Does Social Capital Determine Innovation? To What Extent?

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Abstract

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This paper deals with two questions: Does social capital determine innovation in manufacturing firms? If it is the case, to what extent? To deal with these questions, we review the literature on innovation in order to see how social capital came to be added to the other forms of capital as an explanatory variable of innovation. In doing so, we have been led to follow the dominating view of the literature on social capital and innovation which claims that social capital cannot be captured through a single indicator, but that it actually takes many different forms that must be accounted for. Therefore, to the traditional explanatory variables of innovation, we have added 5 forms of structural social capital (business network assets, information network assets, research network assets, participation assets, relational assets) and one form of cognitive social capital (reciprocal trust).Based on the survey data administered from April to June 2000 to 440 manufacturing firms of diverse industries in a region in the South-West of Montréal, we have found that 68,5% of the firms have developed product or process innovations during the three years preceding the survey. Assuming that innovation is not a discrete event but a complex process, we have modeled the decision to innovate as a two-stage decision-making process: in the first stage, the firms deal with the decision about whether to innovate or not whereas, at the second stage, the firms that have decided to innovate must make a decision about the degree of radicalness of the innovation to undertake. In a context where empirical investigations regarding the relations between social capital and innovation are still scanty, this paper makes contributions to the advancement of knowledge in providing new evidences regarding the impact and the extent of social capital on innovation at the two decision making stages considered in this study. Regarding the decision to innovate or not that firms must initially make, we have provided strong evidences that diverse forms of social capital influence this decision and, more importantly, that increases in social capital, especially in social capital taking the forms of participation assets and relational assets, contribute more than any other explanatory variable to increase the likelihood of innovation of firms. As for the decision to be made at the second stage concerning the magnitude of radicalness to bring in the development of new product or process innovations, this paper contributes to the advancement of knowledge by supplying the strongest evidence that diverse forms of social capital determine the radicalness of innovation, and more importantly, that social capital taking the form of research network assets contributes more than any other explanatory variable to explain the radicalness of innovation. The second variable that exerts the strongest impact on the radicalness of innovation is the number of different advanced technologies employed by firms for production.

1. Introduction

The importance of the technical and economic determinants of innovation has received much theoretical and empirical attention. The importance of social capital as a determinant of innovation has received much theoretical attention over the last few years. It is now assumed that the acquisition of knowledge by firms does not only depend on the market or the hierarchy, but also on the social capital accumulated within regions through networks of interaction and learning. Standing in contrast with the transaction cost theory based on the assumption of opportunism and the resulting conditions of market failure, the supporters of the social capital theory argue that firms have capabilities for creating and sharing knowledge that improve their innovative capabilities. The particular capabilities of firms for creating and sharing knowledge are seen as resting on formal and informal regional institutions. However, in contrast to the substantial theoretical insights that have been developed in the literature on innovation over recent years, there are as yet very few empirical tests of these new hypotheses. In this paper, we seek to address this gap and to present estimations of models of how social capital determines innovation at the regional level. More specifically, we: 1) use the data of a recent original regional survey administered to 440 manufacturing firms in the Montérégie region in Québec; 2) integrate the explanatory variables of the innovation literature in a general model comprising the following elements: human embodied knowledge, technology embodied knowledge, in-house creation of knowledge, social capital (measured with three indices: business network, information network, research network), participation assets, relational assets, trust assets, financial capital, marketing assets and pressures from competition; 3) estimate a two-step model where we assume that firms must firstly decide whether or not to innovate and then, in a second step, make a decision about the degree of radicalness of the innovation planned; 4) present and discuss the results of the estimations of these models and derive generic policy implications in terms of governance of innovation.

2. The emergence of social capital as an explanatory factor in the knowledge-based theories of innovation

The conception of innovation has evolved rather drastically over the last forty years. During the 1950s, innovation was considered as a discrete event resulting from knowledge developed by isolated inventors and isolated researchers. Nowadays, innovation is rather considered as the result of a process which success rests upon the interactions and exchanges of knowledge involving a large diversity of actors in situations of interdependence. This evolution in the conception of innovation has generated two consequences: first, innovation is no longer conceived as a discrete event only involving the development of technical solutions, but as a process alsoinvolving social interactions; second, innovation is no longer explained by the sole combinations of tangible forms of capital (physical, financial,..), but also by combinations of intangible forms of capital, especially social capital. We will review these changes in two stages: first, we will review very briefly the changes that have occurred regarding the understanding of the concept of innovation; second, we will review the major theoretical frameworks by distinguishing the engineering theories from the socio-organizational theories of knowledge-based innovations.

