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Social capital and innovation: an empirical analysis in the context of European regions

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Social capital and innovation: an empirical analysis in the context of European regions

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Social capital and innovation: an empirical analysis in the context of European regions

Abstract

Although conceptual support for the relevance of social capital as an antecedent of innovation has received much theoretical attention over recent years, measurement and quantitative evidence are scarce, particularly in regional contexts. Available empirical research referring to different units of analysis (individuals, organizations, and so on) supports, in general terms, a linear positive relationship among some components of social capital and innovation. Yet some studies also offer controversial results by finding non-significant, negative, diminishing returns and quadratic relationships. Building on the social network theory of innovation, this paper seeks to contribute some insights to this stream of research by empirically testing the impact of social capital on innovation in 54 NUTS1 European regions. Our results show that the social capital-innovation relationship has an inverted U-shape, which is consistent with recent research that suggests that some sub-constructs of social capital, such as tie strength, involve maintenance and opportunity costs and that social capital has positive effects but has also its limits.

Keywords: Innovation, social capital, European regions, intellectual capital, learning.

Classification: Research Paper

Social capital and innovation: an empirical analysis in the context of European regions

1. Introduction

The importance of social capital as an antecedent of innovation has received much theoretical attention over recent years (LANDRY et al., 2002). In particular, social network theories of innovation hypothesise a positive and direct relationship between social capital and innovation. Nevertheless, empirical evidence regarding the social capital-innovation relationship is scarce, in a regional context. Some interesting exceptions are the contributions of FLORIDA et al. (2002), BEUGELSDIJK and VAN SCHAİK, (2005a, 2005b), FLEMING and MARX (2006), and HAUSER et al. (2007) who, generally, find a positive relationship between weak social ties and innovative activity.

A main reason for empirical effort being very limited in this area is the lack of agreement regarding the content of the concept of social capital and the appropriate way of measuring it (BEUGELSDIJK and VAN SCHAİK, 2005a). Social capital is a complex construct, which, as was proposed by NAHAPIET and GHOSHAL (1998), has a structural, a relational and a cognitive dimension (and various sub-constructs might also exist inside these dimensions). Consensus exists regarding the multidimensionality of the concept, but concrete proposals to measure social capital from a multidimensional perspective are almost inexistent.

When research has been carried out that overcomes the above limitation by using mainly individual indicators of social capital, regional researchers have focused on the social capital-GDP direct relationship instead of on the more manageable social capital-innovation relationship (e.g. KNACK and KEEFER, 1997, GITESS and VIDAL, 1998,

PUTNAM, 2000, ZAK and KNACK, 2001, BEUGELSDIJK and SMULDERS, 2003, BEUGELSDIJK and VAN SCHAIK, 2005a and 2005b). This stream of research has made an important contribution in relation to the impact of the various dimensions of social capital on innovation. In particular, a great emphasis has been placed on studying and discussing the diverse impact of bridging and bonding on regional growth. On the contrary, empirical research to contrast the social networks theories of innovation at a regional level are practically inexistent (as an exception, see HAUSER et al. 2007). In order to cover this research gap, more emphasis is needed on empirically studying the relationship between social capital and innovation and this is the main aim of this paper. Empirical studies of other units of analysis (such as individuals, teams, business units, organizations, small world, and cities and regions) have mostly shown that some proxies of the various dimensions of social capital have a positive (and usually linear) effect on innovation, as has been conceptually suggested (e.g. COOKE et al., 2005, DAKHLI and CLERCQ, 2004, LANDRY et al. 2002). Yet, some recent research has found a non-significant (e.g. SMITH et al., 2005) or even negative relationship (AHUJA, 2000) and has also suggested that social capital has its limits and that the social capital-innovation relationship might have a diminishing return shape (e.g. VANHAVERBEKE et al., 2002, MCFADEN and CANNELLA, 2004) or an inverted U-shape (e.g. UZZI and SPIRO, 2005, LEENDERS et al., 2003). The main idea behind these findings is that creating new relationships is costly and maintaining existing ties also consumes time, energy and financial resources. As tie strength is increased, there is less time left to seek out new resources that may lead to good ideas to fuel innovation (ZHENG, 2008). This line of reasoning is consistent with the thinking of regional researchers who have emphasized the relevance of weak ties for growth (SCHNEIDER et al., 2000,

BEUGELSDIJK and SMULDERS, 2003, FLORIDA, 2003) and have shown the limits of trust and strong ties.

