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Intangible Capital in Canada: R&D, Innovation, Brand, and Mining, Oil and Gas Exploration Expenditures

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Preface

Because of analysts’ interest in the underlying forces affecting growth in the Canadian economy, a number of Statistics Canada studies have focused on the basic transformations taking place in the determinants of economic growth. These studies focus not so much on short-run patterns that reflect exchange rate or commodity price movements that favour some sectors or regions but on the underlying production process and the nature of innovation. They examine the evolution of new patterns in the economy that are transformational in nature and widespread across all sectors.

Different types of changes have caught the attention of analysts in recent years —ranging from the emergence of the high-tech economy, to the development of the knowledge economy, to the importance of innovation more generally.

Central to the first topic is the notion that the use of advanced technologies, particularly information and communications technology (ICT), is the new critical capital input behind economic growth. The information and communications technology revolution has been manifested in dramatic changes in the focus of investment. In particular, the percentage of investment in machinery and equipment that has been devoted to information and communications technology has increased dramatically over time (Baldwin and Gu, 2007).

Numerous studies at the macro level have found significant positive relationships between the stock of ICT capital and industry macroeconomic performance. Jorgenson and Stiroh (2000) report a positive relationship between U.S. industry multi-factor productivity growth and investments in information technology in the post 1995 period. Working at the industry-level, Stiroh (2001) finds a positive correlation between ICT-investment intensities and labour productivity growth. In Canada, Armstrong et al. (2002) examine the extent to which changes in output growth were driven by investments in information and communication technologies, such as hardware, software and telecommunications equipment. The authors report that the percentage of output growth attributable to ICT investment has increased markedly over the 1995-2000 period—and that there was a close relationship between ICT investment and productivity performance. Gu and Wang (2004) also find a close relationship in Canada between industry multifactor productivity growth and both the use of ICT technologies and highly skilled labour. At the micro level, other studies have confirmed the importance of ICT strategies for the success of individual firms. Baldwin and Sabourin (2001, 2004) find that manufacturing firms making the greatest use of ICT equipment grew more quickly, thereby gaining market share, and increasing their relative productivity.

Beckstead and Gellatly (2003) investigate the profile of Canadian ICT industries to see whether they stood out in terms of their performance with regards not just to productivity growth but also with regards to profitability, output, capital investment, trade, research and development, employment and labour quality. The report also examines a larger collection of *science-based* industries—industries that make contributions to industrial innovation via relatively large investments in research and development and human capital and reports that ICT industries were not the sole source of industrial innovation in the New Economy. Another set of 'Knowledge-based' industries that focused on R&D deserves attention in their own right. GDP growth, employment growth, productivity growth, investments in technology, and R&D expenditures are all areas in which the ICT sector excel; but in many respects, knowledge-based science industries outside the ICT sector that focus on R&D expenditures are equally dynamic, thereby indicating that a broader approach than just the study of technology investments is required to fully capture the nature of the underlying changes that are taking place in the Canadian economy. R&D expenditures, which primarily involve expenditures on skilled labour (scientists) are also related to success. As such science based strategies that are an intrinsic part of the New High-Tech Knowledge Economy are not one-dimensional. They involve the use of high-tech machinery and equipment. But they also simultaneously require the use of highly trained science workers.

Studies on the broader concept of the knowledge economy also focus on the importance of worker skills rather than just on technological machinery and equipment. They investigate whether production processes have increased their emphasis on higher skilled labour, or what some have called ‘knowledge’ workers. These papers focus first on narrow groups of knowledge workers defined in terms of scientists and then on larger groups that take into account higher education levels defined more broadly than just scientists. Beckstead and Vinodrai (2003) and Baldwin and Beckstead (2003) report that the share of employment in the Canadian economy accounted for by ‘knowledge’ workers using both definitions increased at a steady rate over the period 1971-96.

In contrast to the studies of the ICT or the Knowledge Economy, Innovation studies focus on the broader determinants of the innovation process rather than just on new investments in ICT and R&D expenditures. Many innovations are modest, incremental changes, while others are more pathbreaking. Both contribute to the process of industrial renewal. Baldwin and Hanel (2003) report that innovation strategies and inputs to the innovation process differ substantially across manufacturing sectors. In some industries, they are centered on R&D and new product development. These require R&D personnel. In others, they involve incorporating new process technology and making use of the new intermediate products developed in other industries. The latter require engineers and applied scientists. In still other industries, they involve both.

Innovation studies show that innovative firms are found across all industries. Baldwin and Gellatly (1998, 1999, and 2001) make use of survey evidence for firms across all sectors of the Canadian economy and report that there are firms with innovation profiles in all industries—in both manufacturing and service sectors. More importantly, it is these firms that grow more rapidly and are more successful in all sectors (Baldwin and Gellatly, 2003). But their innovation profiles are tailored to the industry environment in which they are found and thus often differ. Some focus on R&D scientists—the creation of new knowledge. Others focus on other types of scientists—engineers—to incorporate new products and materials discovered in other industries into the production process of industries that make use of these discoveries—either as new machinery and equipment or as new intermediate materials. The latter involve expenditures that while different from R&D have many of the same properties—they create long-lived assets and they involve substantial scientific effort. In both cases, expenditures on people are used to make investments that contribute to a firm's success.

This study continues the focus of our previous studies on transformational change. It complements previous studies in that it examines the types of investments that are being made in the innovation process. But it extends the focus beyond just hardware like ICT that has provided the focus of much of macroeconomic productivity analysis. It complements the previous set of studies on the Knowledge economy in that is interested in quantifying the amount of investment that is made in knowledge capital or what has come to be called Intangibles. And in doing so, it parallels previous work in that it recognizes substantial investments are made here in workers—but not just in developing their skills, rather in having them develop new knowledge that consists of knowledge that the firm can harness for innovative activity. It also recognizes that some knowledge investments are made by purchasing R&D, patents, licences, and technological know-how from other companies.

This paper builds on our innovation studies in that it recognizes that there are a variety of different types of investments made in innovation. Only part of these innovation expenditures is included in R&D expenditures. Substantial investments in *science-related* expenditures outside of R&D are also made. The proportion of R&D and non-R&D science expenditures varies across industries because the nature of innovation differs across the sectors.

1. Introduction

Studies of economic growth often focus on the importance of capital and its changing nature. In recent years, attention has focused on the changing pattern of investments in tangible machinery and equipment—in particular on the fact that an increasing proportion of investments in this area consist of investment in information and technology (Baldwin and Gu, 2007). Studies by Gu and Wang (2004) for Canada and Jorgenson et al. (2000) for the United States report a positive correlation between ICT-investment intensities and productivity growth at the industry level.

Attention has also focused more broadly on other types of capital—expenditures that provide less tangible assets. One type of intangible capital that has received much attention is research and development (R&D) which consists mainly of expenditures on the wages of scientists—and produces knowledge capital. Beckstead and Gellatly (2003) study the characteristics of a wide range of industries, both those producing ICT and those making use of extensive amounts of R&D, and find that both have dynamic profiles when it comes to productivity growth but also with regards to profitability, output, capital investment, trade, research and development, employment and labour quality. Science-based strategies were not one-dimensional. They involve both the production and the use of high-tech machinery and equipment. But they also simultaneously involve the use of highly trained science workers.

Both ICT and R&D underpin innovative activity. But innovative activity is not restricted to these two activities. Baldwin and Hanel (2003) note how innovation strategies and inputs to the innovation process differ substantially across manufacturing sectors. In some industries, they are centered on R&D and new product development. In others, these strategies involve incorporating new process technology and making use of the new intermediate products developed in other industries. But innovation profiles are tailored to the industry environment in which they are found and thus often differ. Some industries focus on R&D scientists—and create new knowledge that is manifested in new products that are sold to other industries. Others focus on other types of scientists—engineers—to incorporate new products and materials discovered in other industries into the production process of industries that make use of these discoveries—either as new machinery and equipment or as new intermediate materials. The latter involve expenditures that are generally not classified as R&D but that have many of the same properties in that they create assets and they involve substantial scientific effort.

This study continues the focus of our previous studies on transformational change. It complements previous studies in that it examines the importance of investments that are being made in the innovation process. But it extends the focus beyond just hardware like ICT that has provided the focus of much of macroeconomic productivity analysis and looks at a range of expenditures on intangibles. It complements previous studies on the Knowledge economy in that is interested in quantifying the amount of investment that is made in knowledge capital or what has come to be called Intangibles. And in doing so, it parallels previous work in that it recognizes substantial in-house investments are made here in workers—but not just in developing their skills, rather in having them develop new knowledge that the firm can harness for innovative activity. Investments are made both on R&D science-related investments and in non-R&D science-related investments. The former focus on basic science and early stages of knowledge development for new products and processes. The latter are more closely related to the applied sciences. Investments are also made by purchasing knowledge from outsiders—in the form of R&D services, patents, licences, blueprints, designs, and technological know-how.

2. Intangible Investments

Contrary to investments in machines, investments in knowledge capital involve an investment in an asset that is less tangible. An investment in a machine provides the firm with a capability to produce future goods. So too does an investment in knowledge. A visitor to a plant that has recently invested in a new machine can be shown the machine. But he is less likely to be shown the asset that results from investments in assets whose major benefit is an increase in knowledge—unless that knowledge has been embodied in an asset like a patent and not all innovations are patented (Baldwin and Hanel, 2003).

Intangible assets take many forms. The most familiar are R&D expenditures. These are primarily expenditures on the wages and salaries of scientists—but they also include expenditures on intermediate materials, machinery, equipment and buildings required for the scientific process. R&D expenditures produce new and improved products whose future value to the firm depends on how the market values the new products or process.

Expenditures on computer software have similar characteristics. Some software is purchased; other software is created within the firm by skilled software programmers. Many of these expenditures have a value that lasts into the future.