2.1. From a discrete event conception to a process conception of innovation

Knowledge-based innovation is no longer conceived as a discrete event arising from isolated individuals, but is rather considered as:

- A process, more specifically a problem-solving process (Dosi, 1982);
- A process occurring primarily within firms, not within government agencies or government laboratories ;
- An interactive process involving relationships between firms with the different actors of their environment (Kline and Rosenberg, 1986). These relationships are both formal and informal and insert firms in networks;
- A diversified learning process. Learning may arise from learning-by-using, learning-by-doing, learning-by-sharing (Rosenberg, 1982; Le Bas, 1991; Lundvall 1988, 1995). Learning may arise from internal or from external sources of knowledge (Dogson, 1991). External learning refers to the absorption capacity of firms (Cohen and Levinthal, 1990);
- A process involving the exchange of codified and tacit knowledge (Patel and Pavitt, 1994). The exchange of codified knowledge is essential but insufficient (Winter, 1997);
- An interactive process (Johnson, 1992; Lundavall, 1992) of learning and exchange where interdependence between actors generates a system, an innovative system (Acs, 2000; Braczyk, Cooke, and Heidenreich, 1999; Cooke et al, 2000; de la Mothe and Paquet, 1998; Edquist, 1997; Edquist and Hommen, 1999; Holbrook and Wolfe, 2000; Landry and Amara, 1998; Niosi et al, 1993), a ″système social d'innovation″ (Amable, Barré and Boyer, 1997), a ″milieu innovateur″ (Maillat, 1995; Storper, 1997) or an innovation cluster (Porter, 1998; 2000).

The emergence of this new conception of innovation has considerably renewed the theories of innovation. This theoretical evolution can be characterized by the increasing importance of social ingredients into the explanations of innovations which, originally, were solely based on tangible forms of capital.

2.2. From engineering to social theories of innovation

The progressive inclusion of social ingredients into theories of knowledge-based innovation is well exemplified by reviewing five successive theories of knowledge-based innovation that have been deemed to be important by the students of innovation: knowledge-based innovation derived from science; knowledge-based innovation derived from market needs; knowledge-based innovation derived from linkages between actors in markets; knowledge-based innovation derived from technological networks; knowledge-based innovation derived from social networks.

2.2.1. The Engineering Theories of Innovation

The first explicit theory of knowledge-based innovation is the engineering theory of innovation. In this theory, the innovation opportunities, that is the opportunities to improve the products or the manufacturing processes, are found in the uptake of research results. In this theory, basic research and industrial R&D are the sources of new or improved products and processes. The production and uptake of research follow a linear sequence from the research results to the definition of a product and specifications of production, and the application of technology to make a product that conforms to the specifications defined by research that has resulted into patents and scientific publications. In this theory, production is a solution to an engineering problem (Vannevar Bush, 1945). In these theories, innovation is explained solely by combinations of tangible forms of capital: technological, physical, manpower and financial forms of capital.

2.2.2. The market pull theories of innovation

The limits of the engineering solutions generated in the 1960s' an alternative view supporting that the sources of ideas for solutions should originate from the market. This alternative view gave birth to the market pull theories of innovation. These theories still give a central place to research as a source of knowledge to develop or improve products and processes. However, they represent the first insertion of organizational factors in their explanations: the technical feasibility was still considered as a necessary condition of innovation, but no longer a sufficient condition of successful innovations. The organizational feasibility has to be taken into account to insure the successful development of innovation. (Carter and Williams, 1957; Schmoolker, 1966; Myers and Marquis, 1969). In these theories, innovation is explained by combinations of tangible forms of capital and one intangible factor: data about markets.

2.2.3. The Chain-Link Theories of Innovation

To overcome the fact that the linkages between knowledge and markets are not as automatic and as immediate as assumed in the engineering and market pull theories of innovation, a new generation of theories emerged in two phases: At the beginning of the 1980s, scholars like Mowery and Rosenberg (1978) suggested to pay more attention to the linkages existing between research and the market via engineering, production, technology development, marketing and sales. Later in the 1980s', scholars like Von Hippel (1988) laid the stress on the information generated through the linkages existing between the firm and its customers and suppliers. In these theories, innovation is explained by combinations of tangible forms of capital in conjunction with one intangible form of capital: data about customers and suppliers that are organized to become information for innovators.

2.2.4. The technological network theories of innovation

At the end of the 1980s and during the 1990s, technological networks theories of innovation have been developed by a new group of scholars under the label "systems of innovation" (Lundvall, 1988, 1992, 1995; Nelson, 1993; Niosi et al, 1993; Rothwell, 1992; Edquist, 1997; Amable et al., 1997). The supporters of this type of theories assume that innovative firms are linked to a highly diversified set of agents through networks of collaboration and exchange of information. This view stresses the importance of the sources of information that are external to the firm: clients, suppliers, consultants, government agencies, government laboratories, university research, etc. It predicts that the more sustained and intense the interactions between firms and external sources of information, the more likely there will be uptake of information. In other words, the development and improvement of products and processes must meet simultaneously criteria of technical feasibility (borrowed from the engineering theory), market feasibility and network feasibility. In these theories, the exchange of information is discussed in terms of collaboration, network, partnership in laying the stress on the importance of technological networks.

With the technological networks theories, innovation is explained by combinations of tangible forms of capital in conjunction with one intangible form of capital: technological networks as tools to acquire and absorb data transformed into information.

2.2.5. The social network theories of innovation

The social network theories of innovation are based on two old ideas and a new insight. The old ideas are that innovation is determined by research (borrowed from the engineering theory), and by disorderly interaction processes between firms and other actors (borrowed from the technical network theories of innovation). The insight is that knowledge plays a more and more crucial role in fostering innovation. The growing importance of knowledge as a production factor and as a determinant of innovation can be explained by the continuous expansion of the amount of technical knowledge accumulating over time, and by the use of communication technologies that makes the knowledge available very rapidly on a worldwide scale. (Arundel et al, 1998; Cowan and Foray, 1998).

