GDP ratio of 1.06. When the payments that Canadian firms made for R&D services are included along with domestic R&D expenditures, this ratio increases by 15% to 1.22 (Table 6). When payments for royalties and license fees are included with total R&D expenditures (domestic and foreign purchased), the original BERD ratio (in 1999) increases by 64% to 1.74. Adding in all payments for intellectual property increases the ratio in 1999 to 1.87, or by 76%.

28. It is possible that foreign payments are really payments for services and should be compared to the flow of services from the domestic R&D capital stock. Unfortunately, we lack data on the nature of these foreign payments that allow us to determine the extent to which these foreign payments are investments or for capital services. For a discussion of these issues, see the appendix.

Table 5. Canada’s payments for intellectual services (millions of $ CDN)

	1992	1993	1994	1995	1996	1997	1998	1999	Growth rate
Total services	37,245	41,840	44,413	45,933	48,961	52,619	56,549	60,191	7.1%
Payments for intellectual services:	3,145	3,310	3,864	4,123	4,146	5,140	6,411	7,822	13.9%
(1) R&D services	549	615	769	861	767	962	1,276	1,577	16.3%
(2) Royalties and license fees	2070	2175	2409	2,584	2,659	3,224	4,024	4,951	13.3%
Franchises and similar rights:	410	464	548	628	640	730	811	831	10.6%
Trademarks	298	332	427	513	510	611	647	653	11.9%
Franchises	112	132	121	116	130	119	165	179	6.9%
Other royalties and license fees:	1,661	1,711	1,860	1,955	2,019	2,494	3,213	4,119	13.9%
Patents and industrial design	850	877	958	1,002	933	1,093	1,551	2,333	15.5%
Copyrights and related rights	175	179	260	212	275	353	433	408	12.9%
Software and other royalties	636	655	643	741	811	1,048	1,229	1,378	11.7%
(3) Computer services	421	382	526	496	510	595	730	842	10.4%
(4) Information services	105	138	160	182	210	359	381	452	23.2%
Domestic expenditures on business R&D	5,742	6,424	7,567	7,991	7,997	8,744	9,676	10,228	8.6%

Note: Data on intellectual services comes from Statistics Canada (2001a) and differs slightly from the OECD numbers published in the 2001 edition of the OECD Statistics on International Trade in Services.
Data on domestic R&D expenditures comes from the OECD’s 2003-1 MSTI Database.
Numbers may not add due to rounding.

Table 6. Intellectual investments to GDP ratios, 1992 and 1999

	Ratio in 1992 (1)	Ratio in 1999 (2)	Percentage increase in ratio (3)
(1) Domestic R&D (BERD)	0.83	1.06	28%
(2) Domestic R&D and payments for foreign R&D services	0.91	1.22	35%
(3) All R&D (domestic and foreign payments) and royalties and license fees	1.21	1.74	44%
(4) All R&D, royalties and licence fees, computer and information services	1.29	1.87	46%

Note: Data on intellectual services come from the Statistics Canada's balance of payments database used in Table 5.
Source: Data on domestic R&D and GDP come from the OECD's 2003-1 MSTI database.

Foreign payments for intellectual services will also affect growth in the BERD ratio over time, as each of the four main service categories (R&D services, royalties and license fees, computer services and information services) grew faster than domestic R&D expenditures. Column 3 in Table 6 examines the change in these ratios, when progressively broader definitions of intellectual capital are used. Moving from domestic R&D expenditures to a more comprehensive R&D measure (domestic expenditures plus payments for foreign services) increases the rate of growth in the BERD ratio over the 1992 to 1999 period from 28% to 35%. One quarter of this growth is due to the foreign R&D component.

Adding in payments for royalties and license fees results in a 44% gain in the BERD ratio—where one-half of the growth over the 1992 to 1999 period comes from payments for R&D services and royalties and license fees.

These results confirm our priors that are based on the extent of Canada's integration into the world economy: foreign payments for intellectual services are not trivial when compared to domestic R&D expenditures. And these payments have been increasing in importance. In 1992, the ratio of payments for foreign R&D services to domestic R&D expenditures stood at 0.10; by 1999, this ratio increased to 0.15. Similarly, payments for royalties and license fees expressed as a ratio of domestic R&D stood at 0.36 in 1992 and 0.48 in 1999.

All this emphasizes that it is important to take into account the acquisitions of foreign intellectual services; these expenditures are large, and they have been increasing in importance. It also suggests that it may be quite important to consider the totality of both domestic and foreign expenditures when comparing the innovation intensity of different countries—especially if the reliance of foreign intellectual services differs significantly from country-to-country.

4.4 Canada's innovation expenditures in an international context

In this section, we compare Canada's experience to other countries. We are interested not only in knowing whether investments in innovation outside the narrowly defined domestic R&D ratios are high, but also in knowing whether a focus on alternate metrics changes the nature of cross-country comparisons. If it does, then statisticians have a second reason for treading cautiously in calculating the amount of capital or capital services that are used in different economies.

Our focus is on the size of the payments that are made internationally for the acquisition and use of knowledge capital. The issue is the extent to which these payments matter more for Canada than for other countries. If they do, a focus just on domestic R&D expenditures will understate the amount of R&D that is being used in the production process in Canada relative to other countries.

Our sample consists of countries where data on international payments for knowledge services are readily attainable—Sweden, Finland, United States, Germany, France, Canada, and Italy.

Our research design for conducting cross-country comparisons is to evaluate progressively broader definitions of intellectual capital within a BERD-to-GDP framework. Estimates for 1999 are reported in Table 7. The first column reports standard domestic BERD-to-GDP ratios. We then consider payments for R&D services (column 2), payments for royalties and licence fees (column 3), these two payments together (column 4), and finally payments for R&D, royalties and license fees, and computer and information services (column 5).

Countries in our sample are ranked based on their 1999 domestic BERD-to-GDP ratios that are calculated from the standard data that consider only intramural R&D expenditures. Our sample includes several countries with the highest BERD ratios (column 2) in the OECD population. Sweden, Finland, and the U.S. have domestic BERD ratios of roughly 2.0 or more. Germany and France occupy the middle ground of the sample, with BERD-to-GDP ratios of 1.70 and 1.38%, respectively. Canada has business expenditures on R&D amounting to just over one percent of GDP. Italy is last with a ratio of just 0.51%.

Canada, however, fares much better with regards to its expenditures on foreign sources of intellectual capital. Canada, Finland, Germany and Sweden all spend between 0.16% and 0.20% of GDP on foreign R&D services. France, Italy, and the United States spend relatively little on foreign R&D services.

Canada and Sweden also lead the way in terms of their payments to foreign trading partners for royalties and license fees. These expenditures amount to almost 0.5% of GDP in both countries. Once again, the United States, France and Italy spend the least in this area.

