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Cross-regional R&D teams and Innovation Efficiency: Evidence from U.S. Manufacturing firms

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Abstract
Adopting a mixed design method of both qualitative and quantitative research methodology, we verify the role of spiral of knowledge in the internationalization of R&D teams, in cross-regional integration and in the quality of innovation. Particularly, the framework of knowledge management process adopted in this research is the spiral of knowledge proposed by Nonaka and Takeuchi (1995). However,in this paper we propose a revised form of the Nonaka and Takeuchi model supported by an empirical verification. Our empirical study focuses on U.S. manufacturing firms. More generally,this research proposes a "dynamic approach" that highlights the importance of the conversion process that expands tacit and explicit knowledge in both quality and quantity.
Keywords*:* cross-regional integration; quality of innovation; spiral of knowledge; manufacturing firms

1. INTRODUCTION

Teece (2000; 2003; 2006) states that the superior performance of firms depends on the ability to generate innovation and to protect and use intangible knowledge assets. Knowledge as a source of sustainable competitive advantage is a widely recognized concept in the literature (Candelin-Palmqvist, Sandberg & Mylly, 2012; Darroch, 2005; Evangelista, Iammarino, Mastrostefano & Silvani,2001; Inkinen, Kianto & Vanhala 2015; Hamel and Prahalad, 1994).
However, innovation is not only generated endogenously by the enterprise but also derives from the combination of internal ideas with external ones (March, 1991).
Therefore, an efficient innovation strategy must balance the exploitation of existing knowledge generated by local research with non-local exploration for new knowledge.
Several studies show that access to knowledge dispersed in a globalized world requires R&D teams (Zander, 1997; Nobel and Birkinshaw, 1998). Singh (2008) argues that large firms are able to restrict the leakage of a firm's own knowledge to local players in different locations when they have internationalized R&D teams. However, numerous studies show that cross-regional transfer of tacit knowledge is quite hard even within firm boundaries (Teece, 1977; Kogut and Zander, 1992; 1993; Szulanski, 1996; Sorenson , Rivkin & Fleming,2006).
This problem is very important because the competitive advantage of the company does not derive from the knowledge itself but from the ability to integrate different knowledge (Grant (1996), even when these are located in distant geographical locations.
In this context the formal and informal mechanisms of transfer and integration of tacit and explicit knowledge within the company play a fundamental role in the integration of knowledge across regions (Gupta and Govindarajan, 2000).Numerous studies show that strong interpersonal relationships between international R&D teams are an important mechanism that facilitates the flow of knowledge in companies (Singh, 2005; Sorenson et al., 2006).
The ways in which these relationships must be developed in order to combine tacit and explicit knowledge involves the knowledge management process. In this specific field we find our research that aims to demonstrate the effects of a specific knowledge management framework on the quality of innovation, the geographic distribution of R&D and the cross-regional integration. Particularly, the framework of knowledge management process adopted in this research is the spiral of knowledge proposed by Nonaka and Takeuchi (1995).
Therefore, the objective of this research is to answer the following research question: *What is the role of spiral of knowledge in the internationalization of R&D teams, in cross-regional integration and in the quality of innovation?*
Therefore, our research contributes to the knowledge and innovation literature as: 1) expands the empirical research related to the role of intellectual capital in the generation of innovation; 2) identifies in detail the factors of the SECI model that positively influence the effectiveness and efficiency of the innovation.
The remainder of this paper is organized into five sections. The first section, the literature review, describes knowledge and the knowledge-creation process, and the relationship between distributed R&D, knowledge integration and innovation. The second section describes the sample and the methodology applied. The fourth section provides a discussion of the empirical research and the conclusions.

