

Innovation and Knowledge Creation in an Open Economy

Canadian Industry and International Implications

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ONE

The Economics of Knowledge Creation

1.1 INTRODUCTION

Innovation is the dynamic force that changes the economy. It provides new products and processes. It generates productivity growth and leads to increases in the standard of living. It is at the heart of entrepreneurship.

An analysis of innovation is a study in the economics of knowledge creation and application. Studies of innovation have not been as common as other types of studies in industrial organization – of scale economies, scope economies, sunk costs, multiplant economies, competition, and market structure. One of the reasons is that data allowing for broad descriptions of the innovation process have been lacking. Research has had to rely on case studies that are often unrepresentative of the innovation activity that takes place in the entire population. Case studies tend to focus on high-profile new products and processes. By definition, few firms are at the head of the class at any point in time, and focusing on them alone risks giving a distorted view of change.

This study makes use of the first comprehensive innovation survey to cover the Canadian manufacturing sector. The 1993 Innovation and Advanced Technology Survey, carried out by Statistics Canada, was uniquely designed for analytical purposes and differs in key respects from the standardized European Community Innovation Surveys (CIS).¹ Conducted by Statistics Canada in 1993, the innovation survey used here provides an overview of the complex process that produces innovation in Canadian manufacturing. This process is often referred to as the innovation regime

¹ See European Commission (1994).

or the innovation system, and it consists of the actors, sources of information and networks in Canada and abroad, and outcomes associated with the production of innovations.

This book describes the innovation system of Canadian manufacturing firms. In doing so, we build on an emerging, rich survey-based literature that has developed in the economics of innovation. In this chapter, we describe the analytical framework that underpins subsequent chapters.

Innovation takes place via a system of economic actors. It involves a set of activities – ranging from arm’s-length transactions between firms, to non-arm’s-length transactions that are internal to firms, and finally to transactions with public institutions. As with all economic systems, it consists of a number of interactive parts, sometimes working at arm’s length with one another as suppliers and customers and, at other times, working together in collaborative networks. This book describes how these parts fit together.

At the same time, we recognize that the parts fulfil different functions. Actors are different and they both compete with and complement one another. The actors that interact in the innovation system often operate in quite different ways. The participants either act consciously to coordinate decisions or, by acting competitively, influence or determine the overall innovative performance of the economy. There is no single model that serves to explain how an innovation system should or does work. Heterogeneity of purpose and function occurs.

In this system, large firms differ from small firms. Research and development (R&D)-based firms differ from production-based firms. Firms in industries that tend to originate innovations function differently from firms that operate in industries that ingest new materials and new machinery and equipment. Firms also differ in terms of their nationality. About half of all Canadian manufacturing firms are foreign-owned. Cross-border transactions with suppliers, customers, and partners provide them with access to information networks other than those available to domestically owned firms.

The next section presents the methodological hypotheses underlying our approach to the study.

1.2 INNOVATION: CROSSCUTTING THEMES

1.2.1 The Nature of Innovation: Core Framework

The organization of any study of innovation is perforce organized around a set of themes, whose choice depends upon a set of maintained

hypotheses about how innovation occurs, or a set of issues whose interest depends upon the validity of a particular set of working hypotheses about how innovation takes place.

The first hypothesis relates to the nature of the business population. On the one hand, the Canadian economy might be described as one where the majority of firms search for innovations and only a minority succeed in the type of short three-year span covered by the survey. On the other hand, the economy may be one where only a minority of firms try to innovate and most of these succeed. If the first description were correct, then it is important to understand what characteristics of a firm lead to successful innovation and what causes a firm to try but to fail. In the second case, we need to understand what distinguishes an innovator from a non-innovator. Or in the case where there is a continuum of innovators, we would ask what distinguishes the more innovative from the less innovative.

Our study is based on the view that the latter description is closer to reality than the first – that only a minority of firms attempts to and successfully introduces major innovations. This view is based on evidence that the number of firms reporting major innovations is small. It leads us throughout this monograph to focus on descriptions of the innovators. As a variant, we also describe the difference between those who produce innovations that differ in terms of their novelty.

A second maintained hypothesis underlying this monograph is that innovation is a result of a process that not only requires firms to search for and create knowledge but also requires a firm to develop a number of complementary competencies.

As a result, a study of innovation needs to examine more than just the R&D intensity of firms. This is partially because innovators require competencies other than just R&D. They need technical competencies on the production side that are often resident in engineering departments.

