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SME's OPENNESS COMPLEMENTARITIES TO EXTERNAL SOURCES OF INFORMATION: EVIDENCE FROM CHAUDIÈRE-APPALACHES MANUFACTURING FIRMS

Primary Sub-theme: Open innovation (S6)

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Abstract

This paper draws on recent developments in open innovation literature to address three crucial questions: to what type of ESI are SMEs in the Chaudière-Appalaches region open? Are SMEs in this region simultaneously open to a set of ESI? Are there differences in the determinants of the openness of these SMEs to different ESI? The study considers the openness of SMEs to four categories of ESI: market sources, research sources, generally available sources of information and regional sources.

The most important results of this study are: (1) there is a relation between the openness of SMEs and the four categories of ESI (Market sources, Generally available information sources, Research sources, and Regional sources), (2) the openness to these four groups of ESI seems to be complementary rather than substitute, and (3) not all variables included in the model explain the openness of SMEs in the Chaudière-Appalaches region to the four groups of ESI.

These findings suggest that policies toward encouraging the adoption of open innovation must go through the edification of open innovation regional initiatives that take into account regions' specificities.

Keywords: open innovation, openness, External source of information (ESI), SMEs.

1. Introduction

Economies are, mostly, composed of small and medium-sized enterprises (SMEs). In Canada, recent studies by Statistics Canada show that SMEs make up 99 percent of industry, account for more than 50 percent of employment, and represent over 85 percent of Canadian exporters (Debus, 2005). This importance has fuelled growing concern among policymakers to encourage innovation in these firms in order to stimulate the national economy (Edwards *et al.*, 2005).

This concern is also apparent in academic debates. In the innovation literature, new models of innovation suggest that this process is becoming a more open and distributed one (Chesbrough, 2003). Firms, according to these new models, combine knowledge from a wide range of external actors and sources to help them achieve and sustain innovation. Many authors have reported the significant role of ESI to support innovation activities in SMEs (Bommer and Jalajas, 2004; Costa and Teixeira, 2005; Amara *et al.*, 2008). Others have reported the importance of particular external sources (von Hippel, 1988; Romijn and Albaladejo, 2000; Fontana *et al.*, 2006).

In this study, the groups of ESI studies are: market sources, generally available information sources, research sources and regional sources. Despite considerable research efforts examining the importance of these groups of ESI for innovation, little is known about the complementarities in their use and about their determinants in the context of SMEs.

The aim of this paper is three-fold. First, different groups of ESI are studied in order to see to what extent SMEs are open. Second, complementarities and substitutions between various groups of ESI are studied in order to see how SMEs strategically use different groups of ESI to support their innovative activities. Third, heterogeneities in the determinants of SMEs are explored by choosing among four groups of ESI. Studying these complementarities in combination with their determinants can provide insights into the factors that enhance the openness of SMEs to different groups of ESI.

2. Contribution of the paper

Prior studies have suggested that appropriability methods, absorptive capacity (humain capital and R&D capacity), newness of firms on the market, and technology intensiveness can help to develop a conceptual framework for the study of the determinants of openness (Laursen and Salter, 2005). This study extends these lines of

analyses to include those pertaining to the SMEs' market and business partners. More specifically, we explore both the influence of geographical proximity and the vulnerability of these SMEs in their transactions with clients and suppliers on the openness of these firms to the four groups of ESI.

Moreover, while prior studies have simply tried to investigate the determinants of the openness to various ESI, this paper uses a Multivariate Probit (MVP) model to reflect the fact that in practice, firms, especially SMEs, consider being open simultaneously to various groups of ESI. The four groups of ESI included in this study are market sources, research sources, generally available sources, and regional sources. The explanatory variables included in the MVP model are absorptive capacity variables (engineers, technicians and R&D employees), strategic variables (appropriability methods, transactions with most important suppliers and clients), geographical proximity variables, and control variables (technology intensiveness, age, and size). By simultaneously considering four groups of ESI and their determinants, this paper contributes to shed light on how SMEs in the region of Chaudière-Appalaches in the province of Quebec (Canada) are open to ESI to support their innovative process.

This rest of the paper is organized into six sections. Section three presents the theoretical background of the study and highlights the link between the use of ESI and the concept of openness. Section four outlines the hypotheses of the study and the determinants of openness. Information about the data, methods and descriptive analysis are provided in section five. Section six presents the analytical plan adopted in this paper to answer our research questions. Section seven presents our results. Finally, the paper concludes, in section eight, by signalling important findings of the study, some important implications for SMEs, and limits of the research.