Compared to the technological networks theories of innovation, the social network theories of innovation lay more emphasis on the strategic importance of relational rather than technical tools, and on knowledge rather than technological networks as crucial intangible factors. The development of knowledge-based innovation requires the capacity to implement technical and relational tools (Lengrand and Chatrie, 1999): technical tools refer to the acquisition and utilization of new information and communication technologies. These technical tools do not create competitive advantages because they are readily available to others. The creation of competitive advantages rests in relational tools: that is the way of doing business, both in the internal and external environments of firms. As for networks of cooperation, Lengrand and Chatrie (1999) claim that knowledge networks appear as a new form of cooperation network taking multiple forms that are added over and above the technological networks that they define as the first form of cooperation networks.

The evolution from the technological network theories of innovation to the social network theories of innovation has been led by the more and more pressing challenge to transform information into knowledge, i.e., information contextually connected to the development or improvement of products or manufacturing processes. Knowledge-based innovation requires not one but many kinds of knowledge. Furthermore, it requires the convergence of many kinds of knowledge detained by different categories of actors. According to Lengrand and Chatrie (1999:14):

> «Productivity is no longer seen as an "additional productivity of operations" but rather as a "systemic productivity of relations" where a firm's competitiveness depends on the productivity of its "interfaces" or "interactions". These new criteria require a new organizational and functional paradigm where the performance of firms depends on the density and pertinence of relations and cooperation between the actors of the productive system (other firms,

> suppliers, financiers, research institutions, education, regional development agencies, etc.) through collaborative networks and clustering. Thus, knowledge networks represent a further step, where capacities and rights to access a value located outside the company are developed.»

In these theories, knowledge is embodied in networks and communities, and social capital becomes an essential ingredient to understand innovation.

In the social network theories, innovation results from combinations of tangible forms of capital in conjunction with intangible forms of capital characterized by disorderly and sustained interactions occurring between firms and diversified sets of actors. These interactions are holistic, influenced by history, social values, institutions, and interdependence.

3. Social capital and innovation

3.1.1. Social capital defined

According to Coleman (2000, p 16):

> «Social capital is defined by its function. It is not a single entity but a variety of different entities, with two elements in common: they all consist of some aspect of social structures, and they facilitate certain actions of actors—whether persons or corporate actors—within the structure. Like other forms of capital, social capital is productive, making possible the achievement of certain ends that in its absence would not be possible. Like physical capital and human capital, social capital is not completely fungible but may be specific to certain activities. A given form of social capital that is valuable in facilitating certain actions may be useless or even harmful for others. Unlike other forms of capital, social capital inheres in the structure of relations between actors and among actors.»

The contribution of social capital to innovation is achieved by reducing transaction costs between firms and between firms and other actors, notably search and information costs, bargaining and decision costs, policing and enforcement costs (Maskell, 1999). Therefore, the overall hypothesis of the social capital theory in the matter of innovation is that: «Firms in communities with a large stock of social capital will… always have a competitive advantage to the extent that social capital help reduce malfeasance, induce reliable information to be volunteered, cause agreements to be honored, enable employees to share tacit information, and place negotiators on the same wave-length. This advantage gets even bigger when the process of globalization deepens the division of labor and thus augments the needs for co-ordination between and among firms.» (Maskell, 1999, p.7).

Social capital can take different forms, primarily trust, norms, and networks (Dasgupta and Serageldin, 2000; Fountain, 1998; Lesser, 2000; Putnam,1993). Trust is developed over time through repeated series of interactions. Firms in milieux characterized by high levels of trust are more likely to innovate. Indeed, according to Knack and Keefer

(1997, p.1252): «Individuals in higher-trust societies spend less to protect themselves from being exploited in economic transactions. Written contracts are less likely to be needed, and they do not have to specify every possible contingency. Litigation may be less frequent. Individuals in high-trust societies are also likely to divert fewer resources to protecting themselves-through tax payments, bribes, or private security services and equipment—from unlawful (criminal) violations of their property rights. Low trust can also discourage innovation. If entrepreneurs must devote more time to monitoring possible malfeasance by partners, employees, and suppliers, they have less time to devote to innovation in new products or processes.»

Norms of appropriate behavior also develop over time as a result of a series of interactions and exchange of resources. The norm that is the most often mentioned in the literature on social capital is reputation for trust-worthiness. Like for the case of trust, norms act as constraints on narrow self-interest, leading individuals to contribute productively to exchange instead of behaving opportunistically.

Finally, networks develop as actors develop reliable and effective communication channels across organizational boundaries. According to Le Bas, Picard and Suchecki (1998, p. 628-629): «les relations technologiques et/ou scientifiques construites à l'occasion de l'interaction de la firme avec son environnement constituent un élément déterminant non seulement pour la mise en œuvre du processus d'innovation, mais également pour son succès. La capacité de la firme à emprunter ces connaissances est fonction de son aptitude à s'immerger dans des réseaux, à entrer en contact, par le biais de quelque intermédiaire que ce soit, avec d'autres entreprises, avec des centes de recherche, des instituts, des universités, des organismes publics de transfert ou de valorisation de la technologie. Ainsi, l'immersion d'une firme dans un réseau participe avec l'investissement en R&D interne à la performance technologique de la firme. Nous pensons également que cette immersion peut expliquer le succès commercial de l'innovation.».