When we consider foreign payments for R&D services and royalties and licence fees together (column 4), Canada and Sweden together top the list—at 0.7% of GDP. The United States is last in our sample with these payments amounting to about 0.15% of their GDP. France spends proportionately less on R&D services and royalties and license fees than Germany (0.22% versus 0.40%, respectively).

Table 7. Cross-country comparisons of balance of payments for knowledge capital (1999)

	Domestic BERD/GDP (%)	R&D payments/ GDP (%)	Royalties and licence fees/GDP (%)	R&D payments, royalties and licence fees/GDP (%)	R&D payment, royalties, licence fees, computer and information services/ GDP (%)	Ratio of all intellectual payments to domestic BERD
	(1)	(2)	(3)	(4)	(5)	(6)
Sweden	2.74	0.20	0.46	0.66	1.08	0.39
Finland	2.20	0.17	0.29	0.46	0.95	0.43
United States	1.98	0.01	0.14	0.15	0.16	0.08
Germany	1.70	0.19	0.21	0.40	0.61	0.36
France	1.38	0.07	0.16	0.22	0.27	0.19
Canada	1.06	0.16	0.51	0.67	0.81	0.76
Italy	0.51	0.04	0.12	0.15	0.23	0.44

Note: Data for Canada come from Statistics Canada (2001) and for other countries from OECD/Eurostat (2001).

When we add in expenditures for computer and information services, the relative rankings change slightly. Sweden and Finland are now both ahead of Canada—but the rankings for the other countries remain about the same. It is noteworthy that if we only consider domestic BERD/GDP ratios, Canada is around 50% as knowledge intensive as the U.S. When all the payments categories are added in, Canada becomes 90% as knowledge intensive as the U.S.

What is more critical for our purposes is what these results suggest about the general importance of foreign payments for intellectual services. The results in Table 7 show that foreign inflows of intellectual services have a major impact on the amount of intellectual capital available in domestic economies. In the final column of Table 7, we calculate the ratio of foreign payments (column 5) to domestic R&D expenditures (column 1). Canada's foreign expenditures are relatively more important than all other countries.

5. *Specialized science workers: measuring creative capacity and investment*

This paper has pointed out that the science-based part of the innovation system consists of more than just expenditures on R&D and that current international discussions to modify the way in which the National Accounts takes into account innovation expenditures should think about a wider set of categories than just R&D when considering how to proceed. This does not arise because we argue that a large number of complementary expenditures in training or marketing are being missed. Rather, we argue that even if we restrict ourselves to the science-related area, substantial expenditures are being missed—either because they involve the engineering component of innovation or because they involve payments abroad for intellectual capital that are missed by standard BERD-GDP ratios that rely only on domestic expenditures. If these components are ignored, the expenditures on science-related innovation that need to be properly capitalized will be understated—possibly considerably more so in Canada than in other countries.

In the first section, we argued that science-related technological expenditures outside the narrow confines of the Frascati definition of R&D also involve a substantial investment component and for consistency should be capitalized if the National Accounts are going to try to deal in an appropriate fashion with knowledge investments or the flow of services from knowledge capital.[29] One of the more important components here is the payment for intellectual capital that has been produced by others.

In the second section, we focused on the relative magnitude of foreign technology purchases and found that these intellectual services represent increasingly important components of Canada's innovation system. In our view, all of the examples that we have noted include an investment component—as their impact on production systems is apt to be long-lived.

Our analysis of intellectual capital is intended to inform discussions on the appropriateness of the conceptual framework that should be used as national accountants begin to consider strategies for capitalizing intangible science-related investments such as R&D. From a national accounting perspective, one practical constraint immediately comes to the fore—strategies for capitalizing R&D and other science-related intangible assets need to be amenable to measurement. As we note earlier, the foreign payments that we examine herein are standard Balance of Payments categories. These services are well measured and incorporated into current estimates of final demand. But these payments for foreign services do not capture the full extent to which Canadian firms acquire or produce intangible assets outside of the standard R&D activities. Such a measure would require a complete accounting of the activities that create science-related intellectual capital domestically—reliable estimates of which are not currently available.[30] The first section provided some evidence from innovation surveys of the size of these activities—but does not allow us produce generalized estimates—probably because these surveys have collected this type of data as curiosities rather than as key elements required by the system of national accounts.

In this section, we consider another strategy for capitalizing intellectual assets that is, in our view, more amenable to immediate measurement without the development of new surveys—namely, the use of earnings data to measure the embodied contribution that specialized scientific workers make to the development of intangible science-based capital that are generated as part of the innovation process. While it does not solve the problem of having to measure foreign payments for intellectual capital, it informs the discussion of what might be missed domestically by focusing just on R&D.

There is a clear precedent for such an approach. In the Canadian System of National Accounts and in the United States, the wages and salaries of programmers are used to proxy the contribution that the development of in-house software makes to aggregate investment flows. We

29. We avoid the issue of whether some of these payments are rental payments for capital that has been invested by others—since the distinction is difficult to be made in practice.
30. Data on domestic payments for technology are collected from Statistics Canada's industrial R&D survey, but are not currently published.

essentially adopt this approach here, but extend it beyond just R&D personnel to encompass a broader group of workers who are regarded as producing knowledge capital that is important for the production process. We extend it first to all scientists in the spirit of the results from the first section that show that there are substantial expenditures on technology outside of the narrowly defined R&D process. These expenditures generally revolve around scientific personnel.

At a very basic level, one could envisage statistical estimates based on specialized science-based labour input as a proxy for the stock of creative technological capacity (the science-based human-capital stock) that is used by the innovative system. Creative capacity here refers to the embodied contribution that specialized scientific workers make to the process of knowledge creation. Much of the research on external R&D and technology strategies discussed earlier stresses the role that the skills of science-based workers play in the development and adaptation of these strategies. Different categories of science workers contribute to the formation of intellectual capital—research scientists by engaging in formal R&D; engineering consultants, technologists and technicians by incorporating new technologies into existing production systems. By examining the number of workers and their remuneration in occupational categories that are commonly seen to produce knowledge capital of a scientific nature, we can measure the importance of this process to an economy.

While wage and labour statistics are relatively amenable to measurement, one is faced with a spectrum of choices regarding the types of workers that should be included in any attempt to quantify an economy's stock of intellectual capital. One sensible starting point in the spirit of the usual R&D definition is to focus on the stock of scientists and engineers—highly trained workers who are generally regarded as the driving force behind the levels of scientific progress and technological innovation that characterize an economy. In doing so, we are not implying that other categories of workers do not make valuable contributions to knowledge. We are simply delineating the importance of this often studied category of workers in the economy and asking what the conclusions might be if we extend the investigation beyond the commonly studied category of R&D workers to 'science' workers in general.