Building on the social network theory of innovation, this study seeks to contribute insights to this stream of research, by empirically testing the impact of social capital on innovation in the context of NUTS1 European regions. Our results support the existence of a significant direct and positive effect of social capital on patents (as a measure of the innovation outcomes) up to a tipping point. The social capital-innovation relationship therefore shows an inverted U-shape. This finding might be considered to be relatively surprising, but is consistent with the above-mentioned recent empirical research carried out mainly at non-geographical levels of analysis and which suggests that some sub-constructs of social capital, such as tie strength, involve maintenance and opportunity costs, and that social capital have positive effects but also have their limits. Human relations are time-consuming and time is not an unlimited resource. If the priority is to build social capital, other targets might be overlooked.

Although our research question focuses on social capital, we build on social networks theories of innovation and as a consequence consider social capital as a moderator of the relationship between knowledge-/learning-related metrics -Research and Development (R&D) expenditure and intellectual capital- and innovation outcomes. The first objective of our research is to study the shape of the social capital-innovation relationship in the European regions. As a more marginal contribution, our research offers some insights to the bonding/bridging debate.

The paper is structured in six sections. The second section reviews main concepts and develop first hypotheses. The third section refers to empirical evidence regarding the social capital-innovation relationship at different units of analysis and provides additional hypotheses to be tested. The fourth section describes the model and the

metrics used. The fifth section presents the results of the empirical analyses. The sixth section concludes with a discussion and avenues for further research.

2. Determinants of innovation outcomes in innovation theories

R&D expenses (a proxy of learning effort and absorptive capacity)

Innovation theories have evolved dramatically over the last 40 years (LANDRY et al., 2002) and new theories have added new explanative factors of innovation outcomes. Nevertheless, a dimension that has been continuously present in these conceptualizations has been the R&D effort (basic research and industrial R&D). During the 1950s, engineering innovation theories considered innovation as a discrete event resulting from knowledge developed by isolated inventors and isolated researchers and stated that R&D effort was the antecedent of innovation outcomes (new or improved products and processes). Subsequently, technical network theories of innovation recognized that innovation was also a result of multiple interaction processes between firms and other actors.

Therefore, according to engineering innovation theories (and also to subsequent innovation theories), an R&D effort is a main antecedent of innovation results. So we propose:

H1: The higher the Gross Domestic Product (GDP) expenditure on R&D, the more successful the innovation outcomes.

Knowledge

Social network theories of innovation have not been developed until very recently. A key new insight to social network theories is that knowledge plays an increasingly more crucial role in fostering innovation (LANDRY et al., 2002). It is argued that the availability of knowledge is a key explanatory variable in innovation and, consequently, in the success of a company or a geographical space (see e.g. ROMER, 1986, 1990,

JOHANSEN et al., 2001). The underlying idea is that knowledge plays an increasingly crucial role in prompting innovation, due to: (1) the continuous expansion of the amount of technical knowledge accumulating over time, and (2) the use of communication technologies that mean knowledge is available very rapidly on a worldwide scale (LANDRY et al., 2002).

From an isolated perspective, the knowledge and knowing capability of a social entity, be it individual, team, organization or a geographical area, is referred to as intellectual capital (NAHAPIET and GHOSHAL, 1998). NONAKA (1994) suggested that organizations that are able to stimulate and improve the knowledge of their employees are in a better position to innovate. Capabilities of knowledge workers lie in their education background and professional experience (and also training, creativity, and motivation). Training programmes help in the production of new knowledge which thereby leads to innovative solutions (EGBU 2006). Additionally, a sense of confidence and competence is strongly associated with the employees' willingness to share knowledge (LIN and KUO, 2007). So, we propose:

H2: The higher the intellectual capital, the more successful the innovation outcomes.