Placing a value on in-house intangible expenditures is important if the balance sheet of firms is to value a firm's assets correctly. But measuring this value has bedevilled the accounting profession because the ultimate value of the assets is difficult to ascertain. For one thing, markets for the knowledge are imperfect and not transparent. This is because the knowledge is often only useful in combination with other specialized inputs of the firm (its employees), and not easily transferable except via a takeover of the firm as a whole. This reduces the scope of third party markets for the product of intangible investments. Second, even where there are third-party markets for the asset or for the asset when combined with other assets via a takeover, the gestation period for the investment may be longer than one year and the interim value of expenditures is difficult to determine. For example, companies that develop software sometimes do not fully realize the value of the software until they are acquired by other firms that then incorporate the new products into their own offerings.[1]

Intangibles also offer challenges to national accounting statisticians who calculate Gross Domestic Product (GDP) by subtracting intermediate expenditures from total revenues to obtain value-added at the industry level that is then aggregated across all industries to

[1] See Aboody and Lev (1998) for a description of the issues surrounding the capitalization of software.

generate an economy-wide estimate of GDP. The size of industry value added will be determined by what expenditures are classified as intermediate expenditures on materials. Expenditures by firms can either be considered as intermediate expenditures or as investments—expenditures that create value in the future. Only the former are subtracted from revenues to create industry value added. If the expenditure is not an intermediate expenditure, the expenditure needs to be capitalized not expensed. And shifting an expenditure from the intermediate category to the investment category will increase GDP (Jackson, 2003). Depending on past investment profiles, it may also change the growth rate and estimates of productivity growth.

While expenditures on machinery and equipment, buildings and engineering construction (pipelines, rail lines, dams) are considered as investments in most National Accounts, many other expenditures that have an investment characteristic are not. There are exceptions. At present, the System of National Accounts in Canada capitalizes expenditures on exploration for oil, gas and minerals as well as software. And there are plans to capitalize research and development. But there are a wide range of other expenditures—from advertising, to training, to general management expenses—that the economics profession considers as having an investment component that are not capitalized.

Studies done for other countries (Corrado, Hulten and Sichel, 2005, 2006; Jalava, Ahmavarra and Alanen, 2007) suggest that intangible investments loom large by comparison to tangible investments. Moreover, when they are appropriately capitalized, the picture of growth and its origins changes dramatically. In particular, the ratio of investment to GDP rises substantially and the share of savings to GDP also increases.

This paper investigates the importance of intangible capital expenditures for Canada and the effect of reclassifying those expenditures that are presently treated as intermediate expenditures to investment expenditures. Section 3 discusses the categories of intangibles that are used in this paper and the rationale for doing so. Section 4 discusses the size of intangible investments. It begins by examining the composition of aggregate intangible expenditures for Canada. Comparisons are then made between tangible and intangible investments and the differences across industries in the composition of intangibles. Section 5 presents the methodology used to estimate the depreciation rates needed to calculate intangible capital stock. Section 6 presents estimates of intangibles capital stock and compares it to tangible capital stock. Section 7 concludes.

3. Intangible Expenditures

3.1 Categories of Intangibles

Generating an estimate of intangible investment requires assumptions about what constitutes an intangible expenditure and a reliable data source. The 1993 System of National Account (SNA 93) states that:

> Fixed assets are tangible or intangible assets produced as outputs from the production process that are themselves used repeatedly or continuously in other processes of production for more than one year. (Section 10.31)

This paper focuses on three categories—science-related intangible investments, mineral exploration investments, and advertising.

The paper differs from previous attempts to investigate the role intangible assets in three ways. First, other attempts to estimate intangibles have made use of ad-hoc sources of data—from advertising councils, from industry sources on investment. This paper makes use of data that are derived from internally consistent and comprehensive Statistics Canada data sources. Data on each of the areas covered here are available from a number of internal Statistics Canada sources and are already incorporated in the Input/Output tables. Series on intangible expenditures are provided to the Input/Output Accounts by individual industry surveys that collect detailed data on inputs like advertising and other purchases. Other information is taken from tax records. Still others, such as data on payments abroad for R&D and licences, come from the Balance of Payments. And Statistics Canada collects detailed investment data at the industry level that can be used to track investments on mineral exploration. All of this information is collected periodically—some annually, others from occasional surveys—and incorporated into the estimates of gross output, value added, materials and service inputs that are used to create annual estimates of GDP at the industry level in the Industry input/output accounts. More importantly, these industry accounts construct both industry make and use tables by commodity that provide detail on both commodities produced and commodities used by industry. This detail is used here to examine the extent to which advertising and science services are purchased by industry. Other information on own-account science expenditure is available from detailed industry data on employment and wages of individual occupations derived from Census and from the Labour Force Survey. Finally, Statistics Canada has developed concordances that allow various data to be integrated together into the set of industry categories over time that are used here.

While others have included a larger set of categories (in particular by extending the data to management and training), the quality of the data in these areas make the evaluation of the conclusions derived therefrom somewhat problematic. In some cases, other studies have had to make use of third party sources on research and development or advertising that are not integrated into Systems of National Accounts industry estimates to provide a coherent and consistent set of data. This paper makes use of Statistics Canada's own survey of R&D that has been integrated into the National Accounts as part of a Satellite Account.

This paper makes use of the Canadian System of National Accounts that has already carefully measured many of the categories of intangibles that have interested others—but have included many of them as part of intermediate expenditures or as wage payments. We choose to commence our investigations by examining those categories of intangibles where relatively high quality data exist.[2] Statistics Canada data sources in these areas provide a solid basis on which to rest estimates of expenditures in each of these areas

[2] Further work will extend our investigations into areas where measurement problems are greater.

since both inputs and outputs are carefully balanced within the Input/Output Accounts. In what follows, we discuss what is included in each category that we consider in this paper and briefly discuss the source of the data series used. More information on the data is contained in Appendix A.

The second novelty contained in this paper pertains to the breadth of the innovation expenditures considered. The paper extends the R&D category that normally receives the brunt of attention to a broader area of science-related expenditures that more fully encompasses science-related innovation expenditures.[3] As is argued in the next section, evidence suggests that R&D as it is normally measured covers only a portion of those science-related expenditures that are required to introduce long-lived innovations in a firm.

Third, the paper recognizes that the importance of classifying expenditures in a particular category as an investment as opposed to an intermediate expenditure depends on the rate of depreciation of the asset that is created. Of course, to be classified as an investment, the annual depreciation rate must be less than 100%--or the expenditure should be classified as an intermediate expenditure. But if the rate of depreciation approaches 100%, classifying an expenditure as an investment as opposed to an intermediate expenditure has less of an impact on estimates of gross national product—and the benefits of revising GDP needs to be offset against the uncertainty that is inherent in the estimates of some of the categories considered to be intangibles. To examine the potential relative size of the intangible capital stock, we compare intangible capital stocks based on varying depreciation rates with the stock of tangible capital. This allows an examination of the relative importance of intangibles, and suggests that there are benefits to capitalizing intangibles and adjusting GDP.

[3] See Baldwin, Beckstead and Gellatly (2005) for arguments on what needs to be included to fully capture science-based innovation expenditures.

In the following section, we motivate our focus—briefly with regards to advertising, mineral exploration expenditures and in somewhat greater detail for our science component—because our approach is more novel in this area.

3.1.1 Science and Innovation

Our first focus is on intangible investments on science. At its core are expenditures on research and development. But they only account for a portion of total science-related expenditures.

There is a widely-accepted definition of R&D, established by the OECD's Frascati manual (OECD, 2002). And statistics on R&D expenditures, collected in accordance with the Frascati manual, are published for a large number of countries as part of the OECD's Main Science and Technology Indicators. But these expenditures underestimate the total amount that domestic businesses spend on science-based innovation capital.

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 and are generally considered to be intangible investments.[4]

Unfortunately for our purposes, the traditional definition of R&D excludes much expenditure 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

[4] The 1993 SNA manual indicated that it considered R&D to be an investment but did not recommend that it be capitalized because of controversy around how narrowly it should be defined. The revised manual has now accepted that it should be capitalized.

Canada, 1991). 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). The emphasis on 'patentable' or 'appreciable' degree of novelty restricts most estimates of R&D expenditures to only a subset of total innovation expenditures. Innovation expenditures range from 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 that involve more mundane but nevertheless essential tasks.

Two issues have to be dealt with when classifying innovation expenditure as falling under R&D or not. The first has to do with dividing up a stream of innovation expenditures that ranges from the earliest stage of 'basic' research, applied research, experimental development that are considered as R&D and the latter stages that only involve practical implementation. In Frascati, basic research is defined to be experimental or theoretical work undertaken primarily to acquire *new* knowledge Applied research is defined to be original investigation to acquire *new* knowledge directed towards a specific practical aim or objective. Experimental development is defined as systematic work, drawing on existing knowledge gained from research and/or practical experience, which is directed towards producing *new* materials products   Each of these early stages that fall within the definition of R&D involves considerable uncertainty. The latter stages are distinguished from the first in that uncertainty has been resolved and only implementation of concept is still required.[5]

The second issue has to do with deciding whether the innovation involves an "appreciable" degree of novelty. Novelty has many dimensions. The innovation can be a world-first, a country-first or just a first for the firm involved. In Canada, only a small percentage of innovations are classified by innovators as world firsts (Baldwin and Hanel, 2003). If novelty is defined as a world-first, very little of scientific expenditures would be classified as R&D. On the other hand, novelty might be defined as a major

[5] Peleg (2003) notes that the tax code in the UK specifically excludes from its definition of R&D expenditures on commercial development that do not involve scientific or technological investigation or that occur after the resolution of uncertainties.

breakthrough. But Hollander (1965), in his study of Dupont's Rayon plants, found that most of the changes that led to productivity gains in rayon were incremental in nature. Use of this criterion to define novelty would leave little as R&D.

Companies that respond to R&D surveys need to first decide whether their project warrants sufficient novelty to be included and then must decide how to divide a project's expenditures between those done before and after 'uncertainty' had been resolved—a difficult decision after the fact. How companies make these decisions is not well understood—nor whether the decision criteria are the same across countries. Nevertheless, what is relevant for this paper is that expenditures reported under R&D cannot be expected to fully cover all relevant innovation expenditures because it is not expected that they do so. And the fact that a scientific expenditure may be incurred in part of the process where uncertainty has been more or less resolved or in the process of less than completely novel new products does not obviate either the usefulness of these expenditures or the need to capitalize them in the National Accounts.