We consider the implications of this and other labour-based strategies via a series of empirical examples. If one accepts the assertion that scientists and engineers represent a lower bound on the amount of intellectual capital being created, then the first objective is to quantify the stock of scientists and engineers, and (following the comparative empirics of earlier sections) ask how this stock of S&E workers in Canada compares to the science-based human capital of competitor nations. For this exercise, we focus exclusively on comparisons between Canada and U.S. data on scientists and engineers that are available from the National Science Foundation (for the 1997 reference year). Though comparable statistics are not available for Canada, we can derive S&E estimates using occupational data from the 1996 Population of Census.[31] Results are reported in Table 8.

31. Comparisons between Canada and the U.S. are complicated by the absence of a well-codified statistical concordance that can be used to formally map U.S. S&E occupations (tabulated from the 1980 U.S. SOC) into their Canadian equivalents (expressed in terms of 1991 CDN SOC). Accordingly, we base our Canadian estimates on a mapping of the NSF's S&E occupational taxonomy into Canadian occupational categories available from the Census. Given that the NSF's S&E degree fields and their S&E occupations have the same structure, we have, in a similar fashion, mapped the Canadian census data on major field of study to the NSF degree categories.

Table 8. Employment in scientific and engineering occupations, by degree field

	Canada	United States
All scientists and engineers	261,230	3,239,200
Computer and mathematical sciences	32,310 (12.5%)	490,000 (15.1%)
Life sciences	33,870 (13.0%)	323,700 (10.0%)
Physical sciences	26,240 (10.0%)	330,800 (10.2%)
Social sciences	42,110 (16.1%)	415,800 (12.8%)
Engineering	98,870 (37.8%)	1,250,400 (38.6%)
Non-S&E degrees	27,820 (10.7%)	428,500 (13.2%)
Total employment	13,253,020	129,558,000
S&E share of total employment	1.97%	2.50%

Note: Parentheses indicate percentage of total scientists and engineers accounted for by each degree field. Total employment has been adjusted to exclude non-civilian military.
Source: Canadian 1996 Census of Population and 1997 data from U.S. National Science Foundation.

Scientists and engineers account for 2.0% of total employment in Canada and 2.5% of total employment in the United States. The size of the S&E workforce in Canada, at approximately 261,000 workers in 1996, is 8.1% of the U.S. S&E workforce of 3.24 million.[32] Some basic differences in the composition of S&E workers are apparent between the two countries. Computer and mathematical scientists make up a larger share of American S&E workers than in Canada. Life scientists and social scientists are better represented in Canada. The engineering share (at about 38%) and the physical sciences share (10%) are basically equivalent in both countries.

It is noteworthy that the Canadian proportions of scientists and engineers are much closer to the U.S. than are the domestic R&D ratios reported in previous sections. Once again, they fall in the 80% range, rather than the 50% range depicted by intramural BERD/GERD ratios. This alternate metric provides a much less pessimistic view of Canada's efforts to produce scientific intellectual capital that is critical to the innovation process, once more suggesting the need for careful consideration of the classification issues being discussed here.

The Canadian S&E estimate reported herein (261,230) is almost twice as large as the official 1996 estimate of R&D personnel (143,500).[33] R&D represents a core knowledge-creating function, but, as we argue herein, R&D is far from the only means by which firms invest in the development of intellectual capital associated with innovation and therefore R&D scientists

32. Following the NSF methodology, relevant post-secondary S&E teachers are treated as in-scope, and are included in the Canadian S&E estimates reported in Table 8. The stock of post-secondary S&E teachers was limited to those with a major field of study in one of the degree field categories. For example, those post-secondary teachers with a major field of study in engineering were included in the engineering degree field category of S&E occupations.
33. See Statistics Canada (2001b).

make up only a portion of all scientists.[34] A priori, one expects the occupational characteristics of R&D workers and S&E workers to be related, albeit imperfectly. While many scientists and engineers undoubtedly engage in R&D (either continuously or on a part-time basis), not all would be expected to engage in the formal activities on which official R&D estimates are based; nor, for that matter, would one expect all R&D personnel to be exclusively drawn from the ranks of scientists and engineers.[35] Differences in employment coverage between R&D personnel and S&E workers also translate into significant earnings differentials. For Canada, the ratio of the total wages and salaries paid to R&D personnel to the total earnings of S&E employees is 0.32.[36]

The salient issue, in the current context, is whether the labour effort of scientists and engineers contributes to the development of capital formation—irrespective of whether or not these workers engage in formal R&D. If national accountants believe this to be the case, then capitalization strategies could be based on the wage and salary estimates of S&E workers.[37]

We chose to begin our discussion of labour measurement strategies with tabulations on scientists and engineers because of the strong perceived link between S&E workers and the creation of the intellectual capital needed for innovation. However, one could as easily argue that S&E workers are not the only identifiable group playing a direct role in the creation of intellectual capital.

If national accountants are amenable to more-inclusive groupings, several new classification systems that have been developed to study high-tech transitions in the Canadian economy may provide guidance when devising measurement strategies. Lavoie and Roy (1998) devised a taxonomy of knowledge workers that distinguishes between five broad categories of occupations: pure science, applied science, engineering, computer analysts and programmers, and social science and humanities. Another possibility is the knowledge worker taxonomy

---

34. There are several other measurement issues that might lead to differences. First, official R&D estimates are reported in terms of person-years (or full-time equivalent personnel), while our S&E figure is a count of all employees (paid- and self-employed) in S&E occupations. Second, the contribution that Canadian businesses make to the above estimate of R&D employment (in 1979, nearly 60% of all R&D personnel were located in business enterprises) is based strictly on R&D-performing firms—and our S&E estimate is based on firms in all sectors of the economy. Thirdly, the census data and the R&D data on employment are based on quite different sources. The first is based on household interviews. The second is based on responses by firms who must estimate the number of personnel that they employ. Each source has its strengths and weaknesses. The census is more comprehensive than the R&D employer-based survey. The census has to rely on the accuracy of individuals to state their own occupation accurately. The employer-based survey has to rely on firms to accurately list the number of R&D personnel in their organization—a number that may not be part of their record keeping system.
35. This said, scientists and engineers have long been long recognized as an associated requirement for R&D. In his 1965 analysis of the contribution of R&D to national output, Weiss explores the relationship between science and engineers and R&D expenditures.
36. This estimate was obtained using 1996 census data on the earnings of S&E occupations, and an estimate of the wages and salaries paid to R&D personnel for 1996 taken from the Science, Innovation and Electronic Information Division, based on a weighted average of published 1995 and 1997 totals. Wage and salary data for R&D personnel are not available for 1996.
37. A deeper issue—beyond our scope here—is whether all, or only some portion, of this labour effort should count towards estimates of capital formation. This issue is analogous to the person-year framework on which estimates of R&D personnel are based, wherein only R&D-based activities factor into labour estimates. The current practice within the Canadian System of National Accounts is to count all wages and salaries of programmers when devising estimates of the investment in in-house software.

developed by Beckstead and Vinodrai (2003). The authors use a multivariate analysis of wage and educational characteristics to develop a comprehensive classification of knowledge occupations in professional, technical and management categories. The authors identified forty occupational groups within eight broad classes: (1) science and engineering professionals, (2) science-based technical occupations, (3) health professionals, (4) other health occupations, (5) education, law and other social-science-related occupations, (6) business professionals, (7) management occupations, and (8) arts and culture professionals.

