LARGE AND SMALL FIRMS' ROLE IN THE KNOWLEDGE-BASED INDUSTRIES INNOVATION PROCESS

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Resumen

Este trabajo es una introducción a la discusión sobre el papel que juegan las empresas grandes y pequeñas en los procesos de innovación que se llevan a cabo en las industrias del conocimiento. El análisis se realiza desde la perspectiva de la tradición schumpeteriana-penrosiana. Se presenta un modelo donde el tamaño de la firma tiene implicaciones importantes para los diferentes momentos en que se llevan a cabo los procesos de innovación. Una conclusión importante en este trabajo es que las empresas pequeñas tienen una gran capacidad de respuesta ante los cambios tecnológicos. Sin embargo, las restricciones financiaras constituyen una limitante para el desarrollo de innovaciones en las empresas pequeñas. Desde esta perspectiva, las alianzas y la cooperación entre las grandes y las pequeñas empresas son una explicación adecuada que surge cuando analizamos la actividad innovadora en las industrias del conocimiento. El trabajo también presenta algunos resultados empíricos sobre el comportamiento de las industrias relacionadas a la biotecnología en Canadá a manera de demostración empírica de este enfoque teórico.

Abstract

This paper is an introduction to the discussion of the role played by knowledge-based large and small firms in the innovation process. It takes into account the theoretical background within the Schumpeterian-Penrosian tradition. The paper reviews a model where firm size has important implications for specific stages of the innovation process. An important conclusion in this work is that small firms are highly responsive when reacting to technological change. However, financial restrictions constitute an important impediment for innovation development in small firms. From this perspective, cooperation and alliances between large and small firms is an adequate response to the problems arising when knowledge-based firms innovate. The paper also presents some empirical results obtained from a survey on biotechnology-related industries conducted in Canada in 1999 as an empirical demonstration of this theoretical approach.

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Palabras Clave: Schumpeter-Penrose; innovación; cambio tecnológico; tamaño de firma; biotecnología.
Key Words: Schumpeter-Penrose; innovation; technological change; firm size; biotechnology.

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Introduction

This is an introductory paper to the discussion of the role played by knowledge-based large and small firms in the innovation process. In so doing, it takes into account the theoretical background developed within the Schumpeterian-Penrosian tradition. In this tradition, firm size has important implications for different steps of the innovation process.

This paper presents a three stage process model that explains collaboration between large and small firms in the knowledge-based industries. The dynamic of this model suggests that an innovation process can be explained as a technological discontinuity/dominant design/industry-level change process (King et al. 2003). Overall, small firms are characterized to be more agile reacting to technological change and innovation development than large firms.

In testing empirically this model, this paper uses supporting evidence from the results achieved in a biotechnology-related industries survey conducted in Canada in 1999 (Niosi 2000a, 2000b). The results confirm that Canadian biotechnology-related industries are commonly organized through alliances and collaborative agreements. This characteristic allows Canadian biotechnology-related firms to have access to complementary knowledge, and thus to be capable of speeding innovation activity and generating new products. In addition, the results demonstrate the importance to have an adequate institutional environment to successfully develop biotechnology innovations. The point to stress is that biotechnology firms may flourish easier when they create appropriate alliances with large corporations for acquiring financial, manufacturing and marketing resources (Niosi 2003). However, this conclusion may be generalized to other knowledge-based industries.

The remainder of this paper is organized in four sections. Section two presents some important ideas derived from the Schumpeterian-Penrosian tradition in relation to the role played by large and small firms into the innovation process. Section three sketches the technological discontinuity/dominant design/industry-level model that analyzes innovation activity in the knowledge-based industries. Section four introduces the importance of financial restrictions to explain the dynamics of cooperation between large and small firms in the knowledge-based industries. Section five some remarks of biotechnology-related industries in Canada. Finally, section six presents some conclusions.

Theoretical Background

Technical change and innovation is a driving force of firm performance and market competition. J. A. Schumpeter, E. Penrose and other authors from the Austrian school emphasize the idea that innovation and technical change are key forces framing competition in markets. Schumpeter (1934, 1942) suggests that innovation is not a spontaneous process. This author points out that innovation depends actually on many factors, such as property rights, market structure, entry barriers, and son on. However, Schumpeter (1934) and Penrose (1959) suggest that technological change influences firm's behavior and its economic environment that in turn determines market structure and competition, as well as all that happens inside the firm influences.