2. LITERATURE REVIEW

The knowledge-creation process

Knowledge is an important intangible asset of an entity that includes know-how (functional knowledge), know-what (tactical knowledge), and know-why (hypothetical knowledge) (Campanella et al., 2014; Sanchez and Heene, 1997).
Knowledge can be combined with the already available knowledge or transformed into new knowledge and improved capabilities (Chen and Huang, 2009). This process is known as knowledge management.
Indeed, according to other authors, knowledge management is related to innovation (Dahiyat, 2015) because it can stimulate the creation of new intellectual capital (Du Plessis, 2007; Huang and Li, 2009). For this reason, knowledge and, mainly, the capability to create and utilize knowledge are considered the most important source of a firm's sustainable competitive advantage (Nonaka and Toyama,2013). Furthermore, some scholars identified knowledge management as a process that turns tacit knowledge in explicit knowledge (Li & Gao, 2003).
The process of transforming tacit knowledge into explicit has been described in the SECI model (Socialization, Externalization, Combination, Internalization) by Nonaka and Takeuchi (1995). In the Knowledge management literature this model is known as a "spiral of knowledge".
Socialization is the process through which the tacit knowledge generates new tacit knowledge within physical social relations. This phase is essential to activate the externalization process.
Externalization is the process through which tacit knowledge becomes explicit through formalization in written documents and operational procedures. In this phase the individual is extracted from the social group and makes his knowledge available to everyone, using the most appropriate tools.
Combination is the process through which knowledge is transformed from explicit to explicit. In this phase, explicit knowledge is combined with new contents becoming more complex. At this stage some tools facilitate the combination, such as indexing and storage software.
Internalization is the phase in which knowledge is transformed from explicit to implicit. This phase is an individual process by which the individual enriches and broadens his tacit knowledge. The tool through which this process is called is defined "learning by doing" (Nelson, 1982).
At this point, after the process of internalization, the individual re-socializes his knowledge and the process resumes from socialization.Thus,the movement through the four modes of knowledge conversion forms a spiral, not a circle, because the knowledge is constantly regenerating. This process takes place continuously, generating the spiral of knowledge.

Distributed R&D and value of innovation

Although the knowledge is generally intangible in nature, it is becoming widely accepted as a major corporate asset capable of generating sustainable competitive advantage in a business (Barney, 1991). The knowledge and capabilities-based views (KBV) has emerged from the Resource Based View (Penrose, 1959) by focusing on intangible resources, rather than on physical assets. In this perspective, knowledge is the most important resource in strategy underlying new value creation (Grant, 1996; Kogut & Zander, 1992). In particular, Kogut and Zander (1996) define the firms as "a social community specializing in the speed and transfer of knowledge" (p. 503).
In literature, there are some basic assumptions concerning knowledge and its role in production. Several studies have argued that novel innovations often derive from combination of accessible pieces of knowledge base (Arora and Gambardella, 1990; Nonaka, 1994; Utterback, 1994; Hargadon and Sutton, 1997). Diverse knowledge provides more elements useful for new innovative combinations, which gives the opportunity not only for important progress, but also for innovations that suffer from low evaluations as the combinations have unforeseen faults (Fleming, 1999).This means that producing a good or service typically requires the combination of multiple types of knowledge (Kogut and Zander, 1993; Lin, Wu, Chang, Wang & Lee, 2012). But the main assumption concerning the knowledge is its limited transferability. Indeed, while explicit knowledge is easily communicated between individuals and organizations, tacit knowledge is manifest only in its practice. Key element to sharing the tacit knowledge are the willingness and capacity of individuals to share with others what they know and to use what they learn (Holste & Fields, 2010; H.F. Lin, 2007; Lee Endres, Endres, Chowdhury & Alam, 2007). Thus, its transfer is costly and slow.In order to overcome this problem, the knowledge integration process allows individuals to apply their specialized knowledge to the production of goods and services (Demsetz, 1991). The importance of integrating knowledge, particularly technical knowledge is well established in the field of strategic management, in particular it appears as a unique source of value creation (Bartlett and Ghoshal, 1989; Cantwell and Piscitello, 2007; McEvily et al., 2004). In the contemporary business context, innovation represents, especially in some sector, a key source in order to achieve a sustainable position in markets. In this sense, organizational theories agreed that businesses have to develop both exploitative (incremental) and exploratory (radical) innovation (Duncan 1976; Gupta, Smith & Shalley, 2006; Tushman and O'Reilly,1996). According to March's pioneering paper