3. Theoretical and empirical background

3.1. The concept of openness

New models of innovation suggest that many innovative firms have adopted an open innovation model, combining knowledge from a wide range of external actors and sources to help them achieve and sustain innovation (Chesbrough, 2003). Many studies on innovation have assessed the importance of ESI as determinants of innovation. Venkataraman (1997) claims that firms which have access to a larger variety of sources of information are in a better position to identify and develop innovation opportunities.

Empirically, many studies have reported positive effects of the use of a variety of ESI on innovation activities (Romijn and Albu, 2001; Laursen and Salter, 2006; Leiponen and Helfat, 2009).

Recently, the use of ESI has been operationalised in the literature with the concept of openness (Laursen and Salter, 2006). This concept, which reflects the external search of firms, has been used as a measure of open innovation (Laursen and Salter, 2006; Keupp and Gassmann, 2009). The openness of a firm is characterized by two dimensions which reflect the number of ESI used (breadth) and the intensity of use of these ESI (depth). In this way, firms may differ both in the number of ESI they use for their innovative activities as well as in the intensity of use of each of these ESI.

3.2. Complementarities between ESI

Researchers in strategic management agree that achieving a competitive advantage depends upon the firm's ability to utilize existing knowledge and to generate new knowledge more efficiently and effectively, compared to competitors (Penrose, 1959; Nonaka, 1994). Openness to different ESI can contribute to the innovation process in different ways. For example, Rothwell (1994) suggests that clients are important because they provide complementary knowledge. Suppliers are also of great importance for firms' innovation projects. According to Leiponen and Helfat (2009), they provide knowledge regarding inputs, including raw materials, plant and equipment, product components, and subsystems. Yeniyurt et al. (2005) noted that supplier knowledge is used to assist the decision-making process by linking customer demands with supplier capabilities, which allows firms to minimize inventory costs. Some authors have even linked the success of projects to the implication of suppliers in the initial stage of projects (Tseng, 2009). Competitors also seem to be an important ESI for firms. Indeed, firms often benefit from competitors as sources for benchmarking and transfer of best practices (Drew, 1997). These ESI (clients, suppliers, competitors) have always been referred to in the literature as market sources (Amara and Landry, 2005; Laursen and Salter, 2006; Amara *et al.*, 2008; Lee *et al.*, 2010).

Likewise, ESI, such as universities and colleges, private and public research laboratories and private research institutions, have been referred to in the literature as research sources (Fontana *et al.*, 2006; Laursen and Salter, 2006; Amara *et al.*, 2008; Tether and Tajar, 2008). Many studies have been interested in examining the importance for firms of being open to these research sources. Many of these studies have been

devoted to studying the link between universities and industry (Cohen *et al.*, 2000; Laursen and Salter, 2004; Fontana *et al.*, 2006). These studies have generally emphasized the role of these ESI in the increase of the innovation rate in the economy (Spencer, 2001) and their importance in the generation of new ideas for innovation (Fontana *et al.*, 2006). Some authors have emphasized the fact that the fallout of the openness to universities as an ESI is very different, according to the firm's sector of activities. For example, Fontana et al. (2006) have found that in chemicals, the openness to these ESI helps firms to reduce costs and risks, and allows them to acquire and update scientific knowledge in order to finalise products. In the agro-industry sector, universities help firms to meet government regulations, especially by testing activities related to bacteriology.

Another group of ESI is referred to in the literature as generally available information sources which include, for example, trade affairs and exhibitions, documentation on patents, professional conferences, meetings, the Internet, computer-based information networks, etc. Once more, the use of these ESI has been proven to be linked to the likelihood to innovate and to the degree of innovation novelty (Amara and Landry, 2005; Cozzarin, 2006).

Finally, the last group of ESI is referred to, in this study, as regional and support sources. The advantage of these sources is their geographical closeness to the firms, which seems to be critical for innovation, according to many authors like Holbrook and Wolfe (2000). In fact, for these authors, innovative capabilities are sustained through local and regional communities of firms and supporting networks of institutions.

To summarize, we can say that the openness of firms to these ESI provide them with different innovation inputs that they rely on in their innovative activities. Also, Leiponen and Helfat (2009) have found that individual sources are not strongly associated with innovation success. They suggest that by using many knowledge sources, firms increase their chances of finding something useful in two ways: first, they will be drawing from the pool of knowledge more often, which improves their chances of 'being lucky' and finding a useful piece of knowledge; second, they stand more of a chance of striking upon complementary knowledge because of the diversity of sources they consult (Mol and Birkinshaw, 2005). These arguments suggest that firms may benefit from complementarities and synergies among knowledge sources (Leiponen and Helfat, 2009). As a consequence of the arguments and findings presented previously, we expect:

> H_1: SMEs' openness to the four groups of ESI tends to be complementary rather than substitute.