Therefore, this study goes beyond an examination of the role that R&D plays. In contrast to more traditional studies of innovation that focus almost exclusively on the relationship between R&D and innovation, the present study recognizes that firms pursue a range of strategies, most of which are complementary to R&D.

Innovation requires a set of complementary strategies in many areas of the firm. For example, firms that innovate have a particularly difficult time finding funds for soft knowledge-based assets. This requires the development or acquisition of specific competencies in the area of finance to access highly specialized capital markets. Innovators also need skilled workers, and they need to inculcate them with firm-specific knowledge. This requires the development of human-resource strategies for training

and the retention of workers whose training costs are substantial. Innovators also have to penetrate new markets, and this requires special marketing capabilities. In sum, this means that innovators need to develop a range of competencies in addition to the scientific skills that are key to the innovation process.

In pursuing our study of the innovation process in Canada, we are guided by both of the maintained hypotheses outlined above. Our prime interest is the characteristics of innovators. And this interest is wide-ranging. But in pursuing this study, we have organized our facts around a set of themes that reemerge in one chapter after another. These involve, on the one hand, the nature of diversity in the innovation process, and on the other hand, the particular problems that knowledge externalities create.

1.2.2 Heterogeneity of Innovation Regimes and the Environment

1.2.2.1 *Sources of Diversity*

The competitive and scientific environment of an industry conditions both the nature of innovations that are produced therein and the actors that function in these markets. But there is considerable heterogeneity in both the actors and the nature of innovative activity. As such, it is inappropriate to depict innovation as a process that has unique characteristics and to prescribe a unique, simple route to success. It is difficult to argue that one country spends too little on R&D or that it has the most desirable innovation system until we understand the nature of optimality (Edquist, 1997). And optimality may require heterogeneity, not homogeneity.

An aggregate statistical picture of the average innovator hides the considerable diversity that exists in the population of innovators. New and improved products and processes are responses to challenges and opportunities, which vary both within and across industries. Internal factors that influence innovation are closely related to the size of the firm, as well as the accumulated knowledge and competencies in the firm. External factors are shaped by technological opportunity and market forces.

Two forces are at work that shape the nature of diversity – forces that are purposive and those that are nondeterministic. The progress of creation and accumulation of knowledge creation through regular R&D activity and by alternative means, both inside and outside the firm, by market conditions, changes in organizational structures, and institutional development are all marked by a high degree of uncertainty.

Uncertainty occurs because technological change involves a trial-and-error process. On the one hand, it involves the type of individual and collective experimentation and learning that is stressed in evolutionary economics. On the other hand, it has features of the type of deterministic, rational cause-and-effect process that are stressed by neoclassical economists.

Evolutionary economics has taught us that the creation and diffusion of technological change is multifaceted. Novelty takes on different forms. Innovations of different kinds are created and introduced by different processes in different organizations and systems. However, as in biological evolution, only some innovations survive. This selection process results in the culling of some innovation regimes and the focusing of systems on a reduced set of regimes – for example, the R&D-centric mode of innovation.

Innovation variety occurs partially due to design and partially due to chance. Variety can be found in different motives of economic agents, types of organizations, and institutions that have developed as a result of country-specific cultures. They come from chance happenings in search and learning procedures, especially in relation to scientific discoveries, and finally from unexpected changes in environmental factors (natural as well as economic, social, and political).

The selection process that reduces variety by culling out the less successful in favour of the more successful innovation processes also involves considerable uncertainty. The selection process operates at the level of both the firm and the economy. Firms decide on which innovative ideas will be developed, which internal resources to devote to innovation, and the complementary assets that they must muster or find outside of their organizations. The survival of one technique via selection will depend on the population of techniques that are chosen for the experiment and the institutional structures that exist to support particular modes of innovation. During the selection process, symbiotic relationships develop between firms. Some are based on economies of scale or network externalities. Others involve complementary arrangements with different firms and institutions, such as national research facilities or universities. These relationships are shaped by the type of supporting economic and technological structures – the maturity of financial markets and the type of training programs that exist to help develop a skilled workforce.

Arrayed against this sometimes bewildering complexity associated with evolutionary models of innovation are more traditional neoclassical models that try to organize the array of information into more

recognizable segments. These models argue that differences in innovation regimes may reflect not so much random choice as purposive responses to differences in relative prices and opportunities. Small and large firms face different capital costs. They might therefore be expected to choose different capital intensities, both in the production and in the innovation process. When one form of external cooperation is costly, firms are likely to find new forms of cooperation that serve to reduce the costs of investments in knowledge creation. When firms can substitute one type of resource for another more scarce resource in their search for innovation, this involves trade-offs that are handled well within the framework of traditional neoclassical economics.