Learning

Yet knowledge is a non-rival (several people can use it at the same time) and, in the medium/long run, non-excludable good (EDWARDS, 2007). This is why learning-economy scholars focus on learning. They affirm that it is the capacity to learn continuously that determines success (LUNDVALL, 1992, 1996). Previous knowledge matters, as a key input in producing current knowledge is past knowledge (ROMER, 1986, 1990, COHEN and LEVINTHAL, 1990). As stated by COHEN and LEVINTHAL (1990), prior related knowledge confers an ability to recognise the value of new

information, assimilate it, and apply it to commercial ends. These abilities collectively constitute what they call a firm's absorptive capacity. In this research, R&D expenditure is viewed as an investment in absorptive capacity and as a way of obtaining innovation outcomes.

Yet, as knowledge has a quasi-public character, new knowledge needs to be (continuously) created through learning to obtain a competitive advantage. Under the umbrella of the learning economy, learning is viewed as an assimilation of existing knowledge and also as the creation of new knowledge by developing associations and linkages that may never have been considered before (i.e. innovation). Interestingly, it has been shown that at an organizational level learning climate would promote creation, transfer, and implementation of knowledge to the workplace routines and processes (LIN, 2001, SHIPTON, et al. 2005).

The learning economy has its parallel at the regional level in literature on the concept of learning regions (MORGAN 1997, BOEKEMA et al., 2000, COOKE and MORGAN, 2000, HASSINK and LAGENDIJK, 2001, COOKE, 2002) and on (2) regional learning (e.g. BOEKEMA et al., 2000). The concept of learning regions (MORGAN 1997, BOEKEMA et al., 2000, COOKE and MORGAN, 2000, HASSINK and LAGENDIJK, 2001, COOKE, 2002) refers to networks driven by policy-making that serve as regional development tools, in which, according to HASSINK (2005): (1) the main actors are strongly but flexibly connected with each other and (2) are open to both intraregional and interregional learning processes. It has been provided empirical evidence of policy-making that prompts regional learning-driving networks to successfully achieve major strategic goals such as the quality promotion or the dissemination of Local Agendas 21 (BARRUTIA et al. 2007, BARRUTIA and ECHEBARRIA, 2007a, ECHEBARRIA et al. 2009).

Regional learning refers to more spontaneous cooperation between actors in a region through which they learn (BOEKEMA et al. 2000).

Social capital

Social capital is a recent yet significant addition to the list of innovation-inducing factors (ZHENG, 2008). Social network theories also echo that the locus of innovation is no longer the individual or the firm, but the network in which a firm is embedded, which shifts attention to social capital (POWELL, et al., 1996). Knowledge is viewed as an intrinsic part of the surrounding social, political and economic context, and knowledge creation occurs through the integration of resources (COLLINSON, 2000). In these theories, knowledge is embodied in networks and communities, and social capital becomes an essential ingredient for understanding innovation. So, high level of social capital is viewed as having a positive effect on regional innovation (STORPER, 1995). It has been argued that social capital prompts the efficiency and effectiveness of the innovation process. According to MASKELL (2001), social capital helps reduce malfeasance, induces the volunteering of reliable information, causes agreements to be honoured, enables employees to share tacit information, and places negotiators on the same wavelength. Efficiency, then, is mainly improved by reducing transaction costs (between firms, and between firms and other actors) and the costs of managing the innovation process. And greater effectiveness is achieved as more (suitable and reliable) quantity and quality of knowledge is accessed. Knowledge can more easily be transferred and utilised within a community made up of firms that understand the same language and share norms and codes (MASKELL, 2001). On the contrary, low level of social capital implies lack of coordination, duplications of effort, and costly contractual dispute (FOUNTAIN and ATKINSON, 1998).