3.3. Determinants of Openness

3.3.1. Absorptive capacity (AC) variables

The search for new combinations of knowledge often requires firms to deal with many different actors outside the firm, including consultants, customers, suppliers and universities (von Hippel, 1988; Spencer, 2003). Such search processes call upon firms to expend considerable efforts to build relationships and understanding to absorb knowledge from external sources (Cohen and Levinthal, 1990; Zahra and George, 2002). The concept of AC is critical to firms' innovative capabilities (Cohen and Levinthal, 1990). In the literature, this concept has been operationalized by different measures such as R&D spending (Cassiman and Veugelers, 2002), and skills and human capital (Zahra and George, 2002; Zahra and Nielsen, 2002; Laursen and Salter, 2005). Since small firms do not generally have a formal R&D department, R&D spending was the measure more used in the literature of the firm's ability to absorb external knowledge. Following Laursen and Saler (2005), the AC is measured, in this study, by the level of skills and R&D employees. In sum, the arguments presented above lead us to expect that:

> H_2: *The level of AC of firms is positively related to their degree of openness to ESI.*

3.3.2. Strategic variables

3.3.2.1. Appropriability methods

Innovation is about exploiting new ideas coming from external sources. Being exposed to ESI could lead to a leak of knowledge, which in turn can act as a strong incentive to limit openness to the external environment (Laursen and Salter, 2005). To avoid this firms try to protect their inventions by using a variety of appropriability mechanisms. Cohen et al. (2000) distinguish between formal methods, such as patents and copyrights, and informal methods, such as lead time on competitors, secrecy, and complexity of the product.

Firms need to be open to ESI in order to innovate and also to appropriate the profits from innovation by adopting adequate appropriability strategies. However, a strong emphasis on appropriability will lead firms to be less open as their fear of theft or leakage forces them to limit their exposure to external sources. Thus, we hypothesize that:

H_3: The tightness of the overall appropriability strategy of firms is negatively related to the degree of openness to external sources.

3.3.2.2. Vulnerability to clients-suppliers

The Openness is a process that reflects the firm's ability to benefit from ESI to support its innovative activities. The openness is enhanced when it is supported by exchanges with important corporate stakeholders, including clients and suppliers. Indeed, one of the important aspects of these exchanges is the relationships established between the firms and their partners through the sale of their products and the purchase of their inputs (Amara et al., 2008). Therefore, we presume that the level of dependence of firms on their most important clients and suppliers will impact on their openness to ESI. Thus, we hypothesize that:

H_4: The higher the dependence of the firms on their most important clients and their most important suppliers, the higher their level of openness to ESI.

3.3.3. Geographical proximity variables

Considering innovation in the context of the open innovation model, innovative firms rely much more on their interaction with users, suppliers and other sources within their innovation system (von Hippel, 1988; Fuchs and Koch, 2005). This proximity assures the exchange of knowledge between actors (Bell and Zaheer, 2007). For example, proximity with clients assures the timely acquisition of strategic information which will maybe later enhance the success of introduction of innovations on the market (Cooper and Kleinschmidt, 1994; Appiah-Adu and Singh, 1998). Geographical proximity that increases the use of these ESI will also increase the trust between firms and their business partners (Bell and Zaheer, 2007). As a consequence of the arguments and findings presented above, we expect that:

H_5: The more the firms are geographically proximate to ESI, the *higher their degree of openness to these ESI.*

3.3.4. Control variables

3.3.4.1. LnSIZE

Size, measured as the total number of employees, is often used as a control variable to explain the innovation capacity of firms. Its use to explain openness to ESI in the context of SMEs is not very much investigated. Laursen and Salter (2005) seem to be the only authors who investigated this relationship in the context of start-ups. These authors have found that the size of the firm determines its degree of openness. Thus, we may expect that:

> H_6: The degree of openness of SMEs to ESI increases with the increase of size.

3.3.4.2. LnAge

To our knowledge, there is no study that has explored the relation between the age of the firm and its degree of openness to ESI. According to Traoré (2004), the age of the firms accounts for differences in the creative capacity, due to accumulated experience and knowledge through the years. We can postulate that this experience will be beneficial to SMEs in their openness to ESI:

> H_7: The openness of SMEs to ESI increases with the increase of the SMEs' age.