(1991), firms have to choose between structures that facilitate exploitation (the use of existing knowledge) and those that facilitate exploration (the search for new knowledge). This shows organizational ambidexterity from a trade-off perspective. Thus, some authors suggest that in order to achieve an effective strategy for innovation, a balance must be found between the exploration of new and non-local knowledge and the exploitation of existing knowledge (Volberda,Baden-Fuller & Van den Bosch, 2001). Indeed, especially in the actual business context, which is characterized by globalization and international markets, in the management literature increased attention has been paid to involvement of both internal and external sources of knowledge within firm innovation processes to enhance innovation itself (Cassiman and Veugelers,2006; Enkel.,Gassmann, & Chesbrough 2009; Rosenzweig,2016). Thus, novel innovations result not just from combining ideas within the firms but from their capacity to share, combine and create new knowledge outside the boundaries of the company (Teece,2007). In industries characterized by regime of rapid technological development, the exploration of new, external and differentiated technologies constitutes an important component to have a competitive advantage.Trough exploitation mechanism, firms to access ideas, knowledge, skills and technologies within an external environment is commonly called as quadruple helix (Carayannis and Rakhmatullin, 2014). Indeed, in these ever-changing sectors the exploitation of new knowledge and skills is necessary to put in place a true competitive strategy (Amburgey, Dacin & Singh 1996; Brockhoff, 1992; Calabrese,Baum & Silverman 2000). Thus, biotechnology sector no single firm has internally existing capabilities necessary for innovation success (Baum, Calabrese & Silverman; 2000; Gemser , Leenders, M. A., & Wijnberg; 1996; Powell 1996; Koput & Smith-Doerr; Shan and Song; 1997). According to DeBresson, and Amesse (1991), more significant innovation resources reside in a network and not in the firm alone; and thus firm collaboration for innovation has taken on a global imperative in order to achieve competitive advantage in international markets and manage some of the more complex aspects of innovation projects (Hoegl & Proserpio, 2004; Shan et al., 1994). Håkansson and Snehota (2002) highlighted the importance of firm collaborations. The authors noted that while a company is a clearly defined within clear boundaries from an organizational point of view, from a resource and activity point of view it is different. An important body of research argued that most significant innovations are not created in isolation, but developed within of a broader context of a network of interdependent relationships (Bower, 1993; Snehota and Håkansson, 1995; Du Chatenier, Verstegen, Biemans, Mulder & Omta,2009).Consequently, a company should not be seen as an island, but as a part of a mainland-a network.