3.2. Forms of social capital measured in this study

In this study, we use survey indicators derived from a regional innovation survey to measure structural and cognitive forms of social capital (Uphoff, 2000). The structural forms of social capital include roles, rules, procedures and networks that facilitate coordinating efforts, creating expectations, and lowering transaction costs. In this study, we will measure three such forms of structural social capital: network assets, relational assets and participation assets. As for the cognitive forms of social capital, they refer to norms, values, attitudes and beliefs affecting interdependence. In this study, we will measure one such form of cognitive capital: trust.

The questions used to assess the levels of these forms of social capital are:

- Network assets: «Which of the following played a role as sources of information needed for suggesting or contributing to the development of new or improved products or manufacturing processes during the last three years? Please check all that apply in indicating the degree of importance on a scale ranging from 1 to 5 where 1= not important at all to 5= extremely important». We distinguished three types of networks: business, information and research networks. The business networks include clients, suppliers, competitors, suppliers of equipment, material and components, consultancy firms and related firms in your corporate group. The information network included trade fairs and exhibitions, professional conferences, meetings and publications, Internet or computer-based information networks, patent documents. As for the research networks, they included government research laboratories, technology transfer organizations, universities and community colleges.

- The levels of the relational assets are assessed from responses to a question about the degree of agreement regarding the degree of acquaintance respondents had with four categories of economic actors. The question was: «Please indicate your degree of agreement with the following statements: I personally know managers and professionals involved in government agencies involved in 1) the promotion of economic development at the regional level; 2) the promotion of economic development at the provincial or national level; 3) university researchers working on projects related to my products; 4) my clients and suppliers. The levels of agreement were measured on a scale ranging from 1 to 5 where 1= do not know at all and 5= know extremely well.
- The levels of participation assets are assessed from responses to a question about the frequency of participation of respondents in meetings, associations and networks of manufacturing firms at four levels: regional, provincial, national and international. The levels of frequency are measured on a scale ranging from 1 to 5 where 1= never participate to 5=participate very frequently.
- The question used to assess the levels of trust is: To what extent is reciprocal trust important as a condition of success in your relationships with 1) clients and suppliers; 2) government agencies and other agencies involved in the promotion of innovation? The degree of importance was measured on a scale ranging from 1 to 5 where 1= not important at all to 5= extremely important.

4. Data and descriptive statistics

The data used in this study have been collected by a survey firm who conducted computer-assisted telephones interviews from April 10 to June 07, 2000. The questionnaire was adapted from the second edition of the Oslo Manual and included questions specifically defined by the sponsor of the survey: Valo Tech inc, a non-profit organization involved in the promotion of innovation in the Montérégie region. The purpose of the survey was to make a diagnostic regarding levels of innovation in the Montérégie region, a region located in the South-West of Montréal. The list of firms used to conduct the survey was provided by the Centre de recherches industrielles du Québec. The initial list included 2321 firms. After having excluded firms that were not manufacturing firms, no longer in operation, impossible to reach after more than 20 calls, or respondents out of town for long periods of time, the actual population of manufacturing firms was 1319. Out of this effective population, 817 firms refused to answer the survey (61,9%), 62 questionnaires were not completed (4,7%) and 440 questionnaires were completed and usable for a return rate of 33,3%. This return rate is higher than most surveys administered to manufacturing firms. Furthermore, a regional survey is especially appropriate to study the factors explaining the influence of social capital on innovation.

Overall, 68,5% of the firms have indicated they have developed or improved innovations of products or manufacturing processes during the last three years. The descriptive statistics of the variables used in this study are reported in Table 1. Overall, the average respondent has dedicated 6,3% of his sales to R&D activities, he has used 4,67 different advanced technologies in his manufacturing processes, he had sales amounting to 6,7 millions of

Canadian dollars in 1999, he has exported 24% of his production outside Canada, he has 49 employees, he has ranked at 9,02 out of a possible maximum of 25 in the matter of business network assets, he has ranked at 6,51 out of a possible maximum of 22 in the matter of information network assets, he has ranked at 4,1 out of a possible maximum of 19 in the matter of research network assets, he has ranked at 9,59 out of a possible maximum of 19 in the matter of relational assets, and finally, he has ranked at 5,23 out of a possible maximum of 10 in the matter of trust assets.

Table 1 here

5. Does social capital determine innovation?

As pointed out in the literature review, innovation is not an event but a process. Although there is not yet well established approaches to model this process, we assume in this study that when making decisions about whether or not to innovate, firms go through different stages. In this study, we assume that firms go through two major stages: first, the decision to innovate or not, and then, after having decided to innovate, the decision regarding the extent of radicalness to adopt, regarding the development of products or process innovations.

5.1. Does social capital determine the decision to innovate?

The model developed for the first decision stage is:

$$\text{Log}\,(P_i/1\text{-}P_i) = \beta_0 + \beta_1 \text{PERR\&D} + \beta_2 \text{NBTADV} + \beta_3 \text{PARASS} + \beta_4 \text{RELASS} + \beta_5 \text{SALES} + \beta_6 \text{EXPORT} + \beta_7 \text{TRUSASS} + \beta_8 \text{COMPET}$$

where,

β_i (i= 0…….8) are the coefficients.