3.3.4.3. Technology intensiveness

Laursen and Salter (2006) and Klevorick et al. (1995) have suggested that in industries with high levels of technological opportunities and extensive investments in search by other firms, a firm will often need to search more widely and deeply in order to gain access to critical knowledge sources. In contrast, in industries where there are low technological opportunities and modest investments in search by other firms, a firm has weaker incentives to draw from external knowledge sources and may instead rely on internal sources. Hence, firms operating in industries characterized by high technological intensiveness may be more open than firms operating in industries characterized by low or medium technological intensiveness. Therefore, we may then assert that:

> H_8: *The higher the* technological intensiveness *of the industry in which firms are operating, the higher their degree of openness to ESI.*

[Figure 1 about here]

4. Methods

4.2. *Data and descriptive statistics*

The data used in this study have been collected by a survey firm, which conducted computer-assisted telephone interviews from October 09 to December 09, 2003. With a focus on the innovation behaviour of firms, the survey questionnaire derives from the methodology of the Oslo Manual and is adapted from the Community Innovation Surveys (CIS) and Statistics Canada surveys on innovation. The survey was administered to the whole population of the manufacturing firms operating in the Chaudière-Appalaches region, a region of traditional manufacturing SMEs located in Canada. The population included 1214 firms. Out of this effective population, 332 firms were out of the population of the study for different reasons. In the end, the resulting sample consists of 615 firms for a return rate of 69.7%.

In this paper, SMEs are defined as firms where the number of employees is 500 and less. This consideration lowered the population under study to 603 firms. Also, in this study, we look at the subset of firms that are innovative, that is, firms that have developed or improved their products or processes during the past three years. This subset amounts to 74.5% (458 firms) of the respondents.

[Table 1 about here]

Considering the openness of these SMEs to the four groups of ESI, Table 2 lists the twelve ESI investigated in this study. Each firm was asked to indicate the degree of importance (use) of each source for innovative activities, using a 5-point scale ranging from 1 (not important) to 5 (extremely important).

Overall, the results indicate that the most important source is clients (32.35%), followed closely by suppliers (21.39%). Next to clients and suppliers, competitors, professional conferences and professional associations are among the key sources of innovation. Finally, results show that research and regional sources are not very important as sources of innovation for SMEs in this region.

Drawing from these results, we might say that the fact that SMEs in the Chaudière-Appalaches region are highly open to clients and suppliers suggests that the innovation activities of these firms are strongly determined by relations between themselves and their suppliers and clients rather than by their interactions with research sources or their proximity to regional sources.

[Table 2 about here]

4.3. *Data coding*

4.3.1. Dependent variables

Four dependent variables are with multiple-item scales are considered in this study, these variables capture the openness of firms to the four groups of ESI presented previously. To measure the openness of firms to these groups of ESI, each firm was asked to indicate the importance on a 5-point Likert scale of each of these sources (Table 3). Because our dependent variable is based on multiple-item scales, we conducted a principal components factor analysis (PCFA) on the construct scales to assess their unidimensionality (Ahire and Devaraj, 2001). We also computed Chronbach's α on the components of these additive scales to assess their reliability. The results of these analyses indicate that all the four variables are unidimensional and their components are reliable.

[Table 3 about here]

4.3.2. Independent variables

According to the framework proposed in this study, explanatory variables were regrouped in four categories: (1) AC variables (i.e., human capital embodied in engineers and technicians, R&D employees), (2) geographical proximity variables (i.e., regional proximity, provincial and national proximity, world proximity), (3) strategic variables (i.e., appropriability methods, vulnerability toward clients, and vulnerability toward suppliers), and (4) control variables (i.e., technological intensiveness, size and age of the firm). The operational definitions and descriptive statistics of these explanatory variables are presented in Table 1.

5. ANALYTICAL PLAN

To assess the presence of any interactions between the indices referring to the four groups of ESI, we firstly estimated a structural equation model (SEM). Secondly, in order to assess the existence of complementarity, independency or substitution between the openness of SMEs to the four groups of ESI, we estimated a Structural Multivariate Probit model (MVP). The MVP specification allows for systematic correlations between different types of ESI. Such correlations may be due to complementarities (positive correlation) or substitution (negative correlation) between ESI. If a significant correlation exists, the use of separate probit models leads to inefficient estimates (Belderbos *et al.*,

2004; Amara et al., 2008). To deal with these questions, our analytical plan will be carried on in two stages: estimation of a SEM and estimation of MVP a model.