It is self-evident that technology is becoming increasingly globalized, and this is also evident in the related literature (Clark and Slotta., 2000; Herstad, Aslesen & Ebersberger, 2014; Sørensen and Sorenson, 2003).Indeed, firms are more likely to increase their reliance on external knowledge in order to achieve innovations for different factors, such as vertical disintegration pressures (Langlois, 2003), the difficult appropriation of investments in intangibles (Chesbrough, 2003), and also the growth of specialised technology markets (Arora, Fosfuri & Gambardella; 2001).Alongside the increasing technology globalization, R&D is currently undergoing a process of globalization (Singh,2005) although progress does vary considerably across different sectors and more or less developed countries (Asakawa and Som, 2008; Chen,2003). Within such a process, firms have placed increasing focus on establishing networks, leveraging and aligning both their internal and external R&D units around the world (Demirbag & Glaister, 2010; Feinberg and Gupta, 2003; Perks,2006; Watanabe, Tsuji & Griffy-Brown,2001). Thus, internationalization of R&D has become important in recent years in response to the increase in technological sophistication. In the internationalization of R&D process, firms reach outside of their boundaries to gain access to knowledge and capabilities that are geographically bound in a foreign location. So, the acquisition of skills is subordinated on the underlying technological capabilities that foster the acquisition of external technologies. Thus, only undertaking international R&D activities is not sufficient to achieve increased innovative outcomes. Because in R&D process increments to an existing stock of knowledge are facilitated by possessing high levels of existing knowledge stock (Ma & Lee, 2008), firms with significant amounts of basic R&D may generate greater innovative output through external collaborations. Many previous studies have shown the importance of basic R&D when firms expand overseas, acquiring new external knowledge (Zahra, Ireland, & Hitt; 2000). In other words, to be successful, firms must possess existing research capabilities that are complementary capabilities that are to ones they seek in foreign nations and they do own (Teece, 1987). According to Dyer & Singh (1998), complementary resources are "*distinctive resources of alliance partners that collectively generate greater rents than the sum of those obtained from the individual endowments of each partner" (pp. 666-667).*

In the knowledge creation process, it is important being in a network. To date, the literature concerning the question of what factors facilitate or impede the integration of knowledge in firms with global technology strategies is growing (Gupta and Govindarajan, 2000; Håkanson and Nobel, 2001, Singh, 2008), but the findings of empirical studies are still controversial (Chen, Huang & Lin, 2012; Penner-Hahn & Shave, 2005; Selmi 2013; Singh 2008; Song,2011;Thompson,2006).

Despite these differences,prior studies argued that integration of scientific knowledge across sources in multiple locations (Leiponen & Helfat,2010) requires the firm' ability and willingness to assimilate diverse knowledge and skills associated with dispersed R&D.
The literature on knowledge integration stated it is possible to define the correlation between the elements concerning the "effectiveness and efficiency of innovation". In fact, while the cross regional and the distribution refer to the efficiency of innovation, the value of innovation refers to the effectiveness of innovation. According to the literature, innovation efficiency is a measure of innovation performance, and it is determined by the cost and the time involved in the innovation project (Brown and Eisenhardt, 1995; Wheelwright and Clark, 1992;Valle and Avella, 2003). Instead, the effectiveness of innovation is related to the organizational and managerial characteristics or factors that allow company to grow and innovate (Jerez-Gómez, Céspedes-Lorente & Valle-Cabrera, 2005).
Instead, firms that remain confined to a single location should have an disadvantage respect to firms that use multiple R&D locations, accessing more and more diverse knowledge sources (Tzabbar and Vestal,2015). Frost and Zhou (2005) stated that mechanisms useful to the integration of knowledge may increases levels of absorptive capacity among participating units.
Drawing on the knowledge-based view of the firm, the aim of this research is to find evidence for the following research hypotheses:
Hypothesis H.1. The factors of the spiral of knowledge positively and significantly influence the quality of innovation
Hypothesis H.2. The factors of the spiral of knowledge positively and significantly influence the geographic distribution of R&D
Hypothesis H.3. The factors of the spiral of knowledge positively and significantly influence the cross-regional integration