Schumpeter (1934, 1942) points out that firms innovate in four different ways: (1) new products and processes; (2) new distribution methods; (3) alternative strategies to penetrate new markets; and (4) new management practices and organizational structures. From this perspective, Schumpeter's idea on innovation can be associated to a two-step alternative evolving process: Mark I and Mark II.

In Mark I (Schumpeter, 1934), markets have a small number of firms and there are no important technological barriers to entry, and thus the creative-destruction process becomes a core explanation to market dynamics. By contrast, Mark II (Schumpeter, 1942) is characterized by an oligopolistc market structure with R&D activities as the main source of innovation and technological change. In Mark II, financing resources may constitute an important barrier to develop innovations (Malerba and Orsenigo, 1997).

On the other hand, Mark I has an innovative base that is continuously enlarged through an entry process of new innovators, and hence through the erosion of competition and technological advantages of established firms. By contrast, Mark II is characterized by an accumulation of technological and innovative capabilities over time. The innovative pattern in Mark II is mostly observed in oligopolistic structures with important R&D activities. Nevertheless, Mark I and Mark II taken together constitute a more complete explanation for competition and innovation. Malerba and Orsenigo (1997) summarize these concepts in terms of opportunity, appropriability, cumulativeness, and base-knowledge (Table 1).

Table 1

Schumpeter's Theory on Innovation

Concept/Definition		Mark I	Mark II
Opportunity	Potential for innovations from each technology adopted	High	High
Appropriability	Ability to innovate and to protect innovations from imitations	Low	High
Cumulativeness	The possibility of innovators to continue in the future with respect to non-innovators	Low	High
Knowledge-Based	The number and types of basic and applied science principles needed to innovate	Low	High

Source: Malerba, F. and L. Orsenigo (1997).

From these concepts, it is possible to get insight on the importance of cooperation between large and small firms in the process of technological change and innovation. Accordingly, Berry and Taggart (1994) suggest that in the knowledge-based industries, small firms are supposed to dominate the source of innovation during the earliest stages of the technology evolution (Mark I), meanwhile large firms are more important in the transitional and mature stages (Mark II).

Innovation in the Knowledge-Based Industries

Qian and Li (2003) point out that the knowledge-based industries are much more dynamic than traditional industries. Knowledge-based industries are characterized to be immersed into intense global competition, shortened product life cycles, as well as rapid technological duplication. Furthermore, King et al. (2003) mention that innovation is vital to achieve competitive advantages in knowledge-based industries. In addition, these authors also point out that a key feature characterizing knowledge-based industries is that they are structured in co-habitat of small and large firms.

The importance of small firms for knowledge-based industries concerns to certain intrinsic advantages derived from their flexibility, nimbleness, and innovativeness (Qian and Li 2003). In this sense, small operational scale is not necessarily a disadvantage in small firms as they may adopt strategies of specialization and alliances (McMillan et al., 2000; Niosi, 2003; Powell, 1998; Qian and Li, 2003). Eventually, firms collaborate in the pursuit of innovation when they do not possess all the necessary innovation-producing resources (King et al., 2003). Niosi (2003) suggests that strategic alliances and cooperation, as well as external financing mechanisms are important factors to explain how knowledge-based firms survive and growth. Additionally, Williamson (1975) claims that an adequate framework to understand the innovation processes carried out within knowledge-based industries is one suggesting the importance of small firms in initial product and technology developments, as well as large firms in production and marketing developments.

The problem arising at this stage is to explain how small firms in technology-based industries can acquire financial resources to successfully pursuit an innovation process. An explanation drawn from the Schumpeterian-Penrosian tradition suggests that collaboration between large and small firms can speed the innovation process subject to this kind of restrictions.

Financial Restrictions in the Innovation Process

Small firms commonly have important financial constraints impeding to go further on the commercialization stage. George et al. (2001) suggest that strategic alliances

with large firms is an adequate mechanism that can improve firm's financial performance by providing adequate external knowledge to develop the capabilities needed to introduce new products into the market.