5.1. SEM model

The first stage of the analytical plan is based on structural equation modelling (SEM). SEM has been developed in a number of academic disciplines to confirm theory. After conducting an exploratory factor analysis and reliability analysis in SPSS, the EQS 6.1 multivariate software was used to test the proposed structural model. EQS 6.1 operates upon the normalised variance–covariance matrix derived from the raw database (Bentler, 1995). In our study, observed variables are used to measure the four latent variables related to different groups of ESI. The relation between observed variables and latent variables will produce a system of equation called measurement model. As recommended by Shook et al. (2004), the fit of the model was assessed with multiple indices: the normed-fit-index (NFI), the non-normed-fit index (NNFI), the comparative fit index (CFI), and the root mean square error of approximation (RMSEA).Values of NFI, NNFI, and CFI greater than 0.90 indicate a good model fit (Byrne, 2006). Values of RMSEA less than 0.05 indicate a good fit, and values as high as 0.08 represent reasonable errors of approximation in the population (Browne and Cudeck, 1992). The $\chi 2$ is reported, but is not given major consideration, because it is highly sensitive to sample size and the number of items in the model (Bentler and Bonett, 1980).

5.2. MPV model

The second stage of the analytical plan is carried on in two sequential steps. Firstly, we have estimated a saturated path model which allows to simultaneously estimate four OLS regressions to explore the correlates of the indices of sources of information used by firms to innovate previously identified with the exploratory factor analysis, namely, market sources index, generally available information sources index, research sources index and regional sources index. The major issue raised from the use of separate models is related to the possibility of getting inefficient estimators if some equations' disturbances are correlated (Belderbos *et al.*, 2004).

This path model was fitted to the data using a maximum likelihood (ML) of a multivariate normal density function, as all dependent variables considered in this study are continuous and normally distributed (Muthén, 1998-2004; Golob, 2003).

Secondly, as the fit of the saturated path model estimated in the first stage cannot be assessed[2], the same model was estimated, but by fixing insignificant parameters (i.e., those with p > 0.10, two-tailed) at 0. This second unsaturated path model can be assessed for model fit as its degree of freedom is different from 0 (Golob and Regan, 2002).

6. RESULTS

6.1. Results of SEM

The structural relationships between the four groups of ESI proposed in the model were estimated using the robust method in EQS 6.1 (Bentler and Wu, 2006). EQS reported that parameter estimates appear in order, which indicate that no particular problems were encountered during the optimization, and that all equality constraints were correctly imposed. The resulting model goodness-of-fit indices indicate a good model fit ($\chi 2 = 74.04$, 48 df, propability 0.009; NFI = 0.946; NNFI = 0.973; CFI = 0.980; RMSEA = 0.039). Also, according to the results obtained from the SEM, we can say that there is a significant (p-value = 0.05) and a moderate positive correlation between the four groups of ESI. (F1-F2 =0.34; F1-F3=0.24; F1-F4=0.25; F2-F3=0.30; F2-F4=0.32; F3-F4=0.33)[3]. These results suggest the presence of bundles of interaction patterns between the four groups of ESI. In the following section, we will estimate the MVP models to assess the presence of complementarity, independency or substitution relations between the four groups of ESI considered in this study.

6.2. Results of the MPV model

The results of the unsaturated path models (which take into account only the significant coefficients) are summarized in Table 4. The results of the comparison of the constrained unsaturated path model with the unsaturated one with free error-terms are also reported in the lower part of Table 4.

6.2.1. Overall model fit, R-squares and error-term covariances

The unsaturated path model had 18 degrees of freedom and an insignificant Chi-square statistic of 13.31 (p-value = 0.773). The R2 estimates are listed on the lower part of Tables 4. The R2 estimates reported in Tables 4 show that market sources index

[2] Saturated models always fit perfectly as they typically have 0 degree of freedom.
[3] F1: Market resources; F2: Generally available information sources; F3: Research sources; F4: Regional sources

(MARKET) and generally available information sources index (INFORM) are the indices of sources of information that are the most effectively explained in both models.

6.2.2. Complementarities among different groups of ESI

The estimates of the error-term covariances of the four regression equations are listed at the bottom of Table 5. We can see that all of these covariances are significant at the 1% level and positively correlated, indicating that none of the indices of ESI substitute for one another. This strongly supports the hypothesis of interdependence (complementarity) between the different indices of ESI used by firms to develop a new product and/or new manufacturing process. This suggests that there is no high redundancy between the different ESI, and that firms have a tendency to rely on a large spectrum of ESI when they engage in an innovation process.

However, some covariances between pairs of indices of ESI are higher than others, suggesting the presence of higher complementarities between some pairs of indices of ESI than others. More specifically, the lower part of Table 5 shows that the highest covariances are between: research sources of information and regional sources of information (0.266), generally available sources of information and regional sources of information (0.238), and between research sources of information and generally available sources of information (0.231). At the other extreme, the lowest covariances are between: market sources and regional sources (0.126), and market sources and research sources (0.135). Overall, the market sources of information appear to be less related to the other sources of information.