3. Sample And Methods

Our analysis is based upon successful patents applied for during between 2016 and 2019.
Our empirical study focuses on 432 U.S. manufacturing firms.. The sample of patents was obtained from USPTO and NBER dataset.
Therefore, according to the literature review, three dependent variables (Y) have been identified: Value of innovation (Y_1), Geographic distribution of R&D (Y_2), and Cross regional knowledge integration (Y_3). These variables measure the value of innovation, the R&D distribution and knowledge integration of firms. To investigate the research hypotheses, the relationships between these three variables and 15 independent variables (X) were analyzed by measuring the spiral of knowledge which was proposed by Nonaka and Takeuchi. The 15 independent variables are factors that affect the knowledge-conversion process in the banking system and can be grouped into the four modes of knowledge conversion using the following classification:
Socialization: Promotion of Periodic Brainstorming (X_1), Periodic Promotion of Internal Conferences on Specific Financial Issues (X_2), Information Networking (X_3), Awards as a Means of Stimulating Knowledge Sharing (X_4), Community of Practice (X_5), and Knowledge Sharing Fair (X_6).
Externalization: Existence of an Enterprise Content Management System (X_7), Existence of a Business Process Management System (X_8), Knowledge Mapping (X_9), and Publishing and Describing Information Through Metadata (X_{10}).
Combination: Indexing (X_{11}), Digital Storage (X_{12}), and Skills Management (X_{13}).
Internalization: Internal Staff Training System (X_{14}) and Storytelling Management (X_{15}).
Finally, the following two control variables that represent the size of team and R&D expenses are: Team size (X_{16}), R&D intensity(X_{17}).
The definition of each variable is provided in Annex 1.
Hypotheses 1, 2 and 3 are tested by the following models:
Value of innovation (Y_1) = *f* (*Socialization; Externalization; Combination; Internalization; Control Variables)*
Geographic distribution of R&D (Y_2) = *f* (*Socialization; Externalization; Combination; Internalization; Control Variables)*
Cross regional knowledge integration (Y_3) = *f* (*Socialization; Externalization; Combination; Internalization; Control Variables)*.
The values of the variables were obtained from the following sources: 1) U.S. Patents and Trademarks Office (USPTO) with 2) additional data fields made available in a National Bureau of Economic Research (NBER) database described by Jaffe and Trajtenberg (2002) and also used by Singh (2008), and 3) questionnaires directly administered to the firms through a computer-aided telephone interviewing (CATI) system.
The questionnaires were submitted to the same sample of 432 staff directors each year from 2016 to 2019. The use of the CATI system enabled a large amount of information on a significant sample of firms to be collected over a four-year period.

The questionnaire consisted of 15 closed-ended questions and only two yes / no responses. The simplicity of the electronic questionnaire allowed for a high response rate and the collection of homogenous remarks over the study period. The questions relate to the following information: 1) the periodic promotion by the management of brainstorming among employees, 2) the periodic promotion of internal conferences on specific financial issues, 3) the existence of formal informational networking, 4) the existence of premiums for bank employees with the best innovative ideas, 5) the existence of incentives for bank employees for the creation of a community of practice, 6) the existence of knowledge sharing fairs for bank employees, 7) the existence of an enterprise content management system, 8) the existence of a business process management system, 9) the existence of software for the bank's knowledge mapping, 10) the use of publishing and describing information through metadata, 11) the use of indexing for information created by employees, 12) the use of digital information storage, 13) the existence of a systematic evaluation system and planning of individual members' skills within an organization, 14) the existence of staff training offices, and 15) the use of the storytelling technique for disseminating knowledge in the bank.
The model includes a number of binary variables, aimed at taking into account factors that have not been measured by the other variables.
The statistical models generally applied for estimating equations where the underlying dependent variable has a non-negligible probability of zero and has a discrete nature are applications and generalizations of the Poisson distribution (Hausman et al., 1984).
With regard to the methodology, hypothesis demonstration was carried out using a fixed negative binomial regression on a set of variables, which is desirable given overdispersion of data. Indeed, our data show extra variation that is greater than the mean. The negative binomial model is an generalization of the Poisson model that allows the variance of the distribution to grow faster than the mean. In addition, the negative binomial model generates correct standard errors for count data that is overdispersed (Cameron and Trivedi, 1986). The same methodological approach is used by other authors in similar works (Gittelman and Kogut,2003; Singh,2008) in order to exploit the longitudinal nature of the data. To analyze data we used Stata 15.

RESULTS

In order to investigate the relationship between the variables under investigation and to address the research hypotheses, a negative binomial analysis was performed (Table 1). The next section contains the discussion about the empirical results, with theoretical and practical implications.