This book takes the view that there is really no incompatibility between the two schools of thought. Innovation, like any firm strategy, involves choices. Some of these choices are operationalized relatively easily within standard frameworks. Others are not so easily rationalized.

In either case, a picture is required of the innovation process. Developing that picture is the objective of this monograph. Throughout, we focus on a plurality of innovation types. Our study breaks with the traditional or standard way of treating innovation in a firm as dependent only on R&D. We embed innovation more broadly in the firm's set of activities. We argue that ideas for innovations come not only from R&D but also from managers and the production department. Innovations are also triggered by ideas from other firms (from suppliers and customers). We argue that both proprietary information and unpriced spillovers are important. The firm may conduct R&D on its own or it may collaborate with others or it may licence information and technology from other firms (including corporate affiliates).

The study is aimed at understanding how these types and the regimes that support them fit together. We do not treat this diversity as simply an ill-defined nebula. Our objective is to understand differences in types of innovators – small versus large, domestic versus multinational, innovative and less innovative industries – and suggest rationales for the coexistence of different innovation regimes.

1.2.2.2 Types of Diversity

Heterogeneity in the innovation system takes several forms.

First, there are distinct differences in innovation types within industries. Each industry consists of a complex network or system of actors, who often pursue different innovation strategies. Technical progress within an industry takes place on several levels – in the components, in the production

process, and in the introduction of improved or new products. Advances are made at different times in different parts of this process, which is co-ordinated by arm's-length market transactions and via knowledge transfers internal to organizations that may be joined in an interfirm network. Sometimes, such as in the case of multinationals, the latter occur as part of transactions within the same firm. Sometimes, such as with joint ventures, they occur between separate legal entities that combine their resources to share knowledge (Nelson and Rosenberg, 1993).

Second, there are substantial differences in the types of outputs produced by innovative firms. A common distinction that is frequently made is between product and process innovators. Product and process innovation use inputs, such as R&D, in different amounts (Arvanitis and Hollenstein, 1994). We, too, follow this distinction throughout this study in order to examine differences in the development of new products and processes. But we point out that there are few innovations that involve just products or just processes; many involve the simultaneous introduction of new products and new processes. The more complex 'product cum process innovations' have, in general, a greater need for internal competencies, such as skill upgrading, than do the two other innovation types.

Third, there is heterogeneity across size classes. Firm size has received much attention in recent innovation studies (Malerba, 1993; Arvanitis and Hollenstein, 1996; Licht, 1997). The relationship between the size of firm and innovation has been in the forefront of economic studies since J. A. Schumpeter's theory associating successful innovation with larger firm size and monopoly power. More recent theoretical and empirical research (Dasgupta and Stiglitz, 1980a, 1980b; Levin and Reiss, 1988) suggests that size and innovation are mutually dependent. Size may convey an advantage to larger firms when it comes to innovation, but successful innovators grow faster than other firms and become larger than non-innovators (Acs and Audretsch, 1988).

Fourth, there are substantial differences across firms of different nationalities. In today's global economy, the ownership of firms is increasingly international and many firms interact across national borders. About half of Canadian manufacturing firms are foreign-owned. Cross-border transactions with suppliers, customers, and partners provide them with access to information networks other than those available to domestically owned firms. It is important to investigate whether foreign affiliates operating in Canada are integrated into the Canadian innovation system. This study therefore examines whether a firm's conduct and performance are

shaped more by ownership or by technological opportunity and market forces.

Fifth, research has shown that innovation systems differ across industries, partially because technological opportunities vary from industry to industry. The incidence and type of innovation is also closely related to the position in the life cycle of a product or a whole new industry. Low rates of innovation are found in traditional industries, such as textiles, wood products, food, and pulp and paper (Evangelista, Sandven, Sirilli, and Smith, 1997).

Several taxonomies of industrial innovation have been constructed with differences in the industry environment as the foundation for their classification. These studies have at their foundation either differences in the technological opportunities of different sectors, some concept of product hierarchy, or the method used to diffuse innovations throughout the economy – issues that relate to spillovers and externalities.

For example, Pavitt (1984) develops a taxonomy based on a classification that divides industries into those that are 1) supplier dominated, 2) production scale intensive – determined by the size and principal lines of activity, and 3) science based. Scherer (1982a, 1982b) chooses to organize his work around a classification that uses the industry where patents are created and where they are used. Robson, Townsend, and Pavitt (1988) extend Scherer's work to develop a stages-model that is based on 1) the intensity of innovation in an industry and 2) the extent to which an industry diffuses products and process innovation to other industries.