Log (P_i/1-P_i) is the logarithm of the ratio of the probability that a firm innovates relative to the probability that the same firm does not innovate.

The independent variables used in this model are:

PERR&D : Percentage of sales dedicated to R&D : measure of internal creation of knowledge by firms

NBTADV : number of different advanced technologies used by firms : indicator of variety of use of knowledge embodied in equipment

PARASS : participation assets : index based on indicators of participation in business meetings, associations, and networks

RELASS : relational assets: index based on indicators of personal acquaintance with four categories of actors involved in the promotion of innovation

SALES : financial assets: measure of financial resources that firms can mobilize for innovation

EXPORT : marketing assets: measure of the percentage of sales shipped by firms outside the country

TRUSASS : trust assets: index of level of reciprocal trust measured as condition of success in your relationships with clients and suppliers, government agencies and other agencies involved in the promotion of innovation.

COMPET : pressure from competitors: index of importance of competitive pressures from 5 sources

ANNEX 1 provides the overview of the operationalizations for the independent variables. The Cronbach's ∝ for the dependent variable and all the independent variables based on multiple items scales is shown in the Annex. The values of the ∝ coefficients reported in Appendix 1 indicate that all the multiple items scales used in this study are reliable.

Results of the regression of the first stage decision, that is the decision about whether or not to innovate, are summarized in Table 2. The equation has good predictive power, with 74% of correct predictions. That is, the model correctly classified 74% of the firms into those who decided to innovate and those who decided not to innovate. The value of the Cox & Snell R^2 is .20, which is quite reasonable for qualitative dependent variable models. Furthermore, the computed value of the likelihood ratio (i.e., 68,3) is much larger than the critical value of the chi-squared statistic with 8 degrees of freedom at the 1 percent level. This suggests that the null hypothesis, that all the parameter coefficients (except the intercept) are all zeros, is strongly rejected. Consequently, the model is significant at the 1 percent level.

The likelihood of firms to innovate increases as the percentage of sales dedicated to R&D increases, as they increase the number of different advanced technologies they use in their manufacturing processes, as their overall levels of sales increase, and as the percentage of their exports increases. The negative relation between intensity of competition and likelihood to innovate means that the more intense competition is, the less likely firms are to develop or improve their products or manufacturing processes.

Three forms of social capital are included in this model as explanatory variables of the likelihood of firms to innovate or not. The results reported in Table 2 indicate that as the participation assets and relational assets of firms increase, their likelihood to innovate, as predicted by the social capital theory of innovation, also increases. However, contrary to the prediction of the social capital literature, trust assets have been found to exert no statistically significant impact on the likelihood of firms to innovate.

Table 2 here

5.2. To what extent does social capital determine the likelihood of innovation?

The presentation of the results of Table 2 was based on the signs and significance of the coefficients of the explanatory variables. It did not take into account the scope of these coefficients because, in the logistic functional form upon which logit regressions are based, the estimated values of coefficients, such as those presented in Table 2, cannot be interpreted as elasticity coefficients or as coefficients reflecting the marginal impacts of the explanatory variables. In order to assess the scope of the impact of the explanatory variables on the likelihood of innovation, we have ascertained the partial elasticities of the variables which explain significantly the likelihood of firms to innovate or not.

The partial elasticities for the variables that have been found to significantly explain the likelihood of innovation of firms were calculated with the equation (3) or (4) presented in Appendix 2. These partial elasticities reflect the average of the elasticity coefficients evaluated for each of the 440 observations. As can be seen in the third column of Table 2, the elasticity coefficient of the variable participation assets is the highest. This coefficient takes a value of .189, thus indicating that a positive relative change of 10% in the index of the participation assets increases the likelihood of innovation by 1.89%. Likewise, a positive relative change of 10% in the index of relational capital, percentage of sales dedicated to R&D, number of different advanced technologies used for production, percentage of sales exported and financial assets, increases the likelihood of innovation of firms by 1.8%, 1.42%, 1,3%, 0.33% and 0.22% respectively. Conversely, a positive relative change of 10% in the index of intensity of competitive pressure decreases the likelihood of innovation of firms by 1.4%.

5.3. Does social capital determine the radicalness of innovation?

Once the decision to innovate has been made, the second decision to make is about the extent of change to bring in the development or improvement of products or manufacturing processes. The more important the changes made to existing products or manufacturing processes, the more radical the innovation is. To study the impact of the explanatory variables on the degree of radicalness of innovation of firms, we have developed the following ordinary least squares model :

$$\text{RADICAL} = \beta_0 + \beta_1\text{PERR\&D} + \beta_2\text{NBTADV} + \beta_3\text{BUISNET} + \beta_4\text{INFONET} + \beta_5\text{RESNET} + \beta_6\text{PARASS} + \beta_7\text{RELASS} + \beta_8\text{SALES} + \beta_9\text{EXPORT} + \beta_{10}\text{TRUSASS} + \beta_{11}\text{SIZE} + \beta_{12}\text{EMPR\&D}$$

where,

β_i (i= 0…….12) are the coefficients.