The point that there are considerable scientific expenditures required for innovation that are outside of what is traditionally included in the R&D category has been made by others who have studied the innovation process. Mowery and Rosenberg (1989) in their case studies of the innovation process 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. But the expenditures in these areas are not consistently included within the ambit measured by traditional R&D measurement programs.

Rosenberg (1976) has emphasized the importance of engineering departments in developing innovations that stem not so much from new products but rather that are associated with the evolution of production processes (that create process as opposed to product innovations)—especially in industries producing standard materials or durable consumer goods. In these industries, operating conditions are difficult and economies of scale depend on the maintenance of capacity in each part of an integrated system of processes. The breakdown of any segment of the production process threatens the integrity of the whole. As Rosenberg recounts, production-engineering facilities are used to identify technical imbalances and resolve bottlenecks that, in turn, allow for improvements in productivity.

These activities involve expenditures both internal and external to a firm. Within a firm, expenditures on scientific activities consist of the payment of wages and salaries of scientists and related support personnel, payments of capital services derived from the tangible capital used by scientists, and payments for materials that are needed. But expenditures are also made for know-how in the form of outside consulting and other forms of technological know-how, via licences or patents. Evidence from innovation surveys indicate these other expenditures are at least as important as the core expenditures that are classified as R&D.

Confirmation of the importance of non R&D innovation expenditures has been provided by a range of survey evidence. Baldwin, Beckstead and Gellatly (2005) report that Canadian firms think of their innovation investments as involving more than just R&D. Using survey evidence for Israel, the U.S. and Canada, Kamin et al. (1982) provide evidence that non-R&D science-related expenditures that do not include capital investments account for about half of total innovation expenditures.

Johnson, Baldwin and Hinchley (1997) using a survey of new Canadian firms from a wide range of industries report that while substantial investments were made in R&D, even more substantial science-related investments occurred elsewhere in the form of expenditures for acquisition of technological know-how. These exclude investments in machinery and equipment but include consulting services from engineers, architects, licences, patents and other technological 'know-how'. And outside of these science-related expenditures are the marketing costs associated with introducing innovations. In industries which are less R&D intensive (the majority of industries), technology expenditures outside of machinery investments are twice as important as expenditures on R&D. Even in those industries where R&D intensity is higher, technology expenditures are half as large as R&D expenditures.

The same story is revealed by evidence from specialized innovation surveys. Baldwin and Hanel (2003) use the 2003 Survey of Innovation and Advanced Technology that covered the Canadian manufacturing sector and report that only 17**%** of a firm's most important innovation expense involved basic and applied research but 10**%** involved the acquisition of technology (e.g., patents, trademarks, licenses, specialist consulting services, disclosure of know-how).

The importance of non R&D innovation expenditures has been reported using Innovation surveys in other countries. Evangelista, Sandven, Sirilli and Smith (1997a) report on innovation costs taken from European Innovation surveys that 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 or patents. In keeping with the Canadian results reported above, the non-R&D innovation investments are generally at least as large as R&D investments. Outside of machinery and equipment, R&D captures only about half of the investments that are required for innovation.

One way to estimate the size of the science-related expenditures outside of R&D is to compare the total wage and salaries paid to all scientists to the wages and salaries paid to R&D scientists. Baldwin, Beckstead and Gellatly (2005) make use of earnings data derived from the Census 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 and to compare it to the wages of R&D scientists derived from R&D surveys.

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. Baldwin, Beckstead and Gellatly (2005) adopt this approach, but extend it beyond just R&D personnel using Census of Population Data to encompass a broader group of science workers who are regarded as producing knowledge capital that is important for the production process—all scientist and engineers (computer and mathematical scientists, life science, physical sciences, social sciences, and engineers).

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 science and engineering (S&E) categories that are commonly seen to produce knowledge capital of a scientific nature, the importance of this process to an economy can be measured

The Canadian S&E estimate so calculated is almost twice as large as the official 1996 estimate of R&D personnel. R&D represents a core knowledge-creating function, but as Rosenberg argued and the innovation surveys show, R&D is far from the only means by which firms invest in the development of science-related intellectual capital associated with innovation and therefore R&D scientists make up only a portion of all scientists. Differences in employment between R&D personnel and S&E workers also translate into significant differences in earnings. For Canada, wages and salaries paid to R&D personnel is only one third the size of the total earnings of all S&E employees in 1996. There are considerable expenditures on science personnel that are not captured in the wages and salaries of R&D personnel.

Ample evidence then exists, both from historical studies of the innovation process and from statistics surveys of industry participants that science expenditures outside of R&D are important—partly because firms incur considerable wage expenditures on scientists outside of the narrow definition that is normally applied when defining R&D, but also because firms purchase considerable intellectual capital from outside of the firm—and the latter is often not included in R&D estimates that only focus on activities conducted *within* the firm. Baldwin, Beckstead and Gellatly (2005) provide an indication of the lower limit on the size of the latter using Canadian balance of payments data that capture payments from abroad that Canadian firms make for

> a) R&D services, which cover payments for basic and applied research and experimental development of new products and processes;
> b) 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); and
> c) 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.[6]

In 1999, expenditures made abroad by Canadian firms in these three areas are 76**%** as large as their R&D expenditures in Canada. And of course to the extent that firms located in Canada are purchasing similar services from other firms within Canada, the amount spent by any firm on science inputs from other firms would be even larger relative to the expenditures that they perform on conducting their own R&D.

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[6] None of these expenditures are included in the official R&D statistics that consider only work performed in Canada—see Baldwin, Beckstead and Gellatly (2005).

3.1.2 Mineral Exploration Expenditures

Science-based expenditures associated with R&D have fascinated analysts partially because of their association with the presumed modernity of laboratory facilities. But the expenditures that resource-based economies like Canada makes on mineral exploration have characteristics that mean they should also be classified as intangible assets.

These expenditures provide new information that is useful for production many years after it is made. Early stage exploration expenditures are used to develop knowledge on where mineral resources are found and on the economic properties of the mineral or petroleum reserves. Like R&D, they often provide little in the way of tangible assets. It is in the later stage development expenditures when mine heads, and drill holes provide more tangible forms of development and that are more closely associated in time with production. R&D can be viewed as early stage investments in innovation that are meant to reduce uncertainty. Exploration expenditures do the same for the resource economy.

The early stage exploration expenditures provide knowledge assets—assets that have economic value. The assets are often traded as rights to exploit a resource or as knowledge about the underlying geology that can be used in other exploration ventures in other regions. In the former case, value can be deduced from transactions in land rights. In the latter case, the value is embedded in the value of the firm and in the individuals who acquire capabilities in interpreting geological information.

In many cases, the exploration expenditures provide knowledge about an asset whose economic exploitation must await other events that change the economics of exploitation—an increase in the price of the mineral, or the development of infrastructure that would make the development of the asset economic. These discoveries or the assets produced can predate production by many decades. For example, offshore oil fields close to Newfoundland were found as a result of drilling expenditures incurred in the 1980s that were not brought into production until after 2000.

3.1.3 Advertising Expenditures

Advertising expenditures provide firms with a reputation that if it extends beyond the present and has an impact on the value of the firm should be considered an investment in intangibles. They provide brand value that has long been recognized as a valuable intangible asset.

Advertising expenditures, like mineral exploration expenditures, involve a mix of categories that provide short-run effects and longer run impacts. The transmission of information on the latest product prices via advertising primarily has a short-run impact. But many expenditures serve to instil long-run loyalties—and enhance the value of the firm. Studies in marketing provide numerous examples of trademarks that have had long-lasting effects—from the Morton salt trademark to the baking soda cow—that served to engender sales to a generation of consumers. Canadian iconic brands include Hudson Bay, Canadian Tire, Tim Hortons, and Cirque de Soleil (Hanna and Middleton, 2008). The value of these brands is revealed by the high price that is placed in acquiring product lines by large companies that specialize in marketing a broad range of consumer product lines.

3.2 Implementation

3.2.1 Science Expenditures

In this study, we measure total innovation expenditures on science using four components—research and development, software, other own account science, and the purchase of scientific services and intellectual property.

We start with estimates of research and development. These estimates are primarily based on the estimates of research and development expenditures developed by the Science, Information and Electronic Division of Statistics Canada. These expenditures include the wages and salaries of scientists, purchased intermediate materials and capital services from investment in buildings and machinery and equipment. Adjustments are made to the series to accord with recommendations of the SNA (2008) to fit into definitions required to be compatible with the National Accounts. In particular, the investments in physical capital are accumulated into capital stock and the capital services associated with this stock are added to wages and salaries. More detail is provided in Appendix A.

The survey based R&D estimates are augmented to include estimates of 'other professional, scientific and technical services' from the Input/Output accounts. The latter includes, for example, payment for research and development services, business consulting services of a wide variety (from general management, to finance, to strategic business plants, to accounting, to the development of advertising strategies).

Second, we also include in the general science category all expenditures on software. These are taken directly from the Input/Output Accounts. These estimates include wages and salaries of software engineers that proxy own-account production, purchases of packaged software and programming services. The software expenditures are consistent in aggregate with the estimates produced in Jackson (2003).

Third, we create a category that corresponds to the own-account 'other' science that was discussed previously. Own account science and engineering expenditures consist of wages and salaries devoted to scientists and engineers in each year. This category is created from occupational data on scientists taken from benchmarks developed from Census data interpolated on an annual basis using the Labour Force Survey.[7] The category consists of total wages and salaries of all scientists less the wage component that is already included in research and development and in software.

[7] Using the methodology developed in Beckstead and Gellatly (2003b)--???.

Fourth, we develop a category that takes into account the purchased services that we previously outlined that are so important to the innovation process. These consist of three main categories. The first are those involving purchased intellectual property that involves transferable property rights—primarily the royalties and licence fees that are expended on intellectual property. The second involves purchased inputs that include architect, engineering and scientific services. These include expenditures related to construction of buildings, engineering services related to roads, electrical, rail and other engineering works.[8]

3.2.2 Advertising Expenditures

Advertising estimates are composed of business expenditures on items like advertising in print media, on radio and television, promotions and contests, business flyers and signs, advertising signs and displays, advertising services, advertising and promotions.