In this study, we utilize the Robson et al. (1988) taxonomy that divides the manufacturing sector into those industries that appear to produce a disproportionate percentage of innovations (the core sector) and those that absorb them (the secondary and tertiary 'other' sector). We do so because Robson shows that industries in both the United States and the United Kingdom fit the taxonomy. But in using the Robson taxonomy, we are careful not to refer to the firms in the core sector as innovative and firms in other industries as non-innovative. Both are innovative.

1.2.3 Knowledge Externalities, Market Imperfections, and Diffusion

Generic knowledge is an economic good with unique characteristics. Some new scientific discoveries and new inventions – unless kept secret or protected by a patent – can be used by anybody without diminishing the amount of the knowledge that can be consumed by others.

This ensures the diffusion of innovation by what the economist calls knowledge externalities or spillovers; but it reduces the incentives that private profit-maximizing firms have to produce new knowledge and to innovate.

In markets where firms cannot be sure that they will reap the economic benefit of investments in innovation, firms have less incentive to invest in as much knowledge as would be optimal. Innovation and knowledge creation will be undersupplied. This conventional market-failure analysis (see Arrow, 1962) has been traditionally used to provide an economic rationale for government support of R&D and innovation.

The existence of spillovers presents a delicate trade-off between adequate incentives to innovate and conditions that favour the diffusion of new technology. If intellectual property rights are well protected, investments in innovation will be larger – and, in some cases, more than is socially optimal. Some models even suggest the possibility of oversupply of R&D when private property rights are assured. These arguments are based, among others, on the existence of inefficient patent races that lead to duplicative R&D (Dasgupta and Stiglitz, 1980a; Tisdell, 1995).

Empirical studies have attempted to document the importance of spillovers at the industry and country level (Bernstein, 1997; Hanel, 2000). At issue in this study is not whether there are spillovers, but the extent to which the intellectual property system is used to reduce the effect of these spillovers. We investigate the methods that firms use to mitigate and minimize the problems that arise from having to operate in imperfect knowledge markets. To do so, we examine two related aspects of spillovers. First, we seek to establish the frequency of occurrence of technology spillovers. Second, we investigate the methods that firms use to mitigate and minimize the problems arising from spillovers.

Market imperfections arising from these problems are addressed by government through the creation and enforcement of intellectual property rights – rights that assign ownership to the outcome of ideas that lead to an innovation. While intellectual property rights are meant to stimulate economic activity, there has been little applied research on whether this is the case. There are two major exceptions. Research by Mansfield (1986) and Levin et al. (1987) has challenged the conventional belief that such rights as patents are an effective means of protecting investments in knowledge creation. In this book we also examine why firms make use of the intellectual property system, and whether they perceive intellectual property rights to be as effective in preventing imitation.

While issues of appropriability are seen by some to generate problems, this view is by no means universal. Pavitt (1984, p. 353) argues that most of the knowledge applied by innovating firms is not general purpose, easily transmitted and reproducible, but is applicable only to specific applications and therefore can be adequately protected by innovators. In his study of innovation in the U.K., Geroski (1995, p. 90) concludes that 'spillovers do not always (and perhaps not even often) seriously undermine the incentives to innovate'.

In a related vein, Von Hippel (1988) notes that appropriability problems affect not only the amount of innovation that takes place but also the nexus or location of that innovation. Recognizing imperfections in appropriability, he identifies the stage of a vertically integrated production chain that is most likely to have inherent advantages in appropriating the benefits of an innovation, and postulates that it is this level that will conduct most of the innovative activity. As such, his theory is essentially based on the notion that appropriability exists – but that it is specific to certain stages of the production process.

We recognize that firms manage to internalize externalities of all types, including those associated with knowledge creation. In the case of knowledge creation, firms often do so through the adoption of various strategies other than the use of patents. They make their new product complex; they develop a first-mover advantage; they develop partnerships with other firms. In this study, we examine how important each of these alternatives is – by directly asking firms how they safeguard their innovations and the extent to which they participate in innovation networks.

The nature and extent of these networks has garnered substantial attention – because they provide the means by which the spillover problem can be mitigated. This has implications for the patterns of organization that we might expect to find in innovative firms. For instance, a number of studies have found that firm diversification is related to the science base (percentage of employees that work in R&D) of the industry in which the firm's primary activity is located – Gort (1962), Amey (1964), Gorecki (1975), Grant (1977). This implies that when a firm develops a specialized science-based asset, it often exploits this asset by extending its operations into new industries.

