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 entrepreuneurship.

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 coordinated 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