Regional literature has singularly focused on social capital, although some authors have also recently suggested that the importance of local networks should not be overstated (WATERS and SMITH, 2008). Regional economies are viewed as synergy-laden systems of physical and relational assets (SCOTT and STORPER, 2003). As such, regions are an essential dimension of the innovation process. The spatial proximity of large numbers of firms locked into dense networks of interaction provides the essential conditions for many-sided exchanges of information to occur (SCOTT and STORPER, 2003). Furthermore, firms come together in both formal and informal organisations that help to streamline their interactions and accelerate information transfers, to build trust and reputation effects, and to promote their joint interests (BECATTINI, 1990, ASHEIM, 2000, DE PROPRIIS, 2005) inside regional (eco)-systems of innovation (HAMDOUCH and MOULAERT, 2006). It has been shown that social capital and learning have a positive relationship because social capital directly affects the combine-and-exchange process and provides relatively easy access to network resources (NAHAPIET and GHOSHAL, 1998, MCFADYEN and CANNELLA 2004). In the regional arena, regional social capital is viewed as a driver and catalyst of knowledge creation and dissemination. In terms of the influential distinction of POLANYI (1967), knowledge may be tacit and codified. Polanyi's main argument is that the more tacit the knowledge, the harder it is to actually transfer. Codified knowledge is easily transferable in information and can be transmitted through information technologies and infrastructures over long distances and across organisational boundaries. Tacit knowledge, however, cannot be easily transferred as it has not been stated in an explicit form and its transfer is extremely sensitive to social context. Therefore, it is commonly argued that the transfer of tacit knowledge within a region requires face-to-face contact and social capital (SCOTT and STORPER, 2003).

It has been also argued that social capital and intellectual capital are complementary and it is the co-evolution of social capital and intellectual capital that underpins organizational advantage (ADLER and KWON 2002, NAHAPIET and GHOSHAL 1998). Social capital helps obtain new intellectual capital and, at the same time, intellectual capital forms the basis from which social system and interactions are formed and taken advantage of social capital (ADLER and KWON 2002; NAHAPIET and GHOSHAL 1998).

So we propose:

H3: The higher the social capital, the more successful the innovation outcomes.

Social capital-learning interaction

Social capital and intellectual capital has been treated largely as independent predictors in social capital-innovation studies (MCFADYEN and CANNELLA, 2004; SMITH et al. 2005). Nevertheless, recent studies have suggested an interaction effect (ZHENG, 2008). For instance, regarding structural holes, knowledge workers' diversity of knowledge and experiences might compensate for the lack of information diversity that comes from lack of structural holes. In the same line, VANHAVERBEKE et al. (2002)'s study suggested that existing technological capital of a firm interacts with a dimension of social capital (its network size) in influencing innovation. In PERRY-SMITH'S (2006) study, where non-redundancy and background heterogeneity were modelled together, non-redundancy turned out to be non-significant. These findings support the argument that human capital and social capital are complementary (ADLER and KWON 2002). It has been suggested that future studies need to fill in the empirical gap in verifying this claim in innovation research (ZHENG, 2008).

So we propose:

H4: The higher the interaction social capital-intellectual capital effect, the more successful the innovation outcomes.

3. Empirical research about social capital and innovation

As far as we now there is no research that study the relation between a fully comprehensive measure of social capital and the innovation outcomes. Nevertheless, the studies that address the effect of the different dimensions of social capital and innovation has, in general terms, supported a positive relationship between social capital and innovation, but conflicting evidence have also been found. It has been argued that network size affects innovation by the availability of a large and probably diverse volume of information and resources (ZHENG, 2008). It helps the formation of new ideas and the potential availability of innovation resources. Network size have shown a linear positive impact on innovation at an organizational level (AHUJA, 2000, SMITH et al., 2005, SHAN et al., 1994) or quadratic (VANHAVERBEKE et al. 2002). VANHAVERBEKE et al. (2002) found a quadratic relationship between a firm's technological alliances and its innovation outcomes. They attributed the diminishing returns to saturation and overembeddedness. At an individual level, MCFADYEN and CANNELLA's (2004) study modelled and found a quadratic relationship between network size and innovation. Their findings suggested that, when a biomedical researcher's co-authors exceeded 93 (over the past five years), they were likely to see a negative return on their publications if they continued to expand their networks. They attributed this diminishing benefit of network size to a potential opportunity cost associated with maintaining and expanding an actor's social network, such as time, money and energy. Initially, the more social contacts an actor accumulates, the more innovations the actor can pull through. However, there is a tipping point where the cost of expanding social ties begins to outgrow the benefit of it.