Estimates here are taken from the input-output tables developed by Statistics Canada for calculating industry GDP using the value added approach.

3.2.3 Mineral Exploration Expenditures

Mineral exploration expenditures consist of all exploration drilling, geological and geophysical expenditures associated with the predevelopment stage of mineral and oil gas industry. The data are taken from the Investment and Capital Stock estimates that feed into the National Accounts. See Appendix A for more details.

3.2.4 Time series consistency

The source data for the intangible estimates is drawn from multiple sources and in some cases, the sources have different taxonomies over time in both the industry and commodity dimensions. In a number of cases, the disaggregated data employed to calculate the industry estimates have time series inconsistencies where classifications change. The discontinuities have been removed.

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[8] For a discussion of the importance of engineering investments, see Baldwin and Dixon (2008)—add in references.

The expenditure estimates and data sources for each category are discussed in detail below and presented in Table 1.

Table 1: Intangible Assets by Composition and Data Source

Asset	Comprises	Data Source	Current Treatment
Advertising	advertising in print media, radio and television; promotions and contests; business flyers; signs	Statistics Canada's L-Level Input-Output Tables	Intermediate Expenditure
Purchased Science and Engineering Services	Royalties; licensing fees; architectural services	Statistics Canada's W-Level Input-Output Tables	Intermediate Expenditure
Mineral Exploration	Exploration Drilling; geological and geophysical expenditures;	Investment and Capital Stock Division estimates	Capitalized as an investment
Software	Purchased software (pre-packaged and custom designed); Own account software	Statistics Canada's Final Demand Input-Output Tables	Capitalized as an investment
Research and Development	Wages and salaries of individuals involved in research and development, purchased materials, investment; other scientific services	Science, Information, Electronic Information Division of Statistics Canada / Statistics Canada's W-Level Input-Output Tables	Not currently included in Gross output estimates / Intermediate Expenditure
Own Account Science and Engineering Services	Wages and salaries of individuals classified as scientists and engineers net of own account software expenditures and research and development wages and salaries	Labour Force Survey and the 1981, 1986, 1991, 1996 and 2001 Censuses	Not currently included in Gross output estimates

The current Canadian System of National Accounts practice is to treat software and mineral exploration as investments while advertising and purchased science and engineering services are treated as intermediate inputs. There are currently no own account research and development or scientific expenditures in estimates of industry value added. The overall estimate of intangible expenditures reported here is produced by combining all estimates. In contrast, tangible investments are measured by the present total investments in machinery and equipment, buildings, engineering minus exploration and software investment.

Estimates of intangibles in Canada are disaggregated by industry and by expenditure type. The industries considered here are business sector S-level industries that correspond to 2-digit NAICS industries except for Finance, Insurance and Real Estate, which is a composite of NAICS 52 (Finance and Insurance), NAICS 53 (Real Estate and Leasing and Rental) and NAICS 55 (Management of Companies and Enterprises). Industries in Canada that have a large public component are not considered. The business sector aggregate adapted here does not include public administration (NAICS 91), Education (NAICS 61) or Health Care and Social Assistance (NAICS 62).

The industry disaggregation is accomplished using data present in the input-output accounts and from the census. Labour income based on own account estimates taken from Census and Labour Force Survey data are benchmarked to the labour income in the Productivity Accounts. Capital Services are estimated by taking the ratio of operating surplus per industry and multiplying it by the percentage of industry tangible capital that is purchased for the R&D process.

4. Intangible Investments in Canada

4.1 Total Economy

The share of intangible investments by three main categories-advertising, mineral exploration and all science (R&D, Software, Other Science Own Account, and Purchased Services) is presented in Table 2. Science and innovation intangible expenditures are the most important—accounting for an average of 77.4% of total intangible investments over the period 1981-2001. Science related innovation expenditures have increased their share over time, rising from 76.5% in 1981 to 78.4% in 2001. Advertising is second with an average share of 18.3**%** and its importance varies procyclically. Mineral exploration is third, making up 4.3 of intangible expenditures on average. The share of mineral exploration fell from its levels of the early 1980s to lower levels in the mid 1980s and has steadily grown since then in response to the resource boom (Figure 1).

Investments in software are the smallest component of all intangibles for the sample period, having a share of 2.5**%** in 1981 and increasing to 6.7**%** by the end of the period. In keeping with the onset of the computer revolution, the share of this component more than doubles over the period.

While R&D has garnered the majority of attention in innovation studies, it accounts for only between 17.6 and 27.3 percentage points of total intangible investments—though its share grew in the late 1990s. The own account other science related investments are considerably more important than R&D. And even the purchased science and engineering component is at least as large as R&D. A portion of this comes from imports of software.[9]

The own-accounts other science, after increasing in the early 1980s, falls slightly thereafter — going from 33.0**%** in 1981 to 24.4% by the end of the period. Investment in machinery and equipment outside ICT has tracked the expenditures on other scientists closely over this period. (See Figure 2). Purchased engineering also declines slightly through the period—from 23.4% of the total in 1981 to 20.1% in 2001. Although the three categories (R&D, Software, and Other Science Own-account) have a relatively stable average share in the total over the time period, there has been a slight shift over the period. The share of own account science expenditures and purchased science decreased during the 1990s while R&D and software increased slightly.

[9] The importance of R&D would be even smaller if exports of R&D were removed from the own-account R&D expenditures as is done in some satellite accounts of R&D.

The decline of other own-account science comes mainly from a switch in the proportion of total scientists to the software category. This is in keeping with other findings that investment in machinery and equipment over this period switched to ITC from more traditional investment goods (Baldwin and Gu, 2007).

Table 2: Share of Intangible Investments by Asset Category (Current $)

				Total Science			
					Own Account		
	Advertising	Mineral Exploration	Total Science	Purchased Science & Engineering	R&D	Software	Own Account Other Science (OAC)
1981	17.7%	5.8%	76.5%	23.4%	17.6%	2.5%	33.0%
1985	18.4%	5.2%	76.3%	20.6%	18.4%	3.9%	33.4%
1990	19.4%	3.1%	77.6%	22.5%	16.6%	5.5%	32.9%
1995	17.7%	3.7%	78.7%	21.7%	19.1%	7.1%	30.8%
2001	15.8%	5.8%	78.4%	20.1%	27.3%	6.7%	24.4%
Average	18.3%	4.3%	77.4%	21.3%	19.0%	5.6%	31.4%

Figure 1: Share of Intangible Investments: 1981-2001

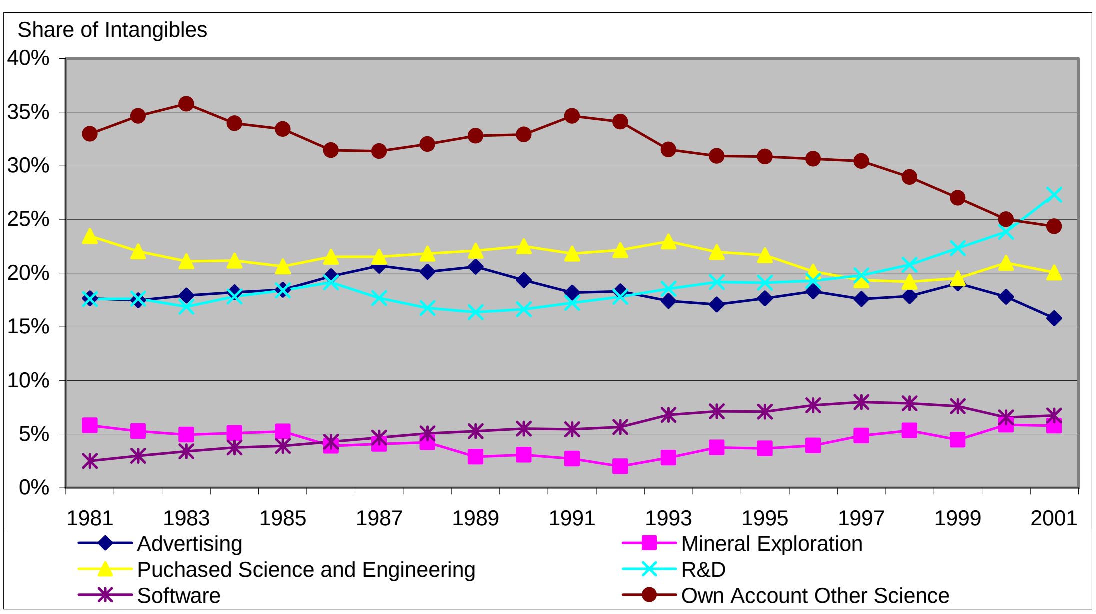
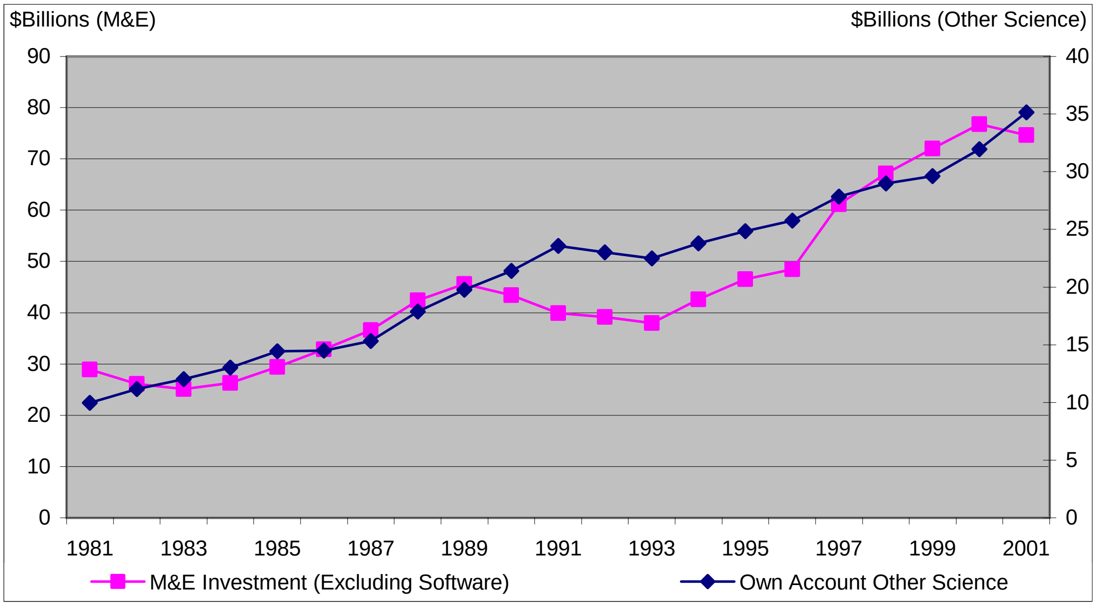
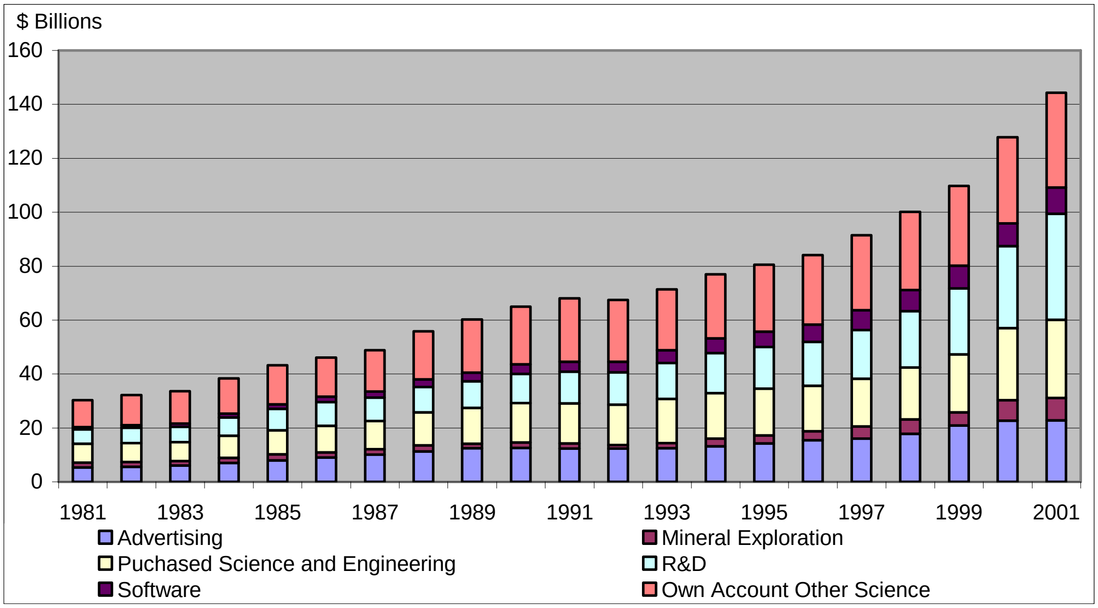