6.2.3. Effects of explanatory variables on ESI indices

As for the extent to which explanatory variables explain the various indices of ESI, results show that anywhere from four to seven variables are significant at levels varying from 1% to 10% in each of the four equations. More precisely, Regional proximity (REG_PROX) and provincial and National proximity (PR&NA_PROX) have a significant and positive impact on the four indices of ESI used by firms to innovate. However, World proximity (WORLD_PROX) has a significant and positive impact on only two indices of ESI, namely Generally available information sources and Research sources.

Likewise, the firm's size, as measured by the total number of employees (LN_SIZE), is significantly and positively related to all indices of sources of information, except the research sources index. With regard to AC embodied in engineers and technicians

(LN_ING&TECH) and in R&D employees (LNPER&D), the results indicate that these two variables exert a significant and a positive impact, only on the research sources index.

As for Age of the firm (LN_AGE) and Appropriability methods (APP_MET), they were found significant and exerting a negative impact on the market sources index for the first, and on Generally available information sources and Regional sources of information for the second. Finally, the results show that firms operating in a high technology sector are more likely to rely on Generally available information sources and Research sources when they engage in the development of a new product and/or new manufacturing process.

[Table 4 here]

7. Discussion and conclusion

Firms, especially SMEs, are becoming more dependent on the use of ESI to support their innovation activities. New models of innovation suggest that firms need to interact with a large number of actors including clients, suppliers and so on. In order to foster our understanding on how SMEs use ESI, we draw on previous literature that used the concept of openness to qualify the use of ESI (Laursen and Salter, 2004; 2006). As Criscuolo et al. (2006), instead of assessing the effect of a specific source, the present study analyzed the openness of SMEs to four groups of ESI. Finally, we investigated the determinants of the openness of SMEs to different groups of ESI.

The results presented in the previous section reveal that SMEs in the Chaudière-Appalaches region are open to the four groups of ESI. However, this openness seems to be more important for market sources than other sources. This result goes in line with previous studies which found that clients and suppliers are most frequently mentioned sources of product and process innovation (Avermaete *et al.*, 2004; Bommer and Jalajas, 2004).

Considering the openness to generally available information sources, SMEs in this region seem to be open to these ESI, but not as much as market sources. These results inform us that these firms consider professional conferences, professional associations, and government agencies for information and promotion as key mechanisms for capturing external knowledge, which suggests that innovation requires more ESI exploration and exploitation. The relatively low openness to research sources suggests that research–industry relations are a concern for a minority of Chaudière-Appalaches SMEs. Finally, we found that the openness of these SMEs to regional sources is not higher, as expected,

even if these sources are geographically proximate to these SMEs. It seems that proximity to ESI is not as important as the type of knowledge that these ESI can provide to these SMEs.

Finally, the results of the MPV model confirm the findings of our SEM model which reports the existence of a relation between the four groups of ESI, and this relation takes the form of complementarities between the openness to these sources, which enhance the probability of SMEs to find different valuable pieces of knowledge for product and process innovation.

Considering the results related to the MPV model, we found that two variables have a significant impact on the openness to the four groups of ESI, namely regional proximity, and provincial and national proximity variables. Some variables have a significant impact only on the openness to three groups of ESI (Market sources, Generally available information sources, and Regional sources) such as the size of the firms. Also, some variables have a significant impact only on the openness to two groups of ESI as is the case for world proximity and technological intensiveness variables which open to Generally available information sources and Research sources. Furthermore, some variables have a significant impact only on the openness to one group of ESI, namely AC variables which are significant only on the openness to Research sources, and the age of the firms which has a significant impact on the openness to Market sources. Finally, some variables included in the model have no impact on the openness to ESI such as vulnerability toward clients and suppliers.

As pointed out previously, these results suggest that SMEs in the Chaudière-Appalaches region should consider the potential of using different ESI to support their innovative activities. The development and improvement of products and processes, by these SMEs, cannot depend only on one type of ESI, but they must rely on variety of ESI (Amara and Landry, 2005), suggesting that these firms may benefit from complementarities and synergies among different knowledge sources (Leiponen and Helfat, 2009).

Finally, our research has several limitations. First, the framework proposed in this study takes into account only four groups of ESI rather than individual ESI. Future research can tackle this issue by exploring specific individual ESI. Second, some traditional ESI such as consultants, trade and exhibitions, and specialized ESI, were omitted in this study. Future research can include these ESI in the analysis since many studies have emphasized the importance of these ESI for innovation activities (Laursen and Salter, 2006; Tether and Tajar, 2008). Finally, this study measured open innovation by only

considering the use of ESI, future research can include in this definition some other aspects related to open innovation such as collaboration R&D, licence agreements, venturing and so on (van de Vrande *et al.*, 2009).