The gains from extending network size may not offset the costs for establishing the new ties (ZUCKER et al. 1995). In addition, negative outcomes of network size need to be

considered as it also lowers the net benefits of enlarging network size. Possible negative outcomes include spillover of key information to competitors in firm alliances, attenuated network strength and less power benefits among existing contacts due to lack of time with too many contacts (AHUJA 2000), overembeddedness in the same network (UZZI 1997), and risks to other actors (PORTES and LANDOLT 1996).

Impact of structural holes (bridging) have shown some controversial results. At an organizational level some research works have obtained positive results (HARGADON and SUTTON, 1997). The effect of structural holes is to provide exposure to information and power and influence on the actor (as an interesting example referring to a company, ING direct, see BARRUTIA and ECHEBARRIA, 2007b). On the contrary, SMITH et al. (2005) found a non-significant relationship and AHUJA (2000) obtained a negative effect. Interestingly, UZZI and SPIRO (2005) studied the Broadway musical industry and found an inverted U-shape relationship. At a regional level, FLEMING and MARX (2006) found a positive relationship between increasing bridging ties and patents. Likewise at a city level, FLORIDA et al. (2002) found a positive relationship between weak social ties and innovative activity. In their study, cities were compared based on their tolerance for gays and bohemians (a proxy for structural holes and sparse network), and it was found that cities that ranked high on these two indexes were also high on innovative activities. Based upon focus group work, FLORIDA (2003) suggested that the 'creative class' (i.e. people engaged in work whose function is to 'create meaningful new forms') prefers weak ties. Participants acknowledged the importance of community, but they preferred 'quasi-anonymity'. He concluded that social structures that historically embraced closeness may now appear restricting and invasive and that where strong ties among people were once important, weak ties are now more effective. Likewise, HAUSER et al. (2007) found the impact of social capital on regional

innovation processes was significant. However, they also found that not all dimensions of social capital exhibited the same explanatory power. Specifically, the dimension ‘associational activity’ represented the strongest driving force for patenting activity. They concluded that their finding contributed empirical evidence for the significance of weak ties in innovative processes.

Overall, tie strength has also shown a positive impact on innovation at an organizational level (ROWLEY et al., 2000, DAKHLI and CLERCQ, 2004, SMITH et al. 2005). Strong ties have a positive influence on innovation by helping to establish trust and cohesion inside the network (ZHENG, 2008). Nevertheless non-significant, diminishing and inverted U-shape results have also been obtained. Interestingly, LANDRY et al. (2002) found a non-significant impact of tie strength with radicalness of innovation. And, Leenders et al. (2003) and MCFADYEN and CANNELLA (2004)’s data drew a quadratic relationship at a team and individual level respectively. MCFADYEN and CANNELLA (2004) suggested that peak knowledge creation for biomedical researchers occurs with about 1.56 collaborations with the same co-author over a five-year period. More interactions seem to bring diminishing benefits. These results are due to the fact that tie strength involves maintenance and opportunity costs. LEENDERS et al. (2003) also found an inverted U-shape of the relationship between tie strength inside a team and team creativity. They suggested that a very low or very high level of interaction frequency impeded team creativity, while when interaction frequency was moderate, creativity was the highest.

Overall, trust is shown to be a contributing factor to innovation. It has shown a positive impact on innovation at an organizational level (DAKHLI and de CLERCQ, 2004, LANDRY et al. 2002 and LEE and CHOI, 2003, COOKE et al., 2005), and at a business unit level (TSAI and GHOSAL, 1998). For instance, COOKE et al. (2005) found that innovative firms tend to make greater use of collaboration and information exchange, to be involved in

higher trust relationships, and to make greater use of non-local networks. Interestingly DAKHLI and CLERCQ (2004)'s research found positive effect of trust and associational activity on innovation. But interestingly in their study regarding European regions, HAUSER et al. (2007) found a non-significant relationship between trust and patents. Norms have also shown a positive relationship with innovation outcomes at an organizational level (O'REILLY, 1989, DAKHLI and CLERCQ, 2004, RUSSELL and RUSSELL, 1992, SMITH et al., 2005).