Figure 2: Own Account Science vs. M&E: 1981-2001



Intangible investment in Canada has expanded by an average of 8.2**%** per year from 1981 to 2001, rising four fold from around $30 billion in 1981 to $144 billion in 2001 (Figure 3). Software investment expanded the fastest, with an average annual growth of 13.9**%** per year. R&D investment had the second highest annual average growth rate (10.8**%**), followed by mineral exploration (10.4**%**), advertising (7.7**%**), purchased science and engineering services (7.5**%**) and own account science and engineering services (6.6**%**).

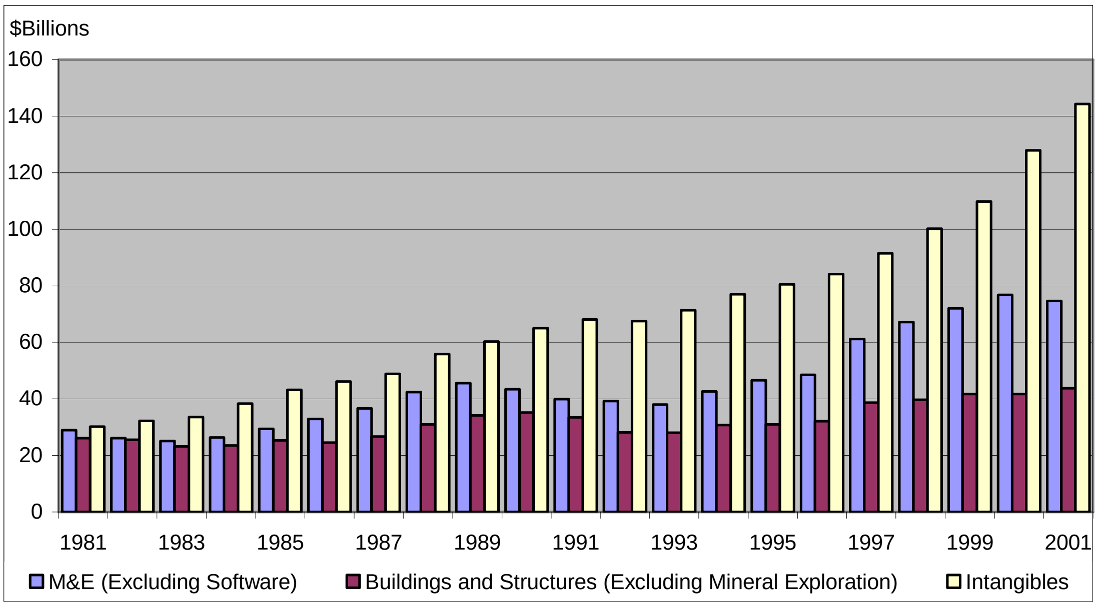
Figure 3: Intangible Composition: 1981-2001



Analyses of the determinants of economic growth often focus exclusively on investment in tangibles. Recent studies on the knowledge economy suggest that knowledge workers have been growing more quickly than total employment (Beckstead and Vinodrai, 2003; Baldwin and Beckstead 2006). Since many knowledge workers produce intangibles, growth in investment in intangibles that come from wage payments should also have been relatively high. At issue is the extent to which it is larger than the growth in investments in tangible assets—machinery and equipment, buildings, and engineering structures. If so, the omission of intangibles from total investment will underestimate the rate at which overall investment has been growing.

Investments in tangible capital, machinery and equipment or buildings and structures, has not kept pace with intangible investment. Investment in machinery and equipment rose at an average rate of 5.2% while buildings and structures only increased at an annual average of 2.9% over the period (Figure 4). As a result, although expenditures on all three capital types are roughly equal in the early 1980s, by the late 1990s and early 2000s, investments in the intangible assets considered here are around twice those in machinery and equipment, and four times larger than investments in buildings and structures. Moreover, investments in intangibles are less cyclical than investments in tangibles. The recession of the early 1990s saw a relatively larger pullback in investment in tangibles than intangibles. And by the end of the decade, the difference between the absolute level of investment in intangibles and tangibles had widened considerably from the 1980s.

Figure 4: Investment Components: 1981-2001



4.2 Industry Differences

Baldwin and Hanel (2003) in their study of the Canadian innovation system stress that inputs to the innovation process differ by industry—with some relying more on R&D scientists and others more on other types, such as engineers. Concomitant with the differences in the innovation profiles across industries, the type of intangible knowledge that is key to innovation in each industry also varies.

Mining, Oil and Gas is dominated by mineral exploration (Table 3). Construction industries focus on purchased science and engineering, which consists mainly of engineering and architect services. Advertising services is most important in Retail Trade, Arts/ Entertainment and Recreation, Accommodation and Food Services, and Other Services.

At the aggregate business-sector level, R&D is dominated by the other own account and purchased science services categories. This is also generally true at the industry level—even in those industries that account for most of the R&D. Other own account science and engineers is most important in Agriculture and Forestry, Utilities, Manufacturing, Wholesale, Information and Culture, Transportation, Finance, Administrative Support, and Utilities.

Professional, Scientific and Technical Services is the one sector where R&D is the most important category—though even here own account other science comes second. R&D is also relatively important in Manufacturing and Wholesale.

Table 3: Share of Intangible Investments by Asset Category in each Industry

	Advertising	Mineral Exploration	Purchased Science & Engineering	R&D	Software	Own Account Other Science (OAC)
Bus. Sect	18.3%	4.3%	21.3%	19.0%	5.6%	31.4%
Agriculture	3.9%	0.0%	34.1%	10.6%	7.1%	44.4%
Mining, Oil&Gas	1.4%	77.5%	5.5%	9.2%	1.2%	5.3%
Utilities	6.7%	0.0%	5.9%	13.2%	11.7%	62.5%
Construction	5.0%	0.0%	90.4%	3.4%	0.3%	0.8%
Manufacturing	18.0%	0.0%	17.3%	23.2%	2.3%	39.2%
Wholesale	26.4%	0.0%	4.7%	22.5%	5.6%	40.8%
Retail	48.9%	0.0%	6.1%	9.8%	7.6%	27.5%
Transportation	19.1%	0.0%	8.9%	6.3%	19.1%	46.7%
Info	26.3%	0.0%	16.2%	14.4%	11.0%	32.1%
FIREL	27.2%	0.0%	2.0%	15.6%	16.1%	39.2%
Professional	5.2%	0.0%	11.4%	44.5%	4.1%	34.8%
Admin	35.1%	0.0%	3.2%	14.7%	11.5%	35.5%
Arts	52.0%	0.0%	16.1%	9.0%	6.5%	16.3%
Accommodation	46.4%	0.0%	42.3%	9.3%	0.5%	1.4%
Other	41.4%	0.0%	2.7%	10.9%	10.0%	35.1%

Although all industries are engaged in intangible investments, when viewed as a share of total business sector expenditure (Table 4), the investments tend to be concentrated in a smaller number of industries. The largest share of total R&D is found in Manufacturing (39.2**%**), followed by Professional, Scientific and Technical (26.7**%**), FIREL (8.9**%**) (Table 4). Combined, these three industries account for 74.8% of all R&D expenditures. Similar concentrations are found in other intangible categories. The top three industries account for 60.1% of advertising investment, 84.5% of purchased science and engineering investment, 53.7% of software investment and 68.1% of own account other science investment.