Table 9. Employment and earnings contributions of knowledge workers[1]

	Share of employment (%)	Share of earnings (%)
Lavoie and Roy (1998):		
Knowledge occupations	6.76	11.52
Pure science	0.14	0.25
Applied science	0.59	1.94
Engineering	1.07	1.97
Computer analysts and programmers	1.10	1.71
Social science and humanities	3.33	4.83
Post-secondary teaching[2]	0.53	0.82
Beckstead and Vinodrai (2003):		
Knowledge occupations	20.54	36.5
Science and engineering professionals	2.58	4.5
Science-based technical occupations	2.22	3.0
Health professionals	0.96	2.8
Other health occupations	2.14	2.8
Education, law and other social science	5.08	8.2
Business professionals	1.72	3.1
Management occupations	4.67	11.0
Arts and culture professionals	1.15	1.1

1 The share of employment in the science group in Table 9 is different from Table 8 because most programmers and medical professionals are included in Table 9 but not Table 8.

2 Lavoie and Roy's classification scheme (1998) also identified certain post-secondary teaching occupations—which were distributed across their five main occupational groups; we report on this teaching category separately.

Source: 1996 Census of Population.

Estimates of the employment and earnings shares that derive from these two classification systems are reported in Table 9.

The quantitative differences between these classification systems are substantial. While the occupational categories in the sciences area as specified by Lavoie and Roy are, at first blush, similar to the subgroupings utilized by the NSF, Lavoie and Roy’s occupational taxonomy takes in a much larger share of total employment (2.0% versus 6.8%, respectively) because of its broader occupational scope. What is more, these knowledge workers also account for 11.5% of total earnings—with the largest single contribution occurring in the social science and humanities. Beckstead and Vinodrai’s framework is more ambitious still. The eight broad occupational classes identified as knowledge-based account for about 20 percent of employees, and over one-third of total earnings. Management occupations and those in education, law and social sciences make the largest contributions—both in terms of employment and earnings.

We should stress that none of the classification schemes described above is offered as a definite basis for capitalization of expenditures. Rather, these examples are simply intended to aid in the identification of issues that, in our view, warrant deeper consideration as national accountants begin to develop strategies for capitalizing intangible investments. As we note in earlier sections, decisions about the appropriateness of capitalizing R&D should begin by considering the adequacy of existing R&D definitions. And, as our analysis of foreign payments for intellectual services illustrates, domestic R&D expenditures are far from the only means by which Canadian firms acquire and develop intellectual capital. Moreover, they do not cover all of the domestically oriented expenditures that drive innovation. A discussion on operationalizing innovation assets should proceed in parallel fashion. If proxies for capitalization focus on labour contribution, national accountants will need to decide which occupational categories best capture the embodied contribution that labour makes to the creation of R&D and other intellectual assets.

6. Conclusion

This analysis has considered the relevance of a broad class of innovation expenditures to the issue of R&D capitalization. In the 1993 SNA (93), R&D is illustrative of a class of knowledge generating activities that are at the boundary between gross fixed capital formation and intermediate expenditures. The evaluation of R&D in the SNA (93) begins by noting that "(r)esearch and development are undertaken with the objective of improving efficiency or productivity or deriving other future benefits so that they are inherently investment—rather than consumption—type activities" (SNA (93), p.145). The current SNA (93) convention of expensing R&D reflects a series of operational challenges which, in practice, impede the ability of statistical agencies to obtain accurate values for GDP since these expenditures are not capitalized. The operational problems that led the SNA (93) not to capitalize R&D include difficulties with the establishment of "clear criteria for delineating [R&D] from other activities", an inability to "identify and classifying the assets produced", "to value such assets in an economically meaningful way", and a lack of knowledge related to "the rate at which (these assets) depreciate over time" (p. 145).

Our focus herein has been with the first of these operational challenges, namely the "establishment of clear criteria" for distinguishing and measuring R&D and related activities. Our interpretation of the R&D concept, noted above, is that it encapsulates a broad set of innovation expenditures related to investments in scientific knowledge. In our view, this more "general" R&D concept is implicit in SNA (93), as, in making its recommendations to expense these activities, it acknowledges the need to "establish clear criteria" for measuring R&D, when clear criteria certainly existed. Since the 1960s, the Frascati manual has provided a well recognized, codified international standard (and definitional framework) for collecting and measuring R&D activities. The "efficiency and productivity" concept advanced by the SNA (93), as its stated objective for R&D activities, is much broader in its scope than that outlined in the Frascati manual. As such, the consideration of a broader class of knowledge-based activities, under the rubric of what national accountants refer to as R&D, is, in our view, appropriate.

Our focus herein on a broad class of science-related innovation categories is not intended to deflect attention away from more traditional measures of R&D, nor needlessly obscure the focus of the capitalization debate by suggesting that the traditional concept be extended to areas that at the moment defy measurement. Rather, our central objective is to raise a number of issues that we regard as relevant to a fundamental aspect of the R&D capitalization debate, namely, "the delineation of clearly definable criteria". These issues, we believe, are essential to informed debate on the desired course of action as national accountants move their discussions forward.

The substantive issue, as we note in the paper, is whether these knowledge-based activities constitute forms of investment that, as a matter of course, should be capitalized—based largely on whether they are substantial, and whether they can be measured.

In this paper, we have considered a broad class of science-related innovation expenditures. It is nevertheless worth emphasizing how many of these innovation expenditures relate to the standard (Frascati) definition of R&D. Activities that the Frascati manual classifies as R&D generally contain some element of novelty. Boundary issues—guidelines for delineating R&D from other, often related, activities—are extensively discussed in the Frascati manual, and care is taken to distinguish research and development from a broader class of scientific and technological activities (e.g., patents) and/or industrial activities (e.g., engineering and tooling expenditures), many of which "undoubtedly" contribute to the innovation process. While beyond the scope of Frascati, many of these activities are consistent with more general concepts of R&D, in that they encompass "work directed towards the innovation, introduction, and improvement of products and processes" (Canadian Oxford Dictionary, 2001). What is more, these expenditures confer future benefits beyond an annual production cycle and are certainly undertaken with the objective of improving efficiency and productivity.