In the Schumpeterian tradition, firm size is important to particular stages of the innovation process. The Schumpeterian concepts of Mark I and Mark II are important to explain the constraints imposed to firms when developing innovations (Malerba and Orsenigo 1997). However, Mark I and Mark II taken together provide a complete explanation of the process of competition and innovation. Under this approach small firms have a specific role as source of technological change. They are supposed to dominant the source of innovation during the earliest stage of the technology evolution, meanwhile large firms are more important in the transitional and mature stages as a source of financial resources and commercialization skills (Berry and Taggart 1994). In the same way, Roberts (1980) points out that small firm possess innovation-enhancing resources advantages in the areas of technological flexibility and entrepreneurial commitment, and large firms have innovation-enhancing resources advantages in the areas of capital, distribution channels and sales force.

In the same way, King et al. (2003) stress the importance of small firms as the principal source of product innovation, and large firms as the principal source of process innovations. These authors point out that small firms are characterized to be more agile than large companies, given that they have a higher degree of responsiveness to market changes. Small firms have an entrepreneurial and management style, and thus they are more disposals to risk acceptance, adaptability, flexibility, and open communications. In opposition, large firms possess reputation, access to financial and managerial resources, manufacturing and marketing facilities, and distribution channels.

The three-stage process model developed by King et al. (2003) is hence an adequate framework to explain collaboration between small and large firms in technology-based industries under financial restrictions. The model explains how technological change affects small and large firms independently and collaboratively, and contributing both together to develop technological innovations. In so doing, this model adopts three assumptions: (1) technological change is a discontinuous

process; (2) a dominant design emerges at some point in time; and (3) there is a period of incremental change in the efficiency and performance of the technology at industry-level.

The dynamics of model explains that an innovation process can be analyzed as a technological discontinuity —> dominant design —> industry-level technological change process. Accordingly, the three-stage process model of technological change and innovation that influence small and large firms' behavior and innovation in technology-based industries takes place in the following terms:

- Technological Discontinuities. The cycle begins with a technological discontinuity. Technological discontinuities are characterized to be largely experimental, and not clear in relation to potential new applications. The question is how small/large firms react to technological changes. An answer to this question is that large firms will try to improve existing technologies generating a delay of investments. This process makes large firms to keep a technology-based resource obsolete, and hence delaying investment in new technologies. In the same way, this process maintains their non-technology-based resources in marketing and manufacturing unchanged. Delays by large firms in pursing new technologies create opportunities for entrepreneurs in small firms in terms of Schumpeterian innovation style.

- Dominant Design. As result of a technological discontinuity, a dominant design emerges. Small and large firms pursue collaboration to develop and appropriate rents from technological innovations. At this stage, a new group of firms emerge offering similar products to satisfy a latent market and new technology can also lead to the creation of new industries. Small firms are more likely to introduce new technologies that create new industries because small firms will be more likely to pursue technological innovations that have limited or uncertain initial appeal in their product applications.

- Industry-Level Technological Change. This period is characterized for incremental changes focused on marginal improvements in the efficiency of the technology performance. Interfirm collaboration is based on small firms becoming aware of resource shortcomings that limit their ability to appropriate rents from the technological innovations. This shift represents a significant point in an industry's

life cycle where small firms begin to seek potential collaborators with the complementary resources they need. At this stage, technology uncertainty is reduced and large firms seek partners in new technological arenas increasingly recognized as viable. This is most likely to occur as the technological innovation matures and a small firm finds itself with the dominant design.

It is worthy to say that a dominant design can be adopted at a different moments. In this sense, Teece (2000) points out that a dominant design can be adopted when:

- Complementary resources become critical to innovation success;
- Competition unit around a dominant design;
- Large firms by virtue of their size, scope, and reputation may advance a dominant design simply by choosing to adopt a particular technology;
- A dominant design also brings new competitive pressures as the focus of competition shifts;
- There is an increase in the need to collaborate for innovation exploitation purposes (small firms are more willing to collaborate with large firms);
- Large firms are more willing to invest in a proven technology and market;
- Established companies are more likely to be competent as the process innovation requires to lower costs.

These statements reveal that the access to all kind of resources associated to large firms is critical to small firms' performance, and thus small firms compete for acceptance of their technology.

Comparing the innovation-related characteristics scheme between large and small firms reveals that large firms' innovative disadvantage are at the same time small firms' innovative advantage, and vice versa. Small firms are particularly responsive to market changes, they are more agile than large firms, they also have a deeper entrepreneurial and management style. Large firms possess reputation, easier

access to resources, greater manufacturing possibilities, marketing, sales, distribution channels, financial resources, and managerial capabilities.