It is for this reason that innovation relies on networks – that actors are tied together in clusters. Suppliers provide customers with new ideas as to how to incorporate new materials or new machinery into the production process. Customers inform suppliers of new machines that are needed in production. Customers and suppliers work with one another. In these

commercial transactions, there is room to internalize information leakage. It is with the goal of understanding these networks that we examine the sources of ideas for innovation. An exploration of the sources of innovation also helps us to understand how diffusion occurs and whether it mainly involves unpriced spillovers, or whether it is internalized via market transactions or via alternate methods.

Problems in pricing a highly uncertain good like a process innovation also lead to new forms of organization to reduce the costs of transferring new technologies. The transfer of technology by a firm can be accomplished either through licensing or through the exploitation of its own technology via exports or with production facilities located abroad. The alternative that is chosen will be determined by the relative efficacy in transferring an asset via an arm's-length transaction rather than making a foreign investment or by exporting. We therefore examine the importance of technology transfer as part of the innovation process and the nature of the contracts that are used.

Another issue that is closely related to knowledge spillovers is the role that technological opportunities play in shaping the innovation process. Some industries, it is argued, are more likely to provide greater opportunities for innovation because of their science base. The state of scientific knowledge in some industries makes it more likely that firms therein can take advantage of knowledge advancements to introduce large numbers of new commercial products or new production technologies. An example is the biotechnology sector, where present advances in genome mapping promise rapid advances in new product introduction. This study therefore investigates whether innovators are more likely to succeed when they form partnerships with universities, who are one of the principal creators of scientific knowledge.

1.3 THE ECONOMIC THEMES

While innovation is essentially about disequilibrium and network economics, many other aspects can still be set within the traditional bounds that are used for most economic studies.

A study of innovation requires that attention be devoted to traditional areas involving the delineation of markets and production processes, as well as the nature of transaction costs and how they give rise to market imperfections.

An economics study should perforce define the output being examined and the inputs that are critical to the innovation process. It should also

investigate the importance of the industry environment (the technological background and the market forces that shape the dynamics of competition within a sector). It needs to focus on how this environment affects the innovation process and the nature of institutions, both private and public, that facilitate innovation.

The study addresses each of these points in turn.

1.3.1 The Nature of Innovation Outputs

A central finding of this study is that innovative firms are not those that serendipitously stumble across inventions. Innovators differ from non-innovators in that they adopt a purposive stance to find new products and to adopt new processes. The Canadian manufacturing sector is not a world where most firms are engaged in intense innovative activity, where some are rewarded by chance and others are not. It is a world that divides into firms that heavily stress an innovation strategy and those that do not.

Within the innovation group, there are considerable differences in the outputs that are produced and in the strategies to produce them. Innovation studies sometimes focus only on innovations that are paradigm-shifting – new products that are so unique that they transform the whole industrial process.

The development of steam engines transformed industrial processes that relied upon waterpower. In turn, electricity in the late 1800s moved the production process away from steam sources. The modern internal combustion engine and the automobile revolutionized urban areas. The electronic chip and the computer are having a similarly dramatic impact on the production process today – both because of their effects on communications and because of their ability to manage information and to monitor and control production processes.

As critical as the introduction of new, frontier technologies may be, they make up only part of the innovation system. As Nelson and Rosenberg (1993, p. 9) argue, ‘most industrial R&D expenditures are on products that have long been in existence’. It is these existing products that serve to define the framework within which improvements can be identified and undertaken.

In this study, we first explore innovation activity in general. By necessity, the issues that can be explored at this level are rather general, since the questions must cover a wide range of types of innovations. At this level, a broad definition of innovation is used. It includes those improvements

and/or new products and processes that are new to a firm even though well known and used in other countries in the world or by other firms in Canada.

There is, however, an important methodological difference between our approach and that suggested by the Organization for Economic Cooperation and Development (1997) in their Oslo innovation manual that has been used in the European Community Innovation Surveys. We explicitly recognize that the innovation process aimed at introducing an original world-first innovation is likely to be different in many respects from the imitation of known products and processes. Building on the first innovation survey done by the Economic Council of Canada in the seventies (De Melto, McMullen, and Wills, 1980), we include a separate section of the survey that asks questions about the most profitable innovation introduced by the firm. This innovation-specific section provides information on the differences in the idiosyncracies associated with different degrees of novelty.