Despite the concentration of intangible expenditures in particular industries, the innovative activities implied by those expenditures are spread across the entire business sector. Intangibles are prominent in both the goods and services sectors. A larger share of advertising and software investments are made by service sector industries while a larger share of purchased science and engineering and mineral exploration expenditures occur in the goods sector. The goods and services sectors invest about the same amount in R&D and own account other science.

Table 4: Share of Intangible Investments by Asset Category by Industry

			Total Science			
	Advertising	Mineral Exploration	Purchased Science & Engineering	R&D	Software	Own Account Other Science (OAC)
Agriculture	0.1%	0.0%	0.6%	0.3%	0.5%	0.6%
Mining, Oil&Gas	0.4%	100.0%	1.5%	2.8%	1.1%	0.9%
Utilities	0.9%	0.0%	0.6%	1.5%	4.5%	4.1%
Construction	3.0%	0.0%	48.6%	1.9%	0.6%	0.3%
Manufacturing	31.9%	0.0%	28.9%	39.2%	13.2%	41.2%
Wholesale	8.4%	0.0%	1.4%	8.1%	6.7%	6.9%
Retail	13.2%	0.0%	1.3%	2.6%	6.8%	4.2%
Transportation	3.3%	0.0%	1.3%	1.0%	10.6%	5.1%
Info	7.0%	0.0%	3.7%	3.9%	11.7%	5.8%
FIREL	15.8%	0.0%	1.1%	8.9%	28.7%	15.0%
Professional	3.4%	0.0%	7.0%	26.7%	8.6%	11.9%
Admin	3.2%	0.0%	0.3%	1.3%	3.3%	2.0%
Arts	3.0%	0.0%	0.7%	0.5%	1.2%	0.5%
Accommodation	3.9%	0.0%	2.9%	0.7%	0.2%	0.1%
Other	2.6%	0.0%	0.1%	0.7%	2.1%	1.3%
Goods Industries	36.2%	100.0%	80.3%	45.6%	20.0%	47.1%
Services Industries	63.8%	0.0%	19.7%	54.4%	80.0%	52.9%

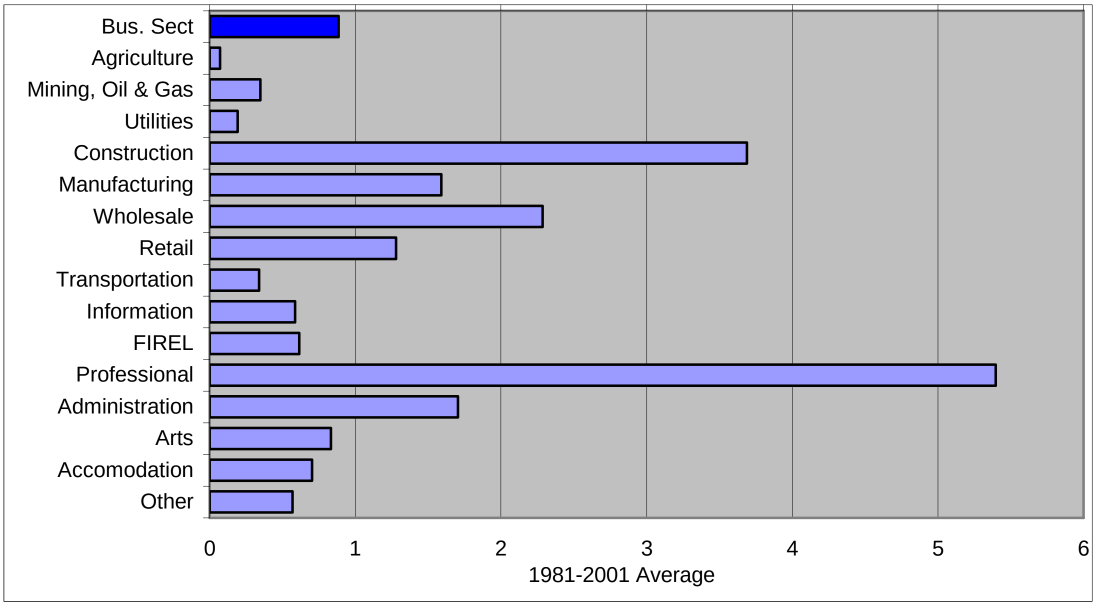
The fastest growth in intangible expenditures comes from software (Table 5). In the overall business sector, software has grown most rapidly thereby increasing its share of total science expenditures. This is also the case across most industries. The rate of growth of software expenditures is as high or higher than most other categories in Utilities, Construction, Manufacturing, Transportation and Warehousing, Professional, Scientific and Technical, Arts and Entertainment, Accommodation, Food and Beverages, and Other Services. Since software expenditures supported the introduction of Information and Communications technologies, the fact that growth was rapid everywhere bears testimony to the widespread impact of the ICT revolution.

Table 5: Intangible Investment Growth by Asset Category in each Industry

			Total Science			
	Advertising	Mineral Exploration	Purchased Science & Engineering	R&D	Software	Own Account Other Science (OAC)
Bus. Sect	7.7%	10.4%	7.5%	10.8%	13.9%	6.6%
Agriculture	8.4%	0.0%	4.6%	18.0%	10.1%	12.4%
Mining, Oil&Gas	7.9%	10.4%	12.8%	15.5%	12.7%	5.4%
Utilities	13.5%	0.0%	10.5%	11.1%	17.1%	-1.0%
Construction	5.2%	0.0%	4.7%	6.0%	14.1%	13.6%
Manufacturing	5.7%	0.0%	10.3%	8.3%	13.9%	7.4%
Wholesale	9.8%	0.0%	24.3%	19.3%	20.4%	3.0%
Retail	7.3%	0.0%	57.4%	12.5%	17.2%	3.6%
Transportation	3.9%	0.0%	5.0%	5.8%	9.3%	7.2%
Info	7.9%	0.0%	6.6%	11.6%	20.2%	11.9%
FIREL	9.4%	0.0%	16.1%	11.7%	9.9%	11.9%
Professional	11.8%	0.0%	13.1%	13.5%	17.1%	3.9%
Admin	12.4%	0.0%	18.8%	15.5%	17.9%	13.0%
Arts	13.6%	0.0%	5.8%	12.6%	15.0%	7.7%
Accommodation	10.9%	0.0%	7.9%	10.7%	29.0%	3.7%
Other	10.8%	0.0%	11.6%	15.2%	17.0%	7.1%

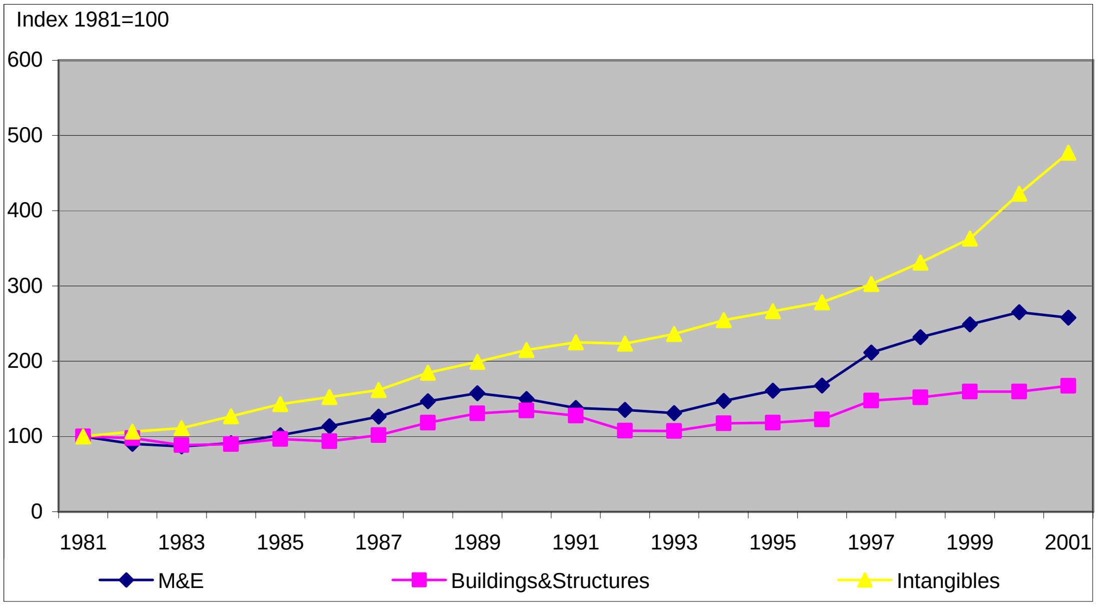
Industries vary in terms of the relative importance of intangibles compared to tangibles. Intangibles are less important than tangibles in Agriculture, Forestry, and Fishing, Mining, Oil and Gas Extraction, Utilities, Transportation and Warehousing, Finance, Insurance, and Real Estate, Information and Cultural, Arts, Entertainment and Recreation, Accommodation and Food Services, and Other Services (Figure 5). Intangibles are more important than tangibles in Construction, Manufacturing, Wholesale and Retail Trade, Professional, Scientific and Technical Services, Administrative Support and Waste Management.

Figure 5: Intangible Relative to Tangible Investment: 1981-2001 Average



At the aggregate level, expenditures on tangibles like machinery and equipment are more cyclical than expenditures on intangibles (Figure 6). Intangibles grew more or less monotonically over the entire period, while tangibles fell back during the recession of the early 1990s. Inputs that involve higher adjustment costs have less cyclicality. Skilled labour tends to be hoarded in downturns because it is costly to hire and train this type of worker because of the non-codifiable knowledge that is embedded in a firm and that has to be imparted to skilled labour in order for the firm to take advantage of its capabilities. Intangibles also share some of the same properties—perhaps because they are complementary factors to skilled workers.