Table 1. Negative binomial regression models (fixed effects)

	Y1	Y2	Y3
X_1	0.096 (8.37)***	0.001 (0.02) ***	0.017 (1.53) ***
X_2	-0.062 (-5.35) ***	0.014 (1.05)	0.047 (4.61) ***
X_3	0.036 (3.13) **	0.018 (1.37)	0.015 (1.51)
X_4	-0.006 (-0.41)	-0.019(-1.39)	0.007 (0.64)
X_5	-0.036 (-0.81)	0.033(2.51) ***	0.017 (1.68) ***
X_6	0.016(1.31)	-0.029 (-2.24) ***	-0.026(-2.77) ***
X_7	0.140(11.78) ***	-0.029 (-2.17) ***	-0.096 (-9.48) ***
X_8	0.128 (11.5)***	0.028 (2.06) ***	0.043 (4.33) ***
X_9	-0.005 (-0.07)	0.050(3.61) *	0.080 (7.85) ***
X_{10}	0.035(0.002) ***	-0.085 (-6.42) **	-0.021 (-2.10) **
X_{11}	-0.003 (-0.11)	0.047(4.61) ***	0.018(1.78) *
X_{12}	0.121(10.23) ***	-0.009 (-0.68)	-0.009 (-0.95)
X_{13}	-0.008(-0.40)	0.028(2.06) **	0.097(9.71) ***
X_{14}	-0.009 (-0.46)	0.021(1.54)	0.001(0.01)
X_{15}	-0.004 (-0.14)	0.006(0.61)	0.013(0.71)
X_{16}	0.002(0.11)	0.006(0.34)	-0.000 (-0.04)
X_{17}	-0.008 (-0.44)	-0.003 (-0.19)	0.012(0.71)
Log likelihood	-4,055	-3,736	-5,113

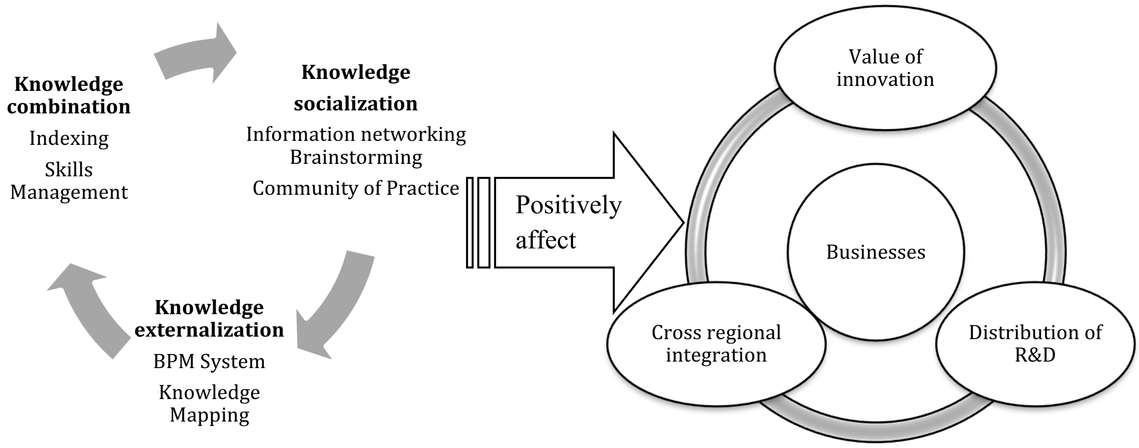
****Correlation is significant at the 0.01 level*
***Correlation is significant at the 0.05 level*
**Correlation is significant at the 0.10 level*

4. DISCUSSION AND CONCLUSION

Considering these results, it seems that Nonaka and Takeuchi's spiral of knowledge has a positive influence on the quality of innovation, the geographic distribution of R&D and the cross-regional integration in the business context, but there is some criticality about the internalization process. Not all 15 selected variables have a positive influence on the three dependent variables of innovation (partially confirmed hypotheses).