Within this theoretical framework, venture capital is recognized to be the dominant source of selection. It provides financial resources and favors new firms with particular strategies and practices, as well as it provides firms management expertise and access to other capabilities (Baum and Silverman, 2004). Venture capital is a form of recognition in relation to other firms, including future alliances (Niosi, 2003). Venture capital investments provide a certification benefit that can enable startup firms to obtain other resources identifying potential (scout) and helping to realize that potential (coach).

In short, this model explains how venture capital contributions may become a dominant source of selection, providing financial resources to startup firms, favoring new firms with particular strategies and practices, providing management expertise, facilitating the access of startup firms to other capabilities to improve their competitive advantages, and conferring certification benefit to acquire other resources (Baum and Silverman, 2004).

Biotechnology-Related Industries in Canada

This section exemplifies the importance of alliances and cooperation between large and small firms in the knowledge-based industries using a survey conducted in Canada in 1999 on biotechnology-related industries (Niosi 2000a, 2000b, 2003). The survey shows that alliances and collaborative agreements are a core variable for explaining firms performance and growth. A total of 70% of the firms surveyed in this study consider this kind of agreements as a major growth factor, 78% of this firms expect to acquire complementary knowledge from their partners, 74% expect to increase the speed of innovation, and 66% to capable to generate new products.

Successful biotechnology innovation developments are associated to an adequate institutional environment that provides research and financial resources (Bartholomew, 1997; Niosi, 2003). This is the case because biotechnology product developments are characterized to be highly uncertain. In this sense, Niosi (2003) suggests that biotechnology firms may flourish easier when they create appropriate

alliances with large corporations for acquiring financial, manufacturing and marketing resources, and regulatory expertise.

Financial resources seem to be among the most important restrictions to biotechnology firm development. According to this survey the most important variable restricting biotechnology firm development in Canada is the access to capital (45%), followed by access to skilled human resources (18%), time of regulatory approval (13%), and intellectual property protection (3%). Consequently, venture capital partners come to be the most important constraint variable to develop biotechnology firms. Taken together, large corporations, research institutions and venture capital partners, bring about an explanation on how external resources and competencies can be acquired by small biotechnology firms to develop new products and innovations.

Similarly, Niosi (2000a and 2000b) finds supporting data to determine the most important variables affecting human health biotechnology firms: (1) number of years in the market; (2) firms focused to produce diagnostic and/or pharmaceutical products; (3) firms actively patenting; (4) existence of venture capital markets; (5) exporting activities; and (6) establishment of strategic alliances.

As the innovation process is characterized to be highly uncertain, firms necessarily have to compete for financial resources, search for alliance partners, create intellectual property, and develop capable management (Baum and Silverman 2004; Niosi 2003). Alliances capital, for example, has the potential to alter their opportunities and constraints. This potential derives from three different reasons: (1) alliances provide innumerable advantages associated with direct or indirect access to complementary resources, knowledge and other assets; (2) alliances may confer an aura of legitimacy which facilitates the acquisition of other resources; and (3) alliance advantages are particularly strong when timely access to knowledge or resources is essential.

On the other hand, Niosi (2000a, 2000b, 2003) finds that intellectual property protection offers significant benefits for the winner of a patent race with three important consequences: (1) the appropriability regime surrounding patents in biotechnology-related industries is particularly strong because patented compounds are difficult to avoid; (2) a biotechnology firm with a patent is in a favorable position

to obtain complementary assets and skills, venture capital financing and partners willing to support commercialization activities; and (3) there is a positive relationship between the number of pending patent applications that a biotechnology firm possesses and its survival chances. Finally, human capital is required as top management team experience and skills is commonly a selection criterion taken up by venture capital partners.

Conclusions

The objective of this paper was to make an introduction to the role played by large and small firms in the knowledge-based industries. From a Schumpeterian-Penrosian perspective, it was established that cooperation and alliances were two useful options for large and small firms to speed up innovation activities. In this sense, financial restrictions revealed to be the most important obstacle for small firms to step forward into the innovation process. The technological discontinuity/dominant design/ industry-level change process model demonstrated to be an adequate approach to analyze this phenomenon. Finally, the biotechnology-related industries in Canada are a good example to explain empirically this phenomenon.

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