The degree of radicalness of innovation (RADICAL) is measured by the number of months that elapsed between the first investments of resources in the most important project of development or improvement of products or processes and the first sales on the market. The operationalizations of the independent variables are presented in Annex 3. At this second decision stage, three additional forms of social capital were introduced as explanatory variables: business network assets, information network assets and research network assets. The questionnaire used for this study did not ask the respondents of firms that had no innovation to answer the questions regarding these matters.

Regression results are summarized in Table 3. As indicated in this Table, 8 out of the 12 explanatory variables introduced in the model explain the degree of radicalness of innovation. The total amount of variance in the magnitude of radicalness of innovation explained by this model is shown by the adjusted R^2 to be .43. One can see that the degree of radicalness of innovation increases as percentage of sales dedicated to R&D increased, as the number of employees dedicated to R&D activities increases, as the number of different advanced technologies utilized for production increases, as the sales of the year 1999 increase. The negative relation between the variable size and radicalness implies that as the number of employees of firms increases, the degree of radicalness of innovation decreases. This counterintuitive result is due to the fact that many large firms in traditional industries are not very innovative in terms of development or improvements of products and manufacturing processes.

As for the 6 explanatory variables concerning social capital, one can see that only two of them significantly explain the magnitude of radicalness of innovation while the other four are not significantly related to radicalness of innovation. As indicated in Table 3, the magnitude of radicalness increases as the relational assets and the research network assets increase. The variable participation assets, which had been found to relate to the likelihood of innovation of firms, does not explain decisions regarding the magnitudes of radicalness of innovation. The variables business network assets, information network assets and trust assets do not explain the radicalness of innovation.

Table 3 here

5.4. To what extent does social capital determine the radicalness of innovation?

To assess the scope of the impact of the explanatory variables on the radicalness of innovation, we have ascertained the partial elasticities of the variables which explain significantly the magnitudes of radicalness of firms that innovate. The partial elasticities for the variables that have been found to significantly explain the degree of radicalness of firms that have innovated were calculated with the equation presented in Note C of Table 3. These partial elasticities reflect the average of the elasticity coefficients evaluated for each of the 204 observations. As can be seen in the third column of Table 3, the elasticity coefficient of the variable research network assets is the highest. This coefficient takes a value of .336, thus indicating that a positive relative change of 10% in the index of the research network assets increases the likelihood of innovation by 3.36%. Likewise, a positive relative change of 10% in the number of different advanced technologies used for production, percentage of sales exported and financial assets, relational assets, number of employees dedicated to R&D, and percentage of sales invested in R&D increases the degree of radicalness of innovation by 2.02%, 1.59%, 1.17%, 0.91% and 0.72% respectively. Conversely, a positive relative change of 10% in the number of employees decreases the degree of radicalness of innovation of firms by 0.08%.

6. Discussion and policy implications

This paper deals with two questions: Does social capital determine innovation in manufacturing firms? If it is the case, to what extent? To deal with these questions, we reviewed e literature on innovation in order to see how social capital came to be added to the other forms of capital as an explanatory variable of innovation. In doing so, we have been led to follow the dominating view of the literature on social capital and innovation which claims that social capital cannot be captured through a single indicator, but that it actually takes many different forms that must be accounted for. Therefore, to the traditional explanatory variables of innovation, we have added 5 forms of structural social capital (business network assets, information network assets, research network assets, participation assets, relational assets) and one form of cognitive social capital (reciprocal trust).

Based on the survey data administered from April to June 2000 to 440 manufacturing firms of diverse industries in a region in the South-West of Montréal, we have found that 68,5% of the firms have developed product or process innovations during the three years preceding the survey.

Assuming, like most of the experts do, that innovation is not a discrete event but a complex process, we have modeled the decision to innovate as a two-stage decision-making process: in the first stage, the firms deal with the decision about whether to innovate or not whereas, at the second stage, the firms that have decided to innovate must make a decision about the degree of radicalness of the innovation to undertake.

In a context where empirical investigations regarding the relations between social capital and innovation are still scanty, this paper makes contributions to the advancement of knowledge in providing new evidences regarding the impact and the extent of social capital on innovation at the two decision making stages considered in this study. Regarding the decision to innovate or not that firms must initially make, we have provided strong evidences that diverse forms of social capital influence this decision and, more importantly, that increases in social capital, especially in social capital taking the forms of participation assets and relational assets, contribute more than any other explanatory variable to increase the likelihood of innovation of firms.

As for the decision to be made at the second stage concerning the magnitude of radicalness to bring in the development of new product or process innovations, this paper contributes to the advancement of knowledge by supplying strong evidence that diverse forms of social capital determine the radicalness of innovation, and more importantly, that social capital taking the form of research network assets contributes more than any other explanatory variable to explain the radicalness of innovation. The second variable that exerts the strongest impact on the radicalness of innovation is the number of different advanced technologies employed by firms for production.

The two stage decision making model used in this study contributes to show that different forms of social capital impact on different decisions. Hence, if participation is associations, meetings and business networks influences the likelihood of innovation, it has no significant impact when firms have to make their decisions regarding the degree of the radicalness to adopt in developing new products or manufacturing processes. This paper show that one form of social capital, namely relational assets, has significant influence on both the decision to innovate and, once the decision to innovate is made, the decision regarding the degree of the radicalness to adopt in developing new or improved products and manufacturing processes. Furthermore, the results of this study show that research network assets are the ingredients that have the highest impact at the second stage of the decision making process when firms must decide about the degree of the radicalness to adopt in developing new products or processes. This last result is also intuitively interesting because it supports the idea that the more radical innovation is, the more firms depend on knowledge created by diverse types of research organizations.