In this study, we focus on a wide range of innovation types. On the one extreme are innovations that are, according to the firms that reported them, 'world-firsts'. Scientific progress opens new avenues for technological breakthroughs, and many of these build on previous knowledge. Less original innovations are divided in this study into 'Canada-firsts' – innovations that were introduced abroad first but are for the first time implemented in Canada and 'other' innovations. The former involve technology diffusion from abroad; the latter involve technical diffusion within Canada. While these two categories represent the less spectacular technological innovations, they make a significant economic contribution to overall economic growth.

In examining the different types of innovations, ranging from the more to the less original, we consider how each is produced, who produces them, and where they are produced. Our maintained hypothesis is that the innovation system for each type of innovation has unique features. Differences exist with regards to the type of inputs used (R&D versus production engineering), the use of partners for joint ventures and other collaborative exercises, the extent to which the firm relies on outside technologies, and problems in financing. We cast our net broadly because the activities and investments associated with becoming a leader in the introduction of a new product or process, and those associated with staying near the head of the class, or catching up with the leaders, are each important and probably differ in many respects. Since our interest in innovation often stems from a desire to better understand the determinants of economic performance,

we need to better understand the overall innovation system – not just part of it.

While we note that there are wide ranges of innovator types – from leaders to followers, from industries that produce innovations used elsewhere to industries that ingest innovations produced elsewhere – we avoid the mistake of claiming that the successful introduction of innovation depends only or primarily on the producers of the innovations. Some firms are responsible for the production of new machines or new materials. Others adapt these machines and material to their production process. It is difficult to ascribe more importance to one than another. Innovation depends on a web of interactions between the two parties. Technologically progressive users of new innovative processes can have a substantial influence on the machines that are created by innovators, as well as on the extent and speed of adoption of new processes. Users of innovations are often at the forefront of the innovation process, requesting and helping to develop new capital equipment purchased from upstream producers.

1.3.2 The Nature of Innovation Inputs

The innovation process is often defined by the type of inputs that are used in the production process. In particular, since Schumpeter first professed a fascination with the way that large corporations systematize their search for knowledge, the role of research and development laboratories has garnered special attention from economists.

This interest in R&D is not misdirected. The importance of R&D has been confirmed by previous research. Brouwer and Kleinknecht (1996) point out that despite different specifications and different measures of innovative output, innovation surveys have always found that innovation is correlated with R&D – underscoring the importance of the continuous accumulation of R&D-type knowledge for innovation output.

The issue is not whether R&D is important, but rather its degree of importance. Chesnais (1993) argues that a focus on R&D alone is inadequate because ‘an R&D system is at best a poor proxy to an innovation system’. In order to understand the system as a whole, we need to evaluate the importance and role of other inputs into the innovation process.

A focus on R&D alone ignores the fact that information in the firm is acquired and developed outside formal R&D systems. Tacit, uncodified knowledge accumulates in the firm through complex interactions that gather, store, and use technical knowledge. An exclusive concentration on R&D ignores the linkages between organizations through which

knowledge is transmitted – linkages that transfer information through arm's-length transactions, across subsidiaries within firms, and via alliances or joint ventures.

A narrow focus on R&D using official measures of R&D is problematic for a second reason. Mowery and Rosenberg (1989) have stressed that there is a certain lack of distinctiveness surrounding the definition used for the collection of official R&D statistics. Only a fraction of technological effort is counted as R&D. Not all expenditures on the creation of new and improved products are covered by the OECD (1993a) 'Frascati' definition of R&D. There are important knowledge-creating activities that firms do not consider to be part of R&D. For example, firms without formal R&D departments ascribe a substantial part of their knowledge-creation process to product design teams and not R&D departments (Felder et al. 1996).

Therefore, this study examines the importance of several sources of knowledge that firms use for innovations. We start by noting that innovations are dependent upon the work that goes on in industrial R&D labs, as well as in university or government laboratories. Our interest in the importance of R&D also extends to whether there are economies of scale attached to the R&D process that apparently give large firms an advantage in the pursuit of this activity.

But we also show that ideas originate from other areas of the firm, such as the production or engineering departments, and that universities are an important part of the innovation process. In examining the importance of non-R&D sources of ideas for innovation, we not only outline the other sources of information but also classify them as complements or substitutes for R&D.

The study also investigates the monetary importance of several types of expenditures required in addition to R&D in order to bring an invention to market. These include expenditures on marketing and technology acquisition. Process engineering is always important and rarely considered as R&D. Design activities, solving production problems, and technology-watching all contribute to the innovation process and are rarely considered to be part of R&D. We find that R&D expenditures, such as those defined in the Frascati manual and compiled in international R&D statistics, are often only a small portion of the resources required to support innovation.