In taking this position, the paper derives a set of innovation intensity measures that are more comprehensive than the traditional measures used to gauge a country’s R&D intensity. These traditional measures are, in our view, not only too narrow but they are also based on an outmoded concept of economic self-sufficiency. These traditional measures examine only the R&D expenditures that are made in the domestic economy and ignore payments that are made abroad for R&D services. In an open economy, intellectual capital will also be imported from foreign suppliers. As trade rules become increasingly liberalized, it makes no more sense to measure investment in R&D as just that which occurs domestically than it would be to measure Canadian investment in plant and equipment as just that which is purchased from domestic manufacturers. In a knowledge-based economy where investments are being made on new scientific knowledge, R&D, when traditionally defined as only intramural expenditures, covers only part of the investments in innovation that are being made.[38]

Empirically, the expenditures that we consider are far from trivial. We have provided three different pieces of evidence here—from innovation surveys, from balance of payments data, and from census information on the importance of scientists. In section 3, we have adduced evidence from innovation surveys that have found that the size of non-R&D expenditures on knowledge creation is often sizable relative to direct in-house expenditures on R&D. In section 4, our investigation of payments to non-residents explores this issue in a complementary way—by noting that foreign payments for R&D are only a small percentage of payments for innovation-

38. We put the issue of whether foreign payments are investments in capital stock or payments for capital services to one side—whether they are one or the other they should be considered.

related intellectual capital. We also note that a singular focus on domestic R&D expenditures will downwardly bias perceptions of the extent to which Canadian firms are investing in, or paying for, new knowledge, a bias that is apt to increase as domestic firms make more use of foreign sources. Foreign firms, of course, are only one possible source of intellectual services, as firms also purchase these services from domestic firms and/or develop these competencies internally.

This paper notes that the usual data on R&D will underestimate, often substantially, the total expenditures that firms make on science-related innovation capital. This occurs for two reasons. First, R&D are only part of the science-related expenditures on innovation. In section 3, we demonstrate that innovation surveys suggest that these expenditures in Canada are twice as large as what is included in R&D statistics. Section 5 of the paper confirms this ratio using slightly different data—wages paid to scientists as opposed to R&D expenditures.

Second, it is common practice to omit payments for R&D that are made to other countries. The latter practice is particularly disadvantageous to countries such as Canada that are characterized by substantial trade in the assets associated with intellectual property. The paper goes on to note that parts of the broader concept of knowledge-based investment are already measured by official statistical agencies—not under the rubric of science and technology programs, but within balance of payments divisions. And as such there is reason to believe that the requisite data needed to expand our definition of investments in science-based intellectual capital beyond those made for R&D is feasible.

This study has documented the payments that Canadian firms make abroad for different intellectual services in order to illustrate the magnitude of the payments for intellectual property that are occurring outside of the R&D expenditures as traditionally measured. As measured in the balance of payments, these payments for other intellectual services are four times the value of the payments made abroad for R&D services.

Ours is not the first analysis to suggest that intangible expenditures related to innovation should be treated as gross fixed capital formation. Corrado, Hulten and Sichel (2004) identify "the issue of whether intangible outlays or knowledge input should be expensed or capitalized…as one of the most important 'new economy' questions (p.4)". The authors conclude that "if business intangibles were fully recognized in national accounting systems, the move would result in significant changes in measures of economic activity" (p. 6). Their set of intangibles includes "computerized information, scientific and creative property and economic competencies". The second category includes a component that incorporates "the scientific knowledge embedded in patents, licenses and general know-how (not patented) and the innovative and artistic content in commercial copyrights, licenses, and designs" (p.18). The authors conclude that spending on "scientific and creative/innovative property"…"was at least as large as scientific R&D spending in the 1990s". Commenting on Corrado et al. (2004), Prescott notes that many of these production-orientated activities certainly satisfy the SNA (93) criteria for investment.

Others have also pointed out the wide-range of expenditures from training to marketing that are crucial to the innovation process. The list of these expenditures is sufficiently large as to call into question the feasibility of considering extensions to the standard definition—for fear of delaying any progress in this area. Our approach has tried to avoid this in two ways. First, we have deliberately limited the scope of our investigation to an ‘expanded’ definition of R&D—actually to one that we believe fits the commonly perceived definition of R&D as science-related expenditures that are directed towards the innovation, introduction, and improvement of products and processes. And we have taken care to make use of empirical evidence. This evidence shows that science-related expenditures in the innovation process, outside of the narrow Frascati definition of R&D, are substantial. At the same time, it points to the feasibility of adopting a slightly broader definition. It extends the scope of the exercise while suggesting that progress on the measurement side is feasible.

The paper has been careful to suggest that the class of innovation expenditures examined herein is amenable to measurement. This is an essential requirement if discussions of R&D capitalization are to move forward. Innovation surveys are now into their second decade and should be prepared to start to make a contribution to the needs of the National Accounts in the area of innovation expenditures. The extramural expenditure categories that we have described are already standard balance of payment categories—classifications that are familiar to national accounting programs. If the information can be captured by balance of payments divisions in various statistical agencies around the world, they can be captured for domestic expenditures as well. Finally, our work on the number of scientists and their wages shows that a viable source of data already exists in this area. This is a source that has already been used in the Accounts to estimate another difficult area—the value of software investments.

That being said, there are a number of issues to be addressed. For one, it is not clear at first blush how many of these expenditures are currently treated in the SNA (93) (as to whether they are capitalized or expensed). While our data are standard import categories in the Balance of Payments—and hence should be included in final demand—many of these foreign purchases of intellectual services, notably those that flow into domestic companies via intercompany transactions, are, in all likelihood, treated as intermediate expenditures. Similar practices may also be occurring in the case of domestic expenditures on knowledge services, as many of these are probably not fully captured by domestic investment surveys.

Finally, the paper argues that failing to move in the direction of an expanded definition of knowledge capital would provide a biased estimate of Canada’s GDP and that the failure will likely result in more of a bias in the case of Canada than for other countries. If R&D as defined by Frascati is capitalized, GDP will increase. If all science-based expenditures (including Frascati R&D) are capitalized, GDP will increase even more. If the Frascati definition is adopted to the exclusion of a more general definition, the estimated GDP of all countries will be underestimated. But this bias will be greater in countries where R&D makes up a smaller proportion of total innovation expenditures. The data presented in this paper shows that Canada’s innovation system directs proportionately more expenditures towards the import of non-R&D science-based services than is the case for many other countries. If Canada were to only capitalize R&D expenditures and not science-based expenditures, we would bias Canadian GDP downward relative to say that of the United States.

While this paper has primarily focused on issues that are germane to the appropriate techniques that should be used to measure GDP, the findings are also relevant to debates on the adequacy of Canada's innovation system. Frascati-based measures of R&D are readily available and, as such, form the basis for most cross-country comparisons of innovation systems. The evidence produced herein suggests that domestic R&D-to-GDP ratios can be misleading—especially in international comparisons of the intensity of innovation spending.

Domestic R&D-to-GDP ratios underestimate the importance of the services of knowledge capital being used in Canada. In 1999, Canadian businesses recorded a BERD-to-GDP ratio of 1.06 percent. When the payments that Canadian firms made for R&D services are included along with domestic R&D expenditures, this ratio increases 15% to 1.22 (Table 6). When payments for royalties and license fees are included with total R&D expenditures (domestic and foreign purchased), the original BERD ratio (in 1999) increases by 64% to 1.74. Adding in all payments for intellectual property yields a BERD ratio in 1999 of 1.87, an increase of 76%.