The most counterintuitive result of this study concerns the absence of impact of the variable trust at both stages of the decision making process. However, before concluding that trust has no impact on innovation, we would suggest to use other measures for this variable.

The results of this paper confirm that the internal creation of knowledge by firms, such as measured by the ratio of sales dedicated to R&D, and the utilization of knowledge embodied in advanced technologies explain both the decision to innovate and the decision to make more or less radical innovations. However, against all expectations, we have supplied evidences indicating that diverse forms of social capital contribute to a larger extent to explain both the decision to innovate or not and the decision to undertake more or less radical innovations. These results suggest that the policy makers involved in the design of policy measures likely to foster innovation should pay attention to diverse forms of social capital, especially to relational assets and to research network assets as well as to the acquisition and utilization of advanced technologies by manufacturing firms.

Finally, the modest R^2 obtained in this study (.40 at the second stage of the decision making process) suggests that other factors should be included in future studies, notably other forms of social capital but also variables regarding diverse forms of learning.

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Table 1

Descriptive statistics of variables used in the regression models

Variables	Type of variable	Minimum	Maximum	Mean	Standard deviation
Percentage of Sales allowed to R&D (PERR&D)	Continuous : %	0	90	6,31	10,61
Number of advanced technologies used (NBTADV)	Continuos : Number	0	21	4,67	4,42
Business network (BUISNET)	Index : 6 items	0	25	9,02	7,13
Information network (INFONET)	Index : 5 items	0	22	6,51	5,51
Research network (RESNET)	Index : 4 items	0	19	4,10	3,94
Participation assets (PARASS)	Index : 4 items	0	19	6,76	3,53
Relational assets (RELASS)	Index: 4 items	0	19	9,59	3,17
Financial assets (SALES)	Continuos: $	0	99000000	6718980,70	13605530,10
Marketing assets (EXPORT)	Continuos : %	0	100	24,05	33,94
Trust assets (TRUSASS)	Index : 2 items	0	10	5,23	2,06
Number of employees (SIZE)	Continuos : Number	0	3000	49,80	171,40
Number of employees in R&D (EMPR&D)	Continuos : Number	0	200	4,75	15,03
Pressure from competition (COMPET)	Index : 5 items	0	23	14,71	2,93

Table 2
Estimated Logit model of factors affecting innovation

Dependant variable : Innovation/No Innovation
Number of cases : 304
Cox & Snell R^2 : .201
Chi-square (d.f.) : 68.39 (8)
Percentage of correct predictions : 74.3%

Independent variables

Variables	**Coefficients** [a,b]	**Partial elasticities of significant variables**[c]
Intercept	-.580 (.000)***	
Percentage of Sales allowed to R&D (PERR&D)	.077 (.001)***	.142
Number of advanced technologies used (NBTADV)	.073 (.082)**	.130
Participation assets (PARASS)	.103 (.063)**	.189
Relational assets (RELASS)	.099 (.099)*	.18
Financial assets (SALES)	.001 (.076)**	.022
Marketing assets (EXPORT)	.015 (.072)**	.033
Trust assets (TRUSASS)	-.041 (.581)	
Competition (COMPET)	-.077 (.101)*	-.141

a Figures between parentheses indicate p-value.

b *; ** and *** indicate that variable is significant at10%, 5% and 1%, respectively.

c See appendix 2.

Table 3
Regression equation predecting radicalness of innovation

Dependant variable : Radicalness of the innovation
Number of cases : 204
Adjusted R^2 : .430
Calculated F = 3.62 ; **Theoretical F** (12 ; 192) = 2.64 at 1 %

Independent variables

Variables	**Coefficients** [a,b]	**Partial elasticities of Significant variables** [c]
Intercept	2.23 (.49)	
Percentage of Sales allowed to R&D (PERR&D)	.068 (2.01) **	.072
Number of advanced technologies used (NBTADV)	.363 (1.32) *	.202
Business network (BUISNET)	-.250 (-.91)	
Information network (INFONET)	-.020 (-.23)	
Research network (RESNET)	.678 (2,00) **	.336
Participation assets (PARASS)	.104 (.31)	
Relational assets (RELASS)	.079 (2,07) **	.127
Financial assets (SALES)	.002 (2,85) ***	
Marketing assets (EXPORT)	.131 (1,66) *	.159
Trust assets (TRUSASS)	-.530 (-1.02)	
Number of employees (SIZE)	-.149 (-2.24) ***	-.008
Number of employes in R&D (EMPR&D)	.229 (1,87) **	.091

a Figures between parentheses indicate T ratios.

b *****; ****** and ******* indicate that variable is significant at10%, 5% and 1%, respectively.

c The partial elasticity of each index is calculated in regard of the mean of partial elasticities of all the observations composing this index. For the function $Y(X) = \alpha_0 = \alpha_1 X$; where Y is the explained variable, X is the explained variable, and α_0 et α_1 are parameters, the partial elasticity of Y in regard of the variable X is given by the expression : $\frac{\partial Y}{\partial X} \bullet \frac{X}{Y}$.