Even within a firm, innovation requires more than technical knowledge arising from engineering or R&D. It requires complementary competencies in finance, marketing, and production. This study therefore asks not

only what sources of ideas are used for innovation, but also what importance is attached by innovators and non-innovators to competencies in each of several different functional areas of the firm – human resources, financing, and management.

One of the most important complementary capabilities for innovation lies in the area of financing. This study investigates two financing issues that affect innovation – the source of funds for investments in innovation and the extent to which government programs that are used in Canada better support some types of innovation than others. In both cases, we find that the industries that receive innovations from the core sector have to rely mainly on their own internal funds.

Finally, we focus our attention not just on the internal innovation production capabilities of a firm, but also on the extent to which firms reach outside themselves for inputs used to produce innovations. Not all innovative ideas are developed entirely within a firm. We show that innovation arises from a network of firms interacting sometimes at arm's length, sometimes in symbiotic relationships that blur the boundaries of a firm. Often the difficulties in creating and ingesting new knowledge cannot be overcome through arm's-length transactions, and firms expand their boundaries to incorporate other firms into a larger innovative network – they enter into collaborative arrangements to create new technologies and for R&D, either directly through mergers or through joint partners and ventures.

1.4 THE ORGANIZATION OF THE STUDY AND PRINCIPAL FINDINGS

In order to explore the above issues, we organized the chapters of the study as follows.

1.4.1 The Innovation Survey

The second chapter focuses on the data source used in this study – a special survey of innovation in the Canadian manufacturing sector. Until the 1990s, most studies of innovation had to use case studies, which did not permit very comprehensive coverage of the innovation process. Or they used patent statistics or R&D data that were more comprehensive in terms of coverage of a wider range of firms than are covered by case studies, but were restricted in terms of the topics that could be investigated.

This study makes use of the 1993 Canadian Survey of Innovation and Advanced Technology, which is hereafter referred to as SIAT or the Survey of Innovation. It focuses on the population of enterprises operating in the Canadian manufacturing sector and covers a wide set of topics relating to a firm's innovation activities. These topics range from the nature of innovations being introduced to the relative importance of R&D, to the impact of innovation on firms, to the impediments that firms face, to financing problems, to the use of intellectual property rights, and finally, to the extent to which complementary strategies in marketing, human resources, and management are required for successful innovation. The survey is included as an appendix.

While innovation surveys offer a potentially rich data source, there are a number of difficult measurement issues that have to be resolved if the data are to be useful. This study makes use of a comprehensive innovation survey that was especially designed for analytical purposes. The survey itself was built on the foundation of earlier Canadian work and preliminary versions of the European harmonized innovation survey (based on the OECD (1997) Oslo manual). However, it avoided some of the pitfalls that exist in the latter.

Standardized surveys are useful in providing benchmark data. But standardization involves a compromise among competing underlying concerns, assumptions, and research agendas. These are likely to differ for countries with widely different innovation concerns. The survey used here was designed to provide answers to issues that the standardized OECD methodology can only handle poorly. We believe that the inconvenience that arises because our survey questionnaire is not perfectly compatible with more recent surveys is more than offset by the wealth of data provided that is specific to the Canadian and North American context.

Since the 1993 Canadian Survey of Innovation was specially designed for analytical purposes, we devote the second chapter to an outline of how this was done. The survey was designed to allow differences in innovation regimes across industries and types of innovations to be explored. The chapter focuses on definitional issues, on how the sample frame was chosen, on several operational issues concerning the survey, and on the size of the response rate that was obtained.

1.4.2 Innovation Intensity

The third chapter focuses on the extent to which innovations were being introduced in Canada at the time of the Innovation Survey and measures

the importance of innovation by the percentage of firms that report having recently introduced a new product or process. Our objective here is not simply to report innovation rates but to illustrate that the industrial population is heterogeneous and that so too are the types of innovations being brought to market. The chapter examines differences in innovation rates across innovator types – product versus process, small versus large, domestic-controlled versus foreign-controlled firms, and science-based versus consumer goods industries.

Innovation is more frequent in a core set of industries (electrical, machinery, chemicals, pharmaceuticals, computers). Almost half of the firms in these industries introduced an innovation, whereas little more than 25% of firms in the tertiary sectors did so. This may be either the result of greater technological opportunity in these industries or due to the fact that these industries contain more products that are in the early stage of their life cycle. Innovating firms that are found in the core sector feed new technology to the rest of the economy.