Therefore, by excluding factors that have a negative influence or are not significant, it is possible to formulate an empirical model for the relationship between the spiral of knowledge and the innovation' effectiveness and efficiency, as defined in the related literature (Alegre and Chiva, 2013).

Figure 1 – Empirical model



This empirical model shows the relevance of knowledge sharing, knowledge externalization and knowledge combination in order to improve the efficacy and effectiveness of innovation. Although the literature about knowledge and innovation is copious, the relationship between Nonaka and Takeuchi's spiral of knowledge and the efficacy and effectiveness of innovation has not been examined systematically. Numerous factors in our empirical model measuring knowledge sharing, knowledge externalization and knowledge combination in companies positively influence the dependent variables that measure efficacy and effectiveness of innovation.

Particularly, our findings provide new evidence regarding the importance of intellectual capital on innovation, showing what factors positively impact on the efficiency (represented by the cross regional and the distribution R&D) and the effectiveness of innovation (namely value of innovation). As shown in Figure 1, some element referring to knowledge socialization (information networking,brainstorming, community of practice, internal conferences), to the knowledge externalization (existence of an Enterprise Content Management System, publishing and describing information through metadata, existence of a Business Process Management System; knowledge mapping) and to the knowledge combination (indexing, skills management) generate a new innovation spiral that promotes and encourages efficacy and effectiveness of innovation with a spiral movement.

More generally, this empirical research shows that the transformation of tacit knowledge into explicit knowledge and the diffusion of knowledge are not to be underestimated in the firms. Indeed, some factors of the spiral of knowledge have a key role in the internationalization of R&D teams, in cross-regional integration and in the quality of innovation.

This process should be included in the new best operative practices of businesses. Indeed, introducing our empirical model in the managerial best practices, firms may improve innovation quality, as well as cross-regional knowledge integration and R&D teams for innovation quality. In this way and according to the literature (Barney, 1991; Kogut and Zander, 1992), intellectual capital management may allow firms to grow and develop, gaining a competitive advantage in markets and manage some of the more complex aspects of innovation projects (Hoegl and Proserpio, 2004; Shan, Walker & Kogut, 1994). We believe our proposed model will enhance scholars' ability to study the relationship between intellectual capital management and innovation (1) encouraging new theorizing about the causes, effects, mechanisms of SECI model; (2) providing a new empirical model that can be used ex ante for new research designs, as well as post hoc for re-interpretations of previous research.

This empirical research not only confirms some statements made in the existing literature on the role of intellectual capital in the enhancement of innovation (Cooke, and Wills,1999) but also addresses a gap in the existing empirical research.

Indeed, compared to the existing literature, this research proposes an operational framework supported by an empirical verification using a large (432 firms) and geographically diverse (24 OECD countries) sample. Moreover, compared to other studies that are limited to investigating the relationship between knowledge and innovation, this research is based on the broader concepts of Nonaka and Takeuchi's spiral of knowledge.

Therefore, this research proposes a "dynamic approach" that highlights the importance of the conversion process that expands tacit and explicit knowledge in both quality and quantity. Concluding this study proposes an innovative approach for the business sector, particularly for works related to the creation of innovation.

ANNEX 1

Y_1 = Value of innovation = This variable measures the number of citations received by a patent. Numerous studies have shown that the number of citations of a patent is an efficient proxy for the value of innovation (Abraham and Moitra, 2001; Ahuja and Lampert, 2001; Argyres and Silverman, 2004; Lee, Yoon & Park, 2009; Rosenkopf and Almeida, 2003). Similarly to Singh (2008) the measurement of citations includes both self-citations and external citations.