The results of these investigations link with the interesting debate that is taking place within regional literature (and other related fields) around the impact of tie strength in regional GDP, i.e. bonding (exclusive, closed social capital with strong ties) and bridging (inclusive, open social capital characterised by weak ties) (GITTESS and VIDAL, 1998; PUTNAM, 2000). Bonding social capital is linked to family or primary friendship relationships. Bridging social capital is linked with weak ties and can be generalised to people who are strangers. ZHENG (2008) echoes the bonding vs. bridging debate, suggesting that tie strength involves maintenance costs, and so a quadratic or diminishing returns relationship between tie strength and innovation is worth more attention.

So we propose:

H5a: The social capital-innovation relationship will be direct, linear and positive.

H5b: The social capital-innovation relationship will be direct, positive and with diminishing returns.

H5c: The social capital-innovation relationship will be direct and have an inverted U-shape.

Table 1. Variable Coding in the Analysis

Concept	Variable	Description	Source
<i>Innovation Outcomes</i>			
Patents (P)	Number of patent applications to the European Patent Office (EPO) per million inhabitants	Applications filed directly under the European Patent Convention or applications filed under the Patent Co-operation Treaty and designated to the EPO (Euro-PCT)	Data originate from the patent database PATSTAT hosted by the European Patent Office (EPO). Eurostat (mean 2000-2004)
<i>Predictors</i>			
Research/Learning Effort (R&D)	Gross domestic expenditure on R&D in Purchasing Power Standards	Business enterprise expenditure, Higher education expenditure, Government expenditure and Private non-profit intramural expenditure on R&D.	Data originate from the national R&D surveys which are based on the Frascati Manual, OECD, 2002. Eurostat
Social Capital (SC)	Social Capital (Sociological Approach)	Social Capital Index	Beugelsdijk and Van Schaik, 2005a. Data from European Values Study (1999/2000)
Employment in high technology sectors (Hi-T) (proxy of intellectual capital and control variable for patents)	Percentage of total employment in High-tech sectors	High-tech manufacturing and knowledge-intensive high-technology services	Various origins and methodologies, statistics are compiled at Eurostat.
Intellectual capital (IC ₁) (education)	Percentage of people that have attained tertiary education	Tertiary education - levels 5-6 (ISCED 1997)	European Union Labour Force Survey (LFS). Eurostat
Intellectual capital (IC ₂) (doing)	Human Resources in Science and Technology (HRST) stocks	Human Resources in Science and Technology including occupation and education	European Union Labour Force Survey (LFS). Eurostat

4. Data and metrics

The main objective of this research is to empirically validate social network theories of innovation in the context of the European regions, by focusing on social capital, intellectual capital and R&D effort as the main drivers of innovation. Table 1 includes a summarized description of the variables used in this research.

We propose the GDP on R&D in Purchasing Power Standards (PPS) to proxy learning effort and absorptive capacity. The underlying concept, which is sometimes

misunderstood, “comprises creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man [sic], culture and society and the use of this stock of knowledge to devise new applications” (OECD, 2002, p.63). This is a simple and robust metric, which measures real effort in terms of actual cost expended for the generation of new marketable knowledge or learning. Furthermore, it is a structural metric that, within the European context, moves slowly and with a generally upward trend and, therefore, makes it possible to proxy the knowledge that has accumulated within a particular geographical area and its absorptive capacity.

There is no consensus on how to measure social capital. Previous literature has concentrated on describing the concept of social capital and its implications. Following a sociologically driven approach, and using data from the European Value Studies (EVS) (see www.europeanvalues.nl), a regional measure of social capital has been proposed: the BEUGELSDIJK and VAN SCHAİK (2005a)’s social capital index, which uses the Eurostat NUTS1 definition of regions. These authors’ index incorporates trust, and active and passive group membership (respondents who are members of a particular association but do not perform voluntary work for that body).