It is noteworthy that if we only consider domestic BERD-to-GDP ratios, Canada is around 50% as knowledge intensive as the U.S. When all the payments categories are added in, Canada becomes 90% as knowledge intensive as the U.S. The Canadian proportion of scientists and engineers is much closer to the U.S. proportion than are the domestic R&D ratios reported in previous sections. Once again, the Canadian ratio is about 80% of the American ratio, rather than 50%, the ratio depicted by intramural BERD-to-GDP ratios.

Appendix: A note on the measurement of innovation capital (stocks and flows)

Recent discussions on the capitalization of R&D have also focused on the more general issue of how payments for a variety of knowledge-based assets should be treated in the SNA (93). Several individuals have raised the example of Microsoft and its investment in Windows. The problems raised by some national accountants is whether some form of double counting occurs if the value of this Microsoft asset was capitalized in the U.S. balance sheet and in the balance sheets of other countries that purchased the right to this Microsoft asset. Other variants of this measurement issue exist, particularly in reference to the treatment of firm-to-firm transfers of knowledge-based capital. For example, how should national accountants treat the purchase of a patent, or of the right to use someone else's R&D?

We start by noting that the answer to these questions depends very much on the measurement objective. There is therefore no single straightforward solution that is applicable to all cases. We address two separate questions below.

1) What constitutes the stock of knowledge capital?

To answer this question, let us return to the example of Microsoft Windows. Determining the appropriate treatment for the licenses that Microsoft grants for Windows requires some information on the licensing agreements that Microsoft has with its client firms. At the simplest level, national accountants need to ascertain the depreciation rate on the knowledge purchased (Windows). And this depreciation rate is determined, in practice, by the contractual terms specified in licensing agreements. Right-to-use agreements that fully depreciate (i.e., expire) in a single year represent intermediate expenditures, and should not be capitalized and depreciated over more than one year. (This is no different than the treatment of inventories vis-à-vis the capital stock). But licensing agreements in which the benefits to the license holder extend beyond a single year represent a form of investment; the payments made for such agreements should be included in the estimate of knowledge capital and depreciated over time.

The practical problem facing national accountants in this example is that the licensing policies of Microsoft for its Windows software may vary across consumers. In some cases, license holders may make a lump sum payment to Microsoft, with no time restrictions on the use of Windows. In these situations, the license holder purchases an asset that lasts longer than one year, and "invests" in knowledge capital. In other situations, license holders may make annual payments to renew their Windows license. In this case, license holders do not purchase an asset whose life extends beyond one year. The treatment of these purchases when estimating the stock of knowledge capital will depend on the terms of the contract. And, of course, this implies that the usual information collected by statistical agencies on the value of purchased inputs is not sufficient—national accountants require additional information on the nature of these licensing contracts before they would know whether to capitalize them or not.

Similar difficulties arise when considering the payments that firms make for other types of knowledge. Suppose a firm contracts out its R&D function to another firm. If these payments for

R&D services confer future benefits (beyond a single year) on the purchaser of the service, national accountants should consider these payments as capital investment—just as they would if the firm had conducted the R&D internally. But if the payments that the firm makes for R&D services do not confer any future benefits to the purchasing firm, they should not be capitalized.

Now consider the case where, instead of purchasing R&D services, the firm obtains the right to use a patent. National accountants can treat this situation just as they treat payments for software. If the right to use the patent extends beyond one year, so too will the benefits to the purchasing firm, and its payments need to be capitalized. However, the depreciation rate for patents that embody R&D will likely differ from the depreciation rate for performed R&D. Patents embody known ideas; R&D involves more uncertainty. Depreciation rates are meant to encompass the extent to which the value of an asset diminishes over time. Accordingly, expenditures that result in no value have depreciation rates of 100%. A substantial portion of R&D expenditures fall into this category because they do not result in new commercialized products or services, or in improvements to existing products and services. But, by definition, patents have some commercialized value or they would not be granted. On average, then, the depreciation rate for patents is likely to be less than the depreciation rates for R&D.

These same issues apply to firm-to-firm payments for technology. We know from Canadian innovation surveys that these payments can either be for an outright transfer of a licence to use technology, or for ongoing transfers of existing and future technologies. In the first case, the purchaser obtains the right to use the technology at any time in the future—and thus the payments made for this technology should be capitalized. In the second case, the payment should also be capitalized (because the technology confers a future stream of benefits)—the only difference here is that the contract promises to transfer future technologies at prices that are determined at a future date.

We note that in discussions about the treatment of different assets, the issue of whether an asset can be resold is occasionally raised. The right to resell an asset does not determine whether that asset should be capitalized. In some situations, Microsoft contracts may allow for the continued use of the software and the right to transfer the software; in others situations, it may not. This right to transfer determines the value that a purchaser is willing to pay for the asset—not whether that value extends beyond one year (at least in most situations).

While the theoretical rules that should be used to define the stock of knowledge capital are straightforward, there is still the issue of double counting. Does capitalizing the payments that firms make to Microsoft create double counting? It does not as long as the appropriate accounting is implemented for the original transaction. Through its original expenditures on Windows, Microsoft creates the ability to earn a future stream of revenues. The value of that activity is the ability to earn future revenues. Its original activity created a piece of paper—a copyright or patent that could be exploited for many years into the future. If the value of that piece of paper were recognized by national accountants as a valuable activity—then Microsoft would be seen as creating the asset when it first engaged in software development. Subsequent sales just realize the value of the asset—and, in effect, depreciate its value because they reduce the remaining stream of potential revenue that can be derived from the sale of right-to-use agreements.

The underlying problem is that the System of National Accounts does not treat the creation of knowledge assets as a meaningful activity. Revenue is only booked when sales are realized. The value of knowledge (which stems from creating proprietary rights and the legal mechanisms to transfer these rights) are not recognized as value- or wealth-creating activities. This valuation problem surfaces in a number of sectors—not the least of which is the natural resource sector. Drilling (a knowledge generating activity) creates reserves and eventually the oil or natural gas that is extracted from the ground. These are investments in future commercialization.

It is of course difficult to estimate the value of Microsoft's knowledge assets when they are first created. This is the case for a large number of knowledge creating activities. But it is not difficult to recognize payments when they are made. It is, therefore, easier to recognize a payment for capital services than the creation of the value of the asset that is used to generate payments for services. This asymmetry should not deter national accountants from attempting to measure the payment for the services derived from knowledge capital or the capital when it is transferred.

We note that the fact that estimating the value of a knowledge asset is difficult to estimate does not mean that not attempting to estimate it is likely to be the optimal strategy. If we attempt to estimate its value, we may make an error. If we do not so, we definitely make an error. Professional judgement is required to decide the relative size of the errors in each case.