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Table 1: Definitions of independent variables and descriptive statistics

Independent variables	**Measure**	**Sub-items**	**Mean (SD)**	**% (Nombre)**	**Cronbach's alpha**
Continuous variables					
Engineers and technicians [Ln_ING&TECH]	Measured as the percentage of the number of technicians and engineers to total number of employees. This variable was matched with the normal distribution using logarithmic transformation.		3.22 (9.70)		
R&D employees [Ln_PER&D]	Measured as the percentage of the number of R&D employees to total number of employees. This variable was matched with the normal distribution using logarithmic transformation.		1.86 (2.72)		
Regional proximity [REG_PROX]	Measured as a weighted index on a Likert scale of the importance of clients and suppliers on a 5-point scale ranging from 1 (low importance) to 5 (high importance) regarding the importance of the role played during the last three years by clients and suppliers located regionally for the development of innovations.	• Clients located within 100 km of your firms • Suppliers located within 100 km of your firms	4.93 (2.14)		0.689
Provincial and National proximity [PR&NA_PROX]	Measured as a weighted index on a Likert scale of the importance of clients and suppliers on a 5-point scale ranging from 1 (low importance) to 5 (high importance) regarding the importance of the role played during the last three years by clients and suppliers located at provincial and national level for the development of innovations.	• Clients located elsewhere in Quebec • Suppliers located elsewhere in Quebec • Clients located elsewhere in Canada • Suppliers located elsewhere in Canada	8.47 (3.91		0.83
World proximity [WORLD_PROX]	Measured as a weighted index on a Likert scale of the importance of clients and suppliers on a 5-point scale ranging from 1 (low importance) to 5 (high importance) regarding the importance of the role played during the last three years by clients and suppliers located elsewhere in the world for the development of innovations	• Clients located in U.S.A • Suppliers located elsewhere in U.S.A • Clients located elsewhere in the world • Suppliers located elsewhere in the world	6.42 (3.36)		0.82
Sales to Clients [SQCLIENTS]	Measured as the percentage of sales to the three most important clients. This variable was matched with the normal distribution using a square root transformation.		47.3 (29.5)		
Sales to suppliers [SUPPLY]	Measured as the percentage of sales to the three most important suppliers.		57.5 (27.25)		
Appropriability methods [APP_MET]	Measured as a six-item index regarding whether or not the firms had used the following methods to protect their intellectual property during the last three years preceding the survey:	• Patents; • Registration of design patterns; • Trademarks; • Secrecy; • Complexity of design; • Lead-time advantage on competitors	1.30 (1.46)		
LnAge [LN_AGE]	Measured as the number of years from which the firm was established to date. This variable was matched with the normal distribution using logarithmic transformation.		22.5 (18.07)		
LnSize [LN_SIZE]	Measured as the number of employees in the firms. This variable was matched with the normal distribution using logarithmic transformation.		41.3 (70.1)		

Table 1 (continued): Definitions of independent variables and descriptive statistics

Independent variables	**Measure**	**Mean (SD)**	**% (Nombre)**	**Cronbach's alpha**
Categorical variables				
Technological intensiveness [TECH_INT]	Technological intensiveness was measured using three binary variables: • LOWTECH is a binary variable coded 1 if the R&D expenditures of the firms is below 2.5%, and coded 0 otherwise; • MEDTECH, is a binary variable coded 1 if the R&D expenditure of the firms is between 2.5% and 7%, and coded 1 otherwise; • HIGHTECH, is a binary variable coded 1 if the R&D expenditure of the firms is more than 7.5%, and coded 1 otherwise.		55.9% 13.6% 13.9%	

Table 2: Sources of information and knowledge for innovation activities in Chaudière-Appalaches manufacturing SMEs