Appendix 1
Internal reliability coefficients (Cronbach's alpha) for variables including multiple item scales

Names of Variables	Number of cases	Number of items in scales	∝
Relational assets (RELASS)	440	4	.74
Participation assets (PARASS)	440	4	.92
Business Network (BUISNET)	440	6	.90
Information network (INFONET)	440	5	.91
Research network (RESNET)	440	4	.92
Trust assets (TRUSASS)	440	2	.37
Competition (COMPET)	440	5	.35

Appendix 2

Determination of the impacts of explanatory variables in Logit model of factors affecting innovation

The logistic function has the following form :: $Z(X) = \frac{1}{(1+\exp(-\gamma_1 - \gamma_2 X))}$ (1)

where X is the explanatory variable and γ_1 et γ_2 are parameters.

The first derivative of the function Z(X) with respect to X permits to assess the marginal impact of the variable X :

$$\frac{\partial Z}{\partial X} = \frac{-\gamma_2 \exp(-\gamma_1 - \gamma_2 X)}{(1+\exp(-\gamma_1 - \gamma_2 X))^2} \quad (2)$$

If $\gamma_2 > 0$ then $Z(X) > 0$. It means that the variable X has a positive impact on the Z(X) and that a positive variation of X will increase Z(X). However, if $\gamma_2 < 0$, then $Z(X) < 0$, which means that a variation of X results in a variation of Z(X) in the opposite direction.

The partial elasticity for the variable X is given by the expression:

$$\frac{\partial Z}{\partial X} \bullet \frac{X}{Z} = \frac{(\gamma_2 \exp(-\gamma_1 - \gamma_2 X)}{(1+\exp(-\gamma_1 - \gamma_2 X))^2} \bullet X \quad (3)$$

The elasticity is also given by the expression : $\frac{\partial Z}{\partial X} \bullet \frac{X}{\hat{Z}}$, (4)

where $\hat{Z}$ is the predicted value of Z.

Appendix 3

Definitions of independent variables

Network	**Importance of the following information sources for the improvement and the development of new products and new processes (1 Not important at all to 5 Extremely important)**
Business network index	• Clients; • Suppliers; • Competitors; • Suppliers of equipments, material, components or software; • Consulting firms; • Other firms belonging to your group.
Information network index	• Fairs/exhibitions; • Professional congresses, meetings, and specialized publications; • Internet and computerized data banks; • Governmental information programs; • Patents documentation.
Research network index	• Public research organizations (CRIQ, CNRC); • Technology transfer organizations; • Universities; • Community colleges.
Relational assets index	**Level of consent with the following statements (1 Do not agree at all to 5 Agree completely)**
	• I know personally professionals or managers in agencies of regional economic development; • I know personally professionals or managers in government agencies involved in economic development; • I know personally university or government researchers linked to the field of my products; • I know personally my clients and suppliers.
Participation assets index	**Participation frequency to meetings, associations or manufacturing industries networks according to the following levels (1 Never to 5 Very often)**
	• At the regional level; • At the provincial level; • At the national level; • At the international level.
Trust assets index	**Importance of trust in the success of relations (1 Not important at all to 5 Extremely important)**
	• With the clients and suppliers; • With the government agencies and non profit organizations involved in promotion of innovation.

Appendix 3 (continued)

Pressure from competition index	**Level of consent with the following statements (1 Do not agree at all to 5 Agree completely)**
	• My clients can easily find a substitute of my products from my competitors; • The arrival of new competitors is a constant threat; • It is hard to keep employees and qualified workers; • Our products become rapidly out of date; • The production technologies evolve rapidly.
Financial asset	• The amount of the establishment's turnover during the last exercise.
Number of advanced technologies used	• The sum of the number of technologies used by manufacturing industries within the following 21 advanced technologies :: 1) Computer Aided Design/Engineering (CAD/CAE); 2) Computer Aided Design/Manufacturing (CAD/CAM); 3) Modeling or simulation technologies; 4) Electronic exchange of CAD files; 5) Flexible manufacturing cells or systems (FMC/FMS); 6) Programmable logic Contro (PLC) machines or processes; 7) Lasers used in materials processing; 8) Robots with sensing capabilities; 9) Robots without sensing capabilities; 10) Rapid prototyping systems; 11) High speed machining; 12) Near net shape technologies; 13) Parts identification for manufacturing automation; 14) Automated storage and retrieval systems; 15) Automated vision-based systems used for inspection/testing of inputs and/or final products; 16) Other automated sensor-based systems used for inspection/testing of inputs and/or final products; 17) Local area network for engineering and/or production; 18) Company-wide computer networks (including Intranet and WAN); 19) Inter company computer networks (including Extranet and EDI; 20) Manufacturing Resource Planning (PRPII)Entreprise Resource Planning (ERP); 21) Computers used for control of the factory floor.
Percentage of sales allowed to R&D	• Percentage of the sales devoted to R&D.
Marketing assets	• Percentage of the exported sales to the United States and the rest of the world .
Number of employees	• Total number of the establishment's employees.
Number of employees in R&D	• Total number of employees working in R&D.