2) What is the amount of knowledge capital being applied to the production process?

In the previous section, we have addressed the issue of how to measure whether a payment that is made for an asset has enhanced the stock of knowledge capital—of a firm, an industry or a country. This will not suffice, however, if the measurement objective is to estimate the extent to which capital services are being used in the production process.

Of interest to many is the extent to which labour has, at its disposal, capital with which it transforms materials into final products. Payments for knowledge-based services that amount to one-year rental payments for the use of capital are akin to the lease payments that are made for physical capital. And both will be treated as an intermediate expense in the standard national accounting framework.

To obtain a better understanding of the production process, national accountants need to separate out the intermediate expenditures that are made for materials from those that take the form of payments for capital services. This is because the amount of capital that is being applied to the production process is the combined sum of capital service flows derived from the amount of capital that is owned and the flow of services that are 'rented'. At the present time, this distinction is not being made. Consequently, the product accounts produced by statistical agencies may have become increasingly unreliable in this area as, (1) improvements in financial intermediation, over the last thirty years, have made it easier to rent capital services, and (2) the amount of technology that is being purchased relative to physical capital has increased. In some industries, increasingly large amounts of expenditures are being made to 'rent' capital services.

How can national accountants make progress in this area? First, statistical agencies could undertake a set of experimental surveys that examine the importance of payments for physical and knowledge capital that take the form of both investment and 'rental'. This would allow us to better understand the nature and the magnitude of this measurement problem.

As a by-product, these surveys would allow statisticians to assess the extent to which a singular focus on R&D captures the expenditures that firms are making on knowledge capital. In the accompanying note, we have argued that there is some reason to believe that capitalizing R&D alone would substantially underestimate the amount of 'knowledge' capital expenditures that are being made in the Canadian economy.

References

Archibugi, D., R. Evangelista and R. Simonetti. 1995. "Concentration, Firm Size and Innovation: Evidence from Innovation Costs." *Technovation*, 15(3): 153-163.

Armstrong, P., T. Harchaoui, C. Jackson and F. Tarkhani. 2002. *A Comparison of Canada-U.S. Economic Growth in the Information Age, 1981-2000: The Importance of Investment in Information and Communication Technologies*. Economic Analysis Research Paper Series 11F0027MIE2002001. Analytical Studies Branch. Ottawa: Statistics Canada.

Audretsch, D.B., A.J. Menkveld and A.R. Thurik. 1996. "The Decision between Internal and External R&D." *Journal of Institutional and Theoretical Economics*, 152(3): 519-530.

Baldwin, J.R. 1997. *The Importance of Research and Development for Innovation in Small and Large Canadian Manufacturing Firms*. Analytical Studies Branch Research Paper Series 11F0019MIE1997107. Analytical Studies Branch. Ottawa: Statistics Canada.

Baldwin, J.R. and W.M. Brown. 2003. *Regional Manufacturing Employment Volatility in Canada: The Effects of Specialization and Trade*. Economic Analysis Research Paper Series 11F0027MIE2003005. Analytical Studies Branch. Ottawa: Statistics Canada.

Baldwin, J.R., D. Beckstead and R. Caves. 2001. *Changes in the Diversification of Canadian Manufacturing Firms and Plants (1973-1997): A Move to Specialization*. Analytical Studies Branch Research Paper Series 11F0019MIE2001179. Analytical Studies Branch. Ottawa: Statistics Canada.

Baldwin, J.R. and G. Gellatly. 1998. "Developing High-Tech Classification Schemes: A Competency-Based Approach." In *New Technology-Based Firms in the 1990s: Volume VI*, edited by R. Oakey, W. During, and S. Mukhtar. Oxford: Elsevier Science, 1999.

Baldwin, J.R. and G. Gellatly. 2003. *Innovation Strategies and Performance in Small Firms*. Cheltenham: Edward Elgar Publishing Ltd.

Baldwin, J.R. and P. Hanel. 2003. *Innovation and Knowledge Creation in an Open Economy: Canadian Industry and International Implications*. Cambridge: Cambridge University Press.

Baldwin, J.R. and J. Johnson. 1999. *The Defining Characteristics of Entrants in Science-based Industries*. Catalogue No. 88-517-XIE. Analytical Studies Branch. Ottawa: Statistics Canada, 1999

Beckstead, D. and G. Gellatly. 2003. *The Growth and Development of New Economy Industries*. The Canadian Economy in Transition Research Paper Series 11-622-MIE No. 002. Analytical Studies Branch. Ottawa: Statistics Canada.

Beckstead, D. and T. Vinodrai. 2003. *Dimensions of Occupational Changes in Canada's Knowledge Economy, 1971-1996*. The Canadian Economy in Transition Research Paper Series 11-622-MIE No. 004. Analytical Studies Branch. Ottawa: Statistics Canada.

Borga, M. and M. Mann. 2002. "U.S. International Services Cross-Border Trade in 2001 and Sales through Affiliates in 2000." *Survey of Current Business*. Bureau of Economic Analysis (October 2002).

Corrado, C. C. Hulten and D. Sichel. 2004. Measuring Capital and Technology: An Expanded Framework. Presented at CRIW/NBER Conference "Measuring Capital in the New Economy", April 26-27, 2002, Washington: D.C.

Croes, M.M. 2000. Data for intangibles in selected OECD countries. Statistics Netherlands. OECD and Dutch Ministry of Economic Affairs.

De Melto, D., K. McMullen and R. Wills. 1980. *Preliminary Report: Innovation and Technological Change in Five Canadian Industries*. Discussion Paper No. 176. Economic Council of Canada.

Evangelista, R., T. Sandven, G. Sirilli and K. Smith. 1997a. "Measuring the Cost of Innovation in European Industry." In *Innovation Measurement and Policies*. A. Arundels and R. Garrelfs (eds). European Commission, Luxembourg. Office for Official Publications of the European Communities, pp. 109-113.

Evangelista, R, G. Perani, F. Rapiti and D. Archibugi. 1997b. "Nature and impact of innovation in manufacturing industry: some evidence from the Italian innovation survey." *Research Policy*, 26: 521-536.

Guellec, D. and B. van Pottelsberghe de la Potterie. 2001. *R&D and Productivity Growth: Panel Data Analysis of 16 OECD Countries*. OECD Economic Studies No. 33, 3001/II.

Industry Canada. 2002. *Achieving Excellence: Investing in People, Knowledge and Opportunity: Canada's Innovation Strategy*. Catalogue No. C2-596/2001E-IN2. Ottawa: Industry Canada.

Johnson, J., J.R. Baldwin and C. Hinchley. 1997. *Successful Entrants: Creating the Capacity for Survival and Growth*. Catalogue No. 61-524-XPE. Analytical Studies Branch. Ottawa: Statistics Canada.