Groups of sources	Knowledge source	Percentage			
		Not used	**Low**	**Medium**	**High**
Market sources	• Clients	7.13	7.30	27.69	32.35
	• Suppliers	12.11	16.09	25.04	21.39
	• Competitors	18.57	19.40	27.20	9.45
Generally available Information sources	• Professional conferences, meetings and publications	26.04	16.42	24.71	7.13
	• Professional associations or business networks information	24.21	17.25	25.70	7.13
	• Government agencies for information and promotion	30.02	16.42	22.06	5.14
Research sources	• Universities	46.43	14.76	10.28	2.82
	• Community colleges	45.61	15.09	11.77	1.82
	• Technology transfer organizations	42.92	11.94	9.95	3.32
Regional sources	• Centre de Recherche Industrielle du Québec (CRIQ)	38.64	12.77	18.24	4.48
	• National Research Council Canada (NRCC)	46.27	12.27	11.28	3.15
	• Centre d'innovations en mécanique industrielle (MECANIUM)/ Centre intégré de mécanique industrielle de la Chaudière (CIMIC)	47.43	10.28	10.61	2.49
Mean		**32.62**	**14.17**	**18.71**	**8.39**

Table 3: Definitions of dependent Variables

Dependent variables	Measure	Sub-items	Method (Range)
Continuous variables			
Openness to Market sources [OPEN_MARKET]	A three-item index regarding the importance of the role played during the last three years by the following three ESI needed for the development of innovations. The firms were to rate the importance of these three ESI on a 5-point scale ranging from 1 (low importance) to 5 (high importance).	• Clients • Suppliers • Competitors	Sum of the 3 items (the index ranges between 1 and 5)
Openness to Genarally available Information Sources [OPEN_INFORM]	A three-item index regarding the importance of the role played during the last three years by the following three ESI needed for the development of innovations. The firms were to rate the importance of these three ESI on a 5-point scale ranging from 1 (low importance) to 5 (high importance).	• Professional conferences • Information programs of governments • Information from professional associations or professional networks	Sum of the 3 items (the index ranges between 1 and 5)
Openness to Research sources [OPEN_RESEAR]	A three-item index regarding the importance of the role played during the last three years by the following three ESI needed for the development of innovations. The firms were to rate the importance of these three ESI on a 5-point scale ranging from 1 (low importance) to 5 (high importance).	• Technology transfer organizations; • Universities; • Community colleges.	Sum of the 3 items (the index ranges between 1 and 5)
Openness to Regional sources [OPEN_REGIONAL]	A three-item index regarding the importance of the role played during the last three years by the following three ESI needed for the development of innovations. The firms were to rate the importance of these three ESI on a 5-point scale ranging from 1 (low importance) to 5 (high importance).	• Provincial research laboratories; • Government research laboratories; • MECANIUM/CIMIC;	Sum of the 3 items (the index ranges between 1 and 5)

Table 4. Unsaturated Multivariate Path Model Results Explaining the Sources of Information Used to Innovate

	Market sources		Generally available Information sources		Research sources		Regional sources	
Independent variables	Coeff. (β)	T statistics	Coeff. (β)	T statistics	Coeff. (β)	T statistics	Coeff. (β)	T statistics
Intercept	1.195***	10.729	1.368***	7.998	.938***	8.756	1.298***	7.326
Percentage of engineers and technicians [LN_ING&TECH][a]					.107***	3.747		
Percentage of employees involved in R&D [LN_PERR&D] [a]					.131***	7.278		
Appropriability methods [APP_MET]	-.047**	-2.349						
Regional proximity [REG_PROX]	.217***	6.588	.080**	2.437	.070**	2.217	.084*	2.452
Provincial and national proximity [PR&NA_PROX]	.313***	8.571	.238***	5.805	.239***	5.985	.202***	5.397
World proximity [WORLD_PROX]			.085**	2.550	.050*	1.591		
Age of the firm [LN_AGE] [a]			-.085*	-1.748			-.121**	-2.394
Vulnerability toward clients [CLIENTS]								
Vulnerability toward suppliers [SUPPLY]								
Number of employees [LN_SIZE] [a]	.047**	2.039	.089***	3.786			.052**	2.242
Low technology sector [BINLOW] [b]			-.120**	-2.034	-.134**	-2.367		
Medium technology sector [BINMED] [b]			-.142*	-1.740	-.121*	-1.562		

Covariances between disturbances	ε_1	ε_2	ε_3	
ε_2	0.184 ***			
ε_3	0.135 ***	0.231 ***		
ε_4	0.126 ***	0.238 ***	0.266 ***	
Number of observations	451			
R-Square	0.327	0.247	0.223	0.131
Unsaturated path model with free error-terms	χ^2 (18) = 13.31, p-value = 0.773			
Constrained unsaturated path model with error-terms fixed at 0.:	χ^2 (24) = 439.94, p-value = 0.000			

*, ** and *** indicate that the coefficient is significant, respectively, at the 10%, 5% and 1% thresholds.
[a] LN indicates a logarithmic transformation.
[b] The reference category is High technology sector [BINHIGH].

Figure 1: Proposed framework for the openness of SMEs in the Chaudière-Appalaches region