Y_2 = R&D dispersion = This variable is measured by adopting the R & D dispersion index. This index is defined as one minus the Herfindahl of geographic concentration of the firm’s (Singh, 2008). Using the definition of Singh (2008), dispersion index is calculated as follows:
where: n is the number of patents that the firm has successfully applied for in the recent 4 years, and nk refers to the subset of patent developed by the first inventor in geographic “region” k.

Y_3 = Cross-regional knowledge integration = this variable is a dummy that has value 1 if the focal patent makes a backward citation to a patent originating in another geographic unit of the same firm (Jaffe and Trajtenberg, 2002; Singh, 2008); otherwise the variable has a value of 0. This variable has been used to capture within-firm knowledge flow.

X_1 = Promotion of Periodic Brainstorming. This variable has the value of one if the firm periodically promotes brainstorming aimed at exchanging and creating new knowledge to generate new financial products; otherwise, the variable has a value of 0.

X_2 = Periodic Promotion of Internal Conferences on Specific Issues. This variable has the value of one if the bank promotes periodic employee conferences to enhance their skills related to specific issues; otherwise, the variable has a value of 0.

X_3 = Information Networking. This variable has the value of one if the firm adopts informal dissemination systems by promoting informal meetings in the company or on leisure time; otherwise, the variable has a value of 0. This variable is a proxy for the firm's ability to promote an informal community of knowledge sharing.

X_4 = Awards as a Means of Stimulating Knowledge Sharing. This variable has the value of one if the firm promotes premium competitions for the best innovative ideas for introducing product or process innovations; otherwise, the variable has a value as 0.

X_5 = Community of Practice. This variable has the value of one if the firm promotes the emergence of informal communities where work practices are shared; otherwise, the variable has a value of 0.

X_6 = Knowledge Sharing Fair. This variable has the value of one if the firm promotes internal fairs (even on-line events) for sharing knowledge. Otherwise, the variable has a value of 0.

X_7 = Existence of an Enterprise Content Management System. This variable has the value of one if the firm uses software to control and verify the integrity of the acquired information; otherwise, the variable has a value of 0.

X_8 = Existence of a Business Process Management System. This variable has the value of one if the firm uses information technology systems that allow managers to use analytics and change either technology or the organization based on the acquired information; otherwise, the variable has a value of 0.

X_9 = Knowledge Mapping. This variable has the value of one if the firm conducts knowledge mapping to develop encoded knowledge that is accessible to everyone; otherwise, the variable has a value of 0.

X_{10} = Publishing and Describing Information Through Metadata. This variable has the value of one if the firm has a system that transforms tacit knowledge into explicit information by publishing it; otherwise, the variable has the value of 0. This variable is a proxy of the level of information encoding.

X_{11} = Indexing. This variable has the value of one if the firm uses software that can briefly describe the content of the information, making it easier for employees to search for and combine explicit knowledge. Otherwise, the variable has a value of 0. This variable is a proxy for the level of information availability.

X_{12} = Digital Storage. This variable has the value of one if the firm uses software that can quickly store and combine the content of information; otherwise, the variable has the value of 0. This variable is a proxy of the firm's ability to combine explicit knowledge.

X_{13} = Skills Management. This variable has the value of 1 if the firm periodically performs a systematic assessment and assesses the competences of staff members. This variable is a proxy of the bank’s ability to combine explicit knowledge.

X_{14} = Internal Staff Training System. This variable has the value of one if the firm has a staff training system in place; otherwise, the variable has the value of 0. This variable is a proxy for the firm's ability to increase the cultural level of employees to increase the potential for knowledge generation.

X_{15} = Storytelling Management. This variable has the value of one if the firm applies the principles of a pedagogic narrative in the enterprise as a means to transform explicit knowledge into tacit knowledge; otherwise, the variable has the value of 0.

X_{16} = Control variable for the team size = This variable measures the effect of the size of the team on the econometric model. This variable is measured by the natural logarithm of the the number of researchers in the innovating team for the focal patent.

X_{17} = Control variable for R&D intensity = This variable is the ratio of R&D to sales for the firm.

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