Jones, O. 2000. "Innovation management as a post-modern phenomenon: The outsourcing of pharmaceutical R&D." *British Journal of Management*, 11(4): 341-356.

Kaiser, U. 2002. "An empirical test of models explaining research expenditures and research cooperation: evidence for the German service sector." *International Journal of Industrial Organization*, 20(6): 747-774.

Kamin, J.Y., I. Bijaoui and R. Horesh. 1982. "Some Determinants of Cost Distributions in the Process of Technological Innovation." *Research Policy*, 11(2): 83-94.

Kleinknecht, A. 1987. "Measuring R&D in small firms: How much are we missing?" *Journal of Industrial Economics*, 36(2): 253-256.

Kleinknecht, A. 1989. “Firm size and innovation: observations in Dutch manufacturing industry.” *Small Business Economics*, 1(1): 215-222.

Lavoie, M. and R. Roy. 1998. “Employment in the Knowledge-Based Economy: A Growth Accounting Exercise for Canada.” *Applied Research Branch Strategic Policy Research Papers*. Catalogue No. R-98-8E. Hull: Human Resources Development Canada.

Lonmo, C. and F. Anderson. 2003. *A Comparison of International R&D Performance: An Analysis of Countries that have Significantly Increased Their GERD/GDP Ratios during the Period 1989-1999*. Science, Innovation and Electronic Information Division Working Paper Series 88F0006XIE No. ST-03-01. Ottawa: Statistics Canada.

Love, J.H. and S. Roper. 2002. “Internal Versus External R&D: A Study of R&D Choice with Sample Selection.” *International Journal of the Economics of Business*, 9(2): 239-255.

Mansfield, E. et al. 1971. *Research and Development in the Modern Corporation*. New York: MacMillan.

Mansfield, E. 1988. “The Speed and Cost of Industrial Innovation in Japan and the United States: External vs. Internal Technology.” *Management Science*, 34(10): 1157-1168.

Mansfield, E. 1989. “Technological Change in Robotics: Japan and the United States.” *Managerial and Decision Economics*, 10: 19-25.

Mohnen, P. and N. Lépine. 1991. “R&D, R&D Spillovers and Payments for Technology: Canadian Evidence.” *Structural Change and Economic Dynamics*, 2(1): 213-228.

Mowery, D.C. 1983. “The Relationship between Intrafirm and Contractual Forms of Industrial Research in American Manufacturing, 1900-1940.” *Explorations in Economic History*, 20: 351-374

Mowery, D.C. and N. Rosenberg. 1989. *Technology and the Pursuit of Economic Growth*. Cambridge: Cambridge University Press.

National Science Foundation. 1972. *Research and Development in Industry, 1970*. Washington, D.C.: U.S. Government Printing Office.

Nicholls-Nixon, C.L. and C.Y. Woo. 2003. “Technology sourcing and output of established firms in a regime of encompassing technological change.” *Strategic Management Journal*, 24(7): 651-666.

Niosi, J. 1999. “The Internationalization of Industrial R&D From technology transfer to the learning organization.” *Research Policy*, 28: 107-117.

Niosi, J. and B. Godin. 1999. “Canadian R&D abroad management practices.” *Research Policy*, 28(2-3): 215-230.

Odagiri, H. 2003. “Transaction Costs and Capabilities as Determinants of the R&D Boundaries of the Firm: A Case Study of the Ten Largest Pharmaceutical Firms in Japan.” *Management and Decision Economics*, 24: 187-211.

OECD. 1994. *Frascati Manual 1993. Proposed Standards for Surveys of Research and Experimental Development*. Paris: OECD.

OECD/Eurostat. 2003. *OECD Statistics on International Trade in Services*. OECD: Paris.

OECD. 2003. *Main Science and Technology Indicators Database*. Volume 2000/2. OECD: Paris.

OECD. 2002. *Main Science and Technology Indicators*. Vol. 2000/2. OECD: Paris.

OECD/Eurostat. 2001. *OECD Statistics on International Trade in Services Database* (2001 edition). OECD: Paris.

Palda, K. 1993. *Innovation Policy and Canada’s Competitiveness*. Vancouver: The Fraser Institute.

Papaconstantinou, G., N. Sakurai and A. Wyckoff. 1996. “Embodied Technology Diffusion: An Empirical Analysis for 10 OECD Countries.” *STI Working Papers 1996/1*. OECD: Paris.

Prescott. E. 2004. “Comments on Scaling the Intangible Capital Wall: Conceptual Issues in the Measurement of Capital”, by C. Corrado, D. Sichel and C. Hulten.

Rosenberg, N. 1976. *Perspectives on Technology*. Cambridge, MA: Cambridge University Press.

Statistics Canada. 1991. *Industrial Research and Development*. Catalogue No. 88-202-XIE. Science, Innovation and Electronic Information Division. Ottawa: Statistics Canada.

Statistics Canada. 2001a. *Canada’s International Transactions in Services*. Catalogue No. 67-203-XIE. Balance of Payments Division. Ottawa: Statistics Canada.

Statistics Canada. 2001b. *Estimates of research and development personnel in Canada, 1979 to 2000*. Working Papers Catalogue No. 88F0006XIE No. ST-01-09. Science, Innovation and Electronic Information Division. Ottawa: Statistics Canada.

Statistics Canada. 2005. *Industrial Research and Development, 2004 Intentions*. Catalogue No. 88-202-XIE. Science, Innovation and Electronic Information Division. Ottawa: Statistics Canada.

Stead, H. 1976. “The Cost of Technological Innovation.” *Research Policy*, 5(1): 2-9.

System of National Accounts (SNA). 1993. Published jointly by the Commission of the European Communities/Eurostat, the International Monetary Fund, the Organisation for Economic Co-operation and Development, the Statistics Division of the former Department for Economic and Social Information and Policy Analysis and the regional commissions of the United Nations Secretariat, and the World Bank. Copyright (c) 1993, European Communities, IMF, OECD, United Nations and World Bank.

Tang, J. and S. Rao. 2003. "Are Foreign-Controlled Manufacturing Firms less R&D-Intensive than Canadian-Controlled Firms?" *Canadian Public Policy*, 29(1): 111-117.

Ulset, S. 1996. "R&D outsourcing and contractual governance: An empirical study of commercial R&D projects." *Journal of Economic Behavior and Organization*, 30(1): 64-82.

Veugelers, R. 1997. "Internal R&D expenditures and external technology sourcing." *Research Policy*, 26(3): 303-315.

Veugelers, R. and B. Cassiman. 1999. "Make and buy in innovation strategies: evidence from Belgian manufacturing firms." *Research Policy*, 28(1): 63-80.

Weiss, H.K. 1965. "Some Growth Considerations of Research and Development and the National Economy." *Management Science*, 11(3): 368-394.

Zahra, S.A. 1996. "Technology strategy and new venture performance: A study of corporate-sponsored and independent biotechnology ventures." *Journal of Business Venturing*, 11(4): 289-321.