Figure 6: Investments by category over time: index 1981 = 100



5. Intangible vs. Tangible Capital Stocks

The relative size of the stock of intangibles relative to the stock of tangible capital ultimately depends on the deprecation rate of intangible investments. If the depreciation rate is sufficiently large, there may be little benefit to adjusting GDP and National Balance Sheet estimates to include intangible capital stocks.

5.1. Capital Stock Estimation

To assess how large the stock of intangible capital may be relative to the stock of tangible capitals, three arbitrary depreciation rates are used: 25%, 50% and 75%. These bound rates that have been used elsewhere by Corrado et al. (2006) which range from 20% for R&D[10] to 60% for brand equity (or advertising).

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[10] Okubo et al. (2006) summarize a range of academic studies for R&D noting that estimates for the depreciation rates range from 12 to 25%, with Pakes and Shankerman (1984) reporting the average annual decay rate of R&D as 25%; Nadiri and Prucha (1996) the annual decay rate of *industrial* R&D as 12%; Lev and Sougiannis (1996) find an average of 15% across six industries; and Bernstein and Mamuneaus (2004) report 25% for the *manufacturing* sector.

The streams of intangible investments are transformed into capital using the perpetual inventory method (PIM) in the following way:

(1) $$N_t = I_t + (1-\delta) N_{t-1}$$

where I_t denotes gross investment in intangible capital at time *t*, N_t, denotes the intangible capital stock at time *t* and δ denotes the depreciation rate of intangible capital that is assumed to be constant over time.

5.2.Deflation

To implement the PIM methodology for calculating the intangible capital stock, it is necessary to deflate the nominal investments to obtain their corresponding volume measures which requires price deflators. These are difficult to obtain for these types of investments for a number of reasons. First, a portion of an intangible investment like R&D is both produced and consumed internally and prices are not readily available. The value of the R&D is either embedded in the value of the goods and services of the products being sold in the market or it is the net present value of future streams of earnings that will be derived from the sale of the knowledge associated with the R&D being undertaken—in future licences, patents, or other forms of technology payment. Even when R&D services are traded between companies, the unit of measurement is heterogeneous for different outputs because it is project specific and therefore not easy to define.

In contrast, enterprises can report what they spend on wages, salaries, third-party contractors, investments in machinery and buildings and other expenses associated with the costs of conducting R&D, creating software, and other forms of intangible assets.

One way then to estimate the flow of the volume goods and services that are not sold in markets is to deflate their value by a price index based on the input costs required to produce them—that is derived from wages and salaries, investment goods, and intermediate purchased expenses that go into their production. This is the approach used by the National Accounts to measure the real value of output of government and the construction assets (buildings and engineering structures) that are referred to as own-account construction.

The disadvantage of this approach is that it implicitly builds in an assumption that no productivity gains occur in the production process—because normally the price of the final product increases at less than the rate of input costs if there are any productivity gains in production over time. This implicit assumption is probably particularly inappropriate generally and even more so for high-tech goods. Productivity growth has been higher in science-based and ICT industries than elsewhere (Beckstead and Gellatly, 2003).

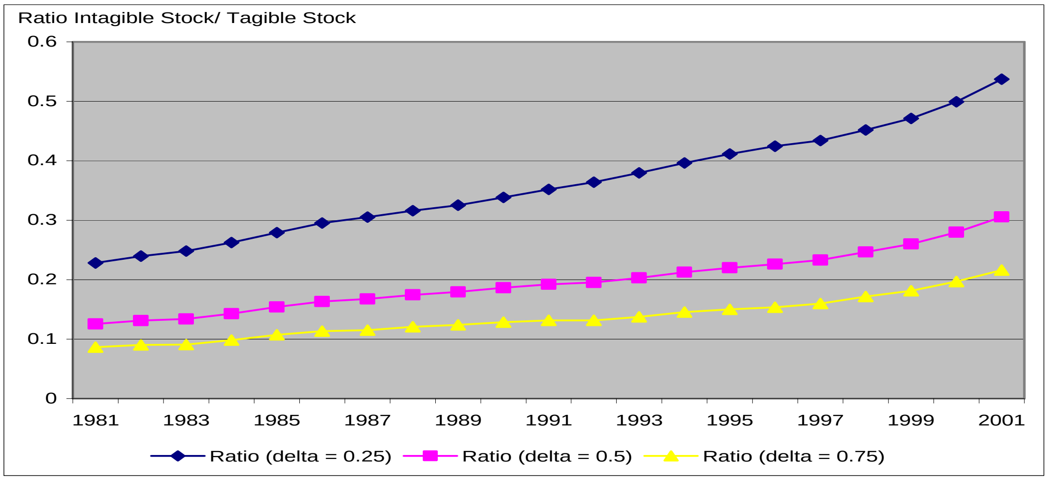
An alternative is to apply the output deflator for the business sector as a proxy for the price of intangibles. Because of productivity growth, this price deflator has increased less than the increase in unit input costs. Since we are dealing with business sector data, we apply the implicit GDP price deflator from the business sector following the argument of Corrado et al. (2006). Using this deflator implicitly involves the assumption that the production of intangibles experienced average rates of productivity growth—provided input costs for the production of intangibles were going up at about the average increase experienced by other inputs in the economy.

In this paper, we use the business sector deflator.

5.3. Intangible Capital Relative to Tangible Capital

The stock of tangible capital used for comparison with the intangible capital stock is derived by the PIM where I_t is real investment in tangible capital. The variable depreciation rate, δ_t, is derived from the Canadian Productivity Accounts (Statistics Canada, 2007) and varies from 9% in 1981 to 13% in 2001 for the business sector.

Figure 7: Intangible relative to tangible capital



When the business sector value added price index is used to deflate intangible expenditures, and a 25% depreciation rate is applied, the ratio of intangible to tangible capital averages 36% over the sample period and ranges from 22% in 1981 to 53% in 2001 (Figure 8). Although the ratio declines as the deprecation rises, even using a 75% depreciation rate results in an intangible capital stock that is, on average, 14% of the stock of tangible assets.

In all cases, intangible capital stock increases relative to tangible capital stock over the study period. The growth rate of the ratio of intangible to tangible capital is not sensitive to the choice of depreciation rate. (Table 6). The growth over the period was 4.4**%** annually when a depreciation rate of 25% was employed. The magnitude of the intangible to tangible capital ratio is higher for lower depreciation rates, however, the average annual growth rate over the entire period is very similar between low and high depreciation rates (4.4% as opposed to 4.6%).

Table 6: Growth in Ratio of Intangible Capital to Tangible Capital

Depreciation Rate (%)	Business Sector Deflator
25	4.4
50	4.6
75	4.7

6. Conclusion

Investments in intangible capital have become increasingly important in the Canadian economy. These investments take several different forms—in scientific knowledge, in creating brand value and in providing an understanding of the location of natural resources.

Traditional estimates of scientific knowledge have focused on R&D and have been based on sources that develop data using the Frascati Manual to guide them. Baldwin, Beckstead and Gellatly (2003) argue that this has the potential for underestimating investments in scientific knowledge—for several reasons. First, it misses substantial expenditures that are made adapting rather than inventing new products and technologies. Second, it ignores the large amount of science that is purchased in the form of technological know-how, whether it be outside R&D (Frascati focuses only on R&D performed within a firm), consulting engineering and other services, patents, architectural services, and blueprints. This paper examines this issue using an expanded definition of knowledge investment that includes not just expenditures on 'novel' processes where there is a degree of uncertainty, but also expenditures on knowledge creation on the factory floor, and purchased knowledge in the form of externally performed R&D, patents, and licences. The paper uses supply-use tables from the Input/Output system produced by the Industry Accounts Division and Census of Population data on the wages and salaries of scientists to produce more complete estimates of total investments made by Canadian business on scientific endeavours. R&D as traditionally measured makes up only about a quarter of the total of science related expenditures. Own account scientific endeavours and purchased science are much larger.

Other intangibles that are covered here include software, mineral exploration and advertising expenditures.

The importance attributed to intangibles accords with previous studies (Corrado, Hulten and Sichel, 2005, 2006; Jalava, Ahmavarra and Alanen, 2007). The intangible investment estimates are at least as large as machinery and equipment or building investment in the early 1980s, and have expanded relative to tangible investments over time. By the end of the 2001, intangible investments are larger that total tangible investments. As a result, the ratio of intangible capital stock has increased relative to tangible capital stock over the period.

Every business sector industry in Canada engages in investments in intangible assets of one kind or another—though the type of intangible investment that dominates differs across industries. This stands in contrast to the R&D estimates alone which would suggest that the manufacturing industry is the most important source of knowledge or intangible asset creation. Service sector industries are as important as goods sector industries when it comes to investments in intangible assets.

Moreover, a noteworthy share of intangible investment in Canada is made in understanding the natural world. These expenditures are made with the explicit purpose of one day finding and extracting non-renewable resources that are abundant in Canada and make an important contribution to national wealth.

The knowledge and intangible investments made across all industries is complementary to investments in tangible assets, particularly machinery and equipment. Investments in scientific knowledge outside of R&D track expenditures in machinery and equipment closely. They are a critical part of the stage of the innovation process that brings on stream new products and production techniques. This study has shown that these expenditures are quantitatively important. And, as Hollander (1965)'s work suggests, these expenditures may also lead to the greatest increases in productivity.

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Appendix A

A.1) Advertising Expenditures:

Data for advertising expenditures are taken from Statistics Canada's Link (L-) level Input/Output tables. The L-level data have consistent commodity aggregations from 1961 to 2004, and, do not require special attention to generate historical estimates.

Five input commodities are used to estimate expenditures on advertising. They are:

1. Business forms, advertising flyers and other printed materials;
2. Advertising in print media;
3. Advertising signs, displays, etc.;
4. Advertising services; and,
5. Advertising and promotion.

These five commodities comprise all expenditures on advertising present in the Input/Output system and capture expenditures from all facets of advertising.