The most original ‘world-first’ innovations are understandably rarer than innovations that introduce to Canada new products or processes created abroad. The larger firms were more likely to report that they created world-first innovations. The core sector was more likely to report a world-first than were the secondary and tertiary other sectors. Only one in six innovations was a world-first, one of three a Canada-first. The most numerous (slightly more than every second innovation) represent the diffusion of technical change, that is, ‘innovations’ that were new to the reporting firm, but that already existed elsewhere in Canada.

1.4.3 The Sources of Knowledge

Innovation is about knowledge creation, acquisition, and adaptation. The fourth chapter discusses how the economics of knowledge creation affects the organization of firms that are involved in innovation.

It addresses several questions. The first is the extent to which spillovers are important and the source of these spillovers – whether specialized public institutions that provide technical information are seen to be an indispensable element of a national innovation system. It also examines the relative importance of links between affiliated firms and links between firms that arise in the form of normal commercial relations (i.e., between suppliers and customers).

The chapter weighs the relative importance of spillovers compared to market transactions that diffuse innovations. Spillovers are classified into

three groups – those associated with commercial transactions, those that fall in the traditional unpriced interfirm group, and those coming from infrastructure facilities like universities. Contrary to the normal emphasis that is placed by neoclassical economic theory on the problem of unpriced spillovers, the survey evidence shows that interfirm transactions dominate the innovation process.

While spillovers are not the most frequent method used to diffuse innovation generally, they are more important in some sectors than others. In particular, they tend to be more important in the downstream technology-using sectors. Here, more use is made of spillovers from competitors. There is also more use made of trade fairs and other avenues for the transfer of information that is more readily codifiable.

The chapter also investigates the extent to which R&D is central to the internal process and how it facilitates the use of external sources. The chapter finds that the R&D-centric model is, by itself, inadequate. Even those firms that use this form of knowledge creation develop other complementary capabilities, especially in management and in their marketing departments. More importantly, there is an alternate mode that focuses on the production department that is essential for process innovation.

1.4.4 Research and Development

Since research and development is seen to have a special and key role in the innovation process, the fifth chapter investigates the importance of this particular factor by examining the extent to which Canadian manufacturing firms incorporate R&D into the innovation process.

This chapter focuses on several dimensions of research and development capacity. It investigates the attitude of firms to the development of innovation and technological capabilities – the stress placed on various business strategies that involve spending on research and innovation. It also examines the commitment of the firm to the phenomenon in question – that is, the existence of and the type of R&D operation.

Differences across industries are examined in order to understand how industry environment conditions the R&D strategy that is adopted. The chapter investigates whether there is a core set of R&D industries that provides a much greater emphasis on R&D activity than elsewhere. It also investigates differences in the extent to which innovation and R&D are closely related.

The chapter reports that contrary to the general impression often left by the official statistics – which in Canada are primarily based on R&D

reported by the minority of firms that claim R&D tax credits – R&D is being performed by about two-thirds of Canadian firms. Knowledge creation and acquisition through R&D in that sense is widespread. What is highly concentrated is a particular form of R&D – that done continuously in separate R&D labs. The latter tends to occur in larger firms and in a small set of core industries that create innovations for transmission to other industries.

1.4.5 Effects of Innovation

The sixth chapter examines the effects of innovation on the organization, activity, and performance of innovating firms. Firms innovate to increase their profitability, which can occur via reductions in costs, improvements in sales, or a combination of both. These general economic objectives of innovative activity are accomplished in many specific ways – by decreasing production costs, by increasing product line diversity, and by improving the quality of the product.

Since not all firms are innovators, it is important to understand the specific effects that Canadian entrepreneurs associate with their innovation – as these delineate both the advantages and impediments to the innovative process. The magnitude of both benefits and impediments determine whether innovation is undertaken.

The chapter finds that while innovation improves the ability of firms to exploit scale economies, these impacts were listed less frequently than improvements in flexibility. In the small Canadian economy, innovation is aimed more at exploiting product-line production economies.

The chapter finds strong evidence that all types of innovation have beneficial effects. Each type of innovator is about equally likely to report benefits of improved profitability. Innovating firms operating in the tertiary ‘other’ sector reported increased profitability just as often as firms in the secondary and core sectors. This pattern emphasizes the important economic contribution associated with the diffusion of innovation from high- to low-tech sectors and the diffusion of technological change through imitation. Original innovation may not occur as frequently in the downstream sectors, but innovation is just as frequently listed as being profitable in these industries.

The sixth chapter also asks whether innovations that are made to improve regulatory compliance are any less successful in improving the profitability and market share of firms. It finds little evidence to suggest that these types of innovations yield any fewer benefits to the innovators.