A.2) Mineral Exploration:

Data for mineral exploration expenditures are taken from investment estimates compiled by Statistics Canada's Investment and Capital Stock Division (ICSD). The data are comprised of estimates for five types of mineral exploration expenditure:

1. Exploration drilling;
2. Drilling expenditures, pre-mining, research and other;
3. Geological and geophysical expenditures;
4. Mine site exploration; and,
5. Exploration and deposit appraisal – off mine sites.

These data cover most aspects of oil and gas or mineral exploration undertaken in Canada. The data span activities from exploration to experimental drilling to chemical and physical tests of ore samples for mineral concentrations and/or recoverable quantities of minerals from ore bodies. The estimates do not cover development drilling of existing known deposits, engineering projects for production facilities, enhancing recovery or tailings ponds.

Because of increased asset detail available after 1997, estimates for geological and geophysical expenditures are only available from 1998 on. Prior to that, this component is included elsewhere. As a result, estimates for geological and geophysical expenditures begin in 1998, and the shares of expenditures on the various components changes at that point (Figure A.2, Table A.2).

Figure A.2: Expenditure shares by component: 1981-2001

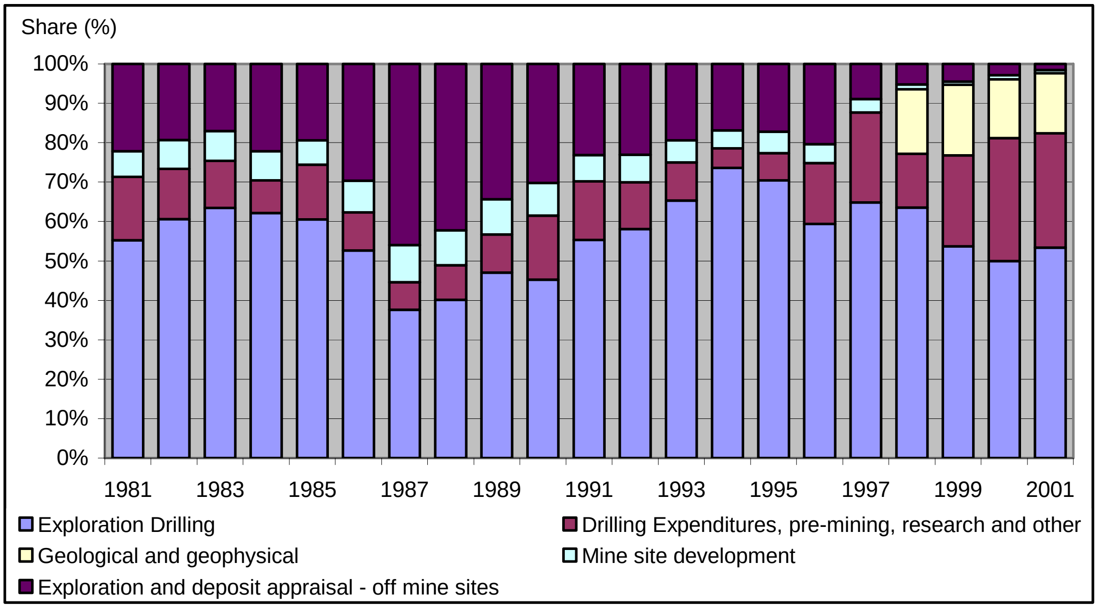

Table A.1: Average Expenditure Shares by Asset Type

	Exploration Drilling	Drilling Expenditures, pre-mining, research and other	Geological and geophysical	Mine site development	Exploration and deposit appraisal - off mine sites
Average					
1981-1997	57%	12%	0%	7%	24%
1998-2001	55%	24%	16%	1%	3%

There is a distinct change in shares for most commodities post-1997 when compared with their pre-1998 values. In particular, mine site development and exploration and deposit appraisal expenditure shares shrink from 7% to 1% and 24% to 3% respectively. The share of drilling expenditures, pre-mining, research and other drops by a half.

A.3) Purchased Science and Engineering Services:

Data for purchased science and engineering services are taken from the W-level Input/Output tables that provide a finer level of disaggregation than the L-level. Two science and engineering commodities are employed as estimates of intangible expenditures:

1. Royalties and license fees (excluding natural resources); and,
2. Architect, engineering and scientific services.

At the W-level, commodity classifications change over time leading to potential time series inconsistencies as the granularity of commodity structures change. In those cases where finer detail information is available post-1997 than in earlier periods, the share of expenditures in the more aggregate classification is employed to split estimates historically.

For example, in 1986 there is a change in commodity classifications. Prior to 1986 architect, engineering and scientific services are included in an aggregate commodity that includes accounting and legal services. Post-1985 the two commodities have separate estimates. The pre-1986 estimates are split into architect, engineering and scientific services and accounting and legal services using the average share of architect, engineering and scientific services in the total from 1986 to 1991.

Changes in commodity classifications can also induce changes in commodity estimates over time as they can induce changes to the balancing procedures used for the Input/Output accounts. Commodity classification changes occur in 1986/1987 and 1996/1997 in the W-level tables. For those years the average growth rate from t-2, t-1, t+1 and t+2 is used to smooth the change. Estimates prior to the breaks are then back cast using Input/Output growth rates. In the case of the Accommodation and Food Services industries, an additional aberrant observation was discovered in 1989. It was smoothed using the same procedure.

A.4) Software:

Software estimates are taken from the Final Demand tables produced by Statistic Canada's Input/Output division. There are two Input/Output commodities that house software estimates and the actual software expenditures can be isolated from the investment components of final demand:

1. Recordings, musical instruments, artists' supplies, etc.; and,
2. Software development, computer service and rent.

At the business sector level the data are consistent with the estimates from the satellite account developed by Jackson (2002) that was subsequently incorporated into the Canadian System of National Accounts.

At the industry level the data exhibit time series discontinuities in 1997/1998 that coincide with changes in commodity classifications and industry classifications. The data are smoothed using a four period average growth rate. For 1997 the growth rate is an average of t-3,t-2,t-1 and t+2 growth rates. For 1998 the growth rate is an average of t-2,t+1,t+2 and t+3 growth rates. The levels are then back-cast using the Input/Output growth rates.

In addition, specific industries exhibit breaks in 1986 and spikes in particular years (see Table A.2). The breaks are smoothed using the average growth rate of t-2, t-1, t+1 and t+2 for the 1986 growth rate. For these industries the levels are back-cast using the smoothed growth rates in 1986. For the spikes the average level of t-1 and t+1 is used to substitute for the spike value.

On aggregate, the smoothing of breaks and spikes does not affect the aggregate level of software investment. Rather, the aggregate is re-distributed across industries in a manner that is consistent over time by industry.

Table A.2: 1986 Smoothing and Spikes by Industry

	1986 Time Series Breaks	Spike	Spike Year
Agriculture, Forestry, Fishing and Hunting	X	X	1995
Construction	X		
Professional, Scientific and Technical Services		X	1994
Administrative and Support, Waste Management and Remediation Services		X	1994
Arts, Entertainment and Recreation	X		
Other Services	X		

A.5) <u>Research and Development:</u>

Research and Development (R&D) investment estimates are drawn from three sources: micro files from Statistics Canada's Science, Innovation and Electronic Information Division (SIEID); the W-level Input-Output tables; and, Statistics Canada's Capital, Labour, Energy, Materials and Services (KLEMS) dataset.

Own account R&D expenditures are valued at cost. This involves estimating labour input, intermediate expenditures and capital services. The SIEID data are used to directly calculate expenditures on labour and intermediate expenses.

The SIEID data also contains data on capital investments in M&E and buildings. This capital investment should already be captured in the investment surveys performed by Statistics Canada. The relevant question is, therefore: what are the capital services that should be attributed to R&D production vs. production of other goods?

The total nominal value of capital services is estimated in KLEMS by industry. The KLEMS capital services estimates and split into R&D and non-R&D capital services using the ratio of R&D investment in M&E and buildings to the total M&E and building investment in each industry. The R&D capital services are added to the labour and intermediate expenditure investments to form the own account capital services estimates.

In Canada, some R&D is purchased. Much of this comes from imports of R&D. These expenditures are captured in the Other Scientific and Technical Services commodity in the W-level Input/Output tables. The commodity is disaggregated from 1997 on. However, prior to 1997, Other Scientific and Technical Services are aggregated into Other Services to Business and Persons. The aggregate is split historically using the average share of Other Scientific and Technical Services in the aggregate from 1997 to 2001. The estimates of Other Scientific and Technical Services are then added to the Own Account R&D estimates to form R&D investments by industry.

Similar to other estimates that span changes in commodity and industry classification changes, the R&D investment estimates exhibit breaks in 1986 and 1997. In each case the growth rate for those years is replaced by the average of growth rates from t-2, t-1, t+1 and t+2. The historical levels are then back-cast.

A.6) Own Account Science and Engineering:

Own Account Science and Engineering (O.A. Science) estimates are derived from census estimates of incomes earned by individuals employed in science and technology occupations. The census estimates are taken from an occupational taxonomy used by the U.S. National Science Foundation. It includes several occupational groups—computer and math scientists, life and related scientists, physical and related scientists, social and related scientists, engineers, science and engineering technologists, and architects. Consistent groupings were created from the 1980 and 1990 Standard Occupational Classification codes. The O.A. Science are then benchmarked to the KLEMS database. The Census wage data for scientists was benchmarked to the Canadian Productivity Accounts database using total wages of all workers. Intercensal data are created using average wage shares of scientists taken from adjoining census points and total wages from the Productivity Accounts.

The resulting estimates of own account science includes R&D scientists captured in the R&D estimates as well as programmers captured in the Software estimates. To adjust for the double counting, the labour income estimates from the SIEID R&D surveys and the labour portion of the own account software estimates are netted out of the own account science estimates derived from the Census Occupation data.

This does not present a problem at the business sector level. However, at the industry level the split between industries from the O.A. Science differs from the split in the R&D and Software estimates. To make the estimates consistent, the O.A. Science estimates are re-split using the average weights from the R&D and Software estimates in 1997. The levels of O.A. Science by industry are then forecast and back-cast from the re-split 1997 level.

The O.A. Science are time series consistent and do not require smoothing due to industry and commodity classification changes.