The outcome variable considered is the number of patent applications to the European Patent Office (EPO) per million inhabitants. Eurostat summarizes the main weaknesses that are usually attributed to this metric: (1) not all inventions are patented and not all patents have the same value; (2) the value distribution of patents is skewed as many patents have no industrial application; (3) inventions that are protected by other means or inventions, whose value does not warrant the costs of patenting, are not patented; (4) the propensity to patent differs across countries and industries; and (5) changes in patent law and regulations result in lower comparability over time. Despite these limitations the number of patent applications is the best metric available to measure innovation as

has been suggested by GRILICHES, (1995) and TRAJTENBERG, (1990), among others. Specifically, the number of patents seems to be a good proxy for measuring the most relevant innovation outcomes, as it includes the most radical and long term profit-impacting innovations (i.e. innovations that are new to the firm and the world). Most investigations use the number of patents granted as the innovation outcome (see e.g. SHAN et al., 1994, AHUJA, 2000, VANHAVERBEKE, et al. 2002). It has been said that the propensity to patent depends on the sector. For instance, ARUNDEL and KABLA (1998) found that 80% of innovations were patented in the pharmaceutical sector while it is only 8% in the textile sector. Therefore, we include the presence of Hi-tech sectors in the region as a control variable.

We use an education-related metric to proxy intellectual capital: the percentage of people that have attained tertiary education. We also use an experience-related proxy: the stock of human resources in science and technology (see HAUSER et al, 2007) .The presence of Hi-tech sectors in the region (in terms of employees) may be also considered as an intellectual capital proxy.

4. Models to be tested and Empirical Results

Models

Empirical models include the factors that may affect patents for region in four categories as explanatory variables: (1) R&D on PPS ($R\&D_i$); (2) Social Capital (SC_i); (3) Intellectual Capital (IC_i); and (4) High-Tech sectors presence ($H-T_i$). Outcome variable is patents per million of inhabitants (P_i). Models to be tested are:

(1) Linear model:

$$P_i = \alpha + \beta_1 R\&D_i + \beta_2 SC_i + \beta_3 IC_i + \beta_4 H-T_i + \beta_5 (SC_i * IC_i) + \varepsilon_i$$

(2) Diminishing returns model:

$$P_i = \alpha + \beta_1 R\&D_i + \beta_2 (SC_i)^{1/2} + \beta_3 IC_i + \beta_4 H-T_i + \beta_5 (SC_i * IC_i) + \varepsilon_i$$

(3) Inverted U-shape model:

$$P_i = \alpha + \beta_1 R\&D_i + \beta_2 SC_i + \beta_3 (SC_i)^2 + \beta_4 IC_i + \beta_5 H-T_i + \beta_6 (SC_i * IC_i) + \varepsilon_i$$

Table 2. Summary Statistics and correlations

	Obs.	Mean	Std. Dev.	Min.	Max	<i>Correlations</i>				
						Patents	R&D	Hi-T	IC (educ)	IC (doing)
Social Capital	54	35.90	18,93	0	100	0.330 ¹	0.373	0.284	0.329	0.546
Patents	54	119.9	121.9	4.83	524.6	1	0.642	0.482	0.188	0.515
R&D	54	1.64	0.88	0.52	3.96		1	0.692	0.402	0.646
Hi-Tech (employees)	54	4.44	1.43	1.73	7.75			1	0.354	0.623
Int. Cap. (educ.)	54	13.30	4.34	5.76	22.94				1	0.796
Int. Cap. (doing)	54	24.9	6.01	13.2	39					1

¹Correlation between log (patents) and social capital is 0.484

Empirical Results

Data were analysed using the Stata 10 statistical software. Preliminary analysis identified a low correlation between the education-related metric for intellectual capital and patents (0.188, see correlations and descriptive statistics on table 2) which indicated that the percentage of people that have attained tertiary education was not a good predictor of innovation results. A high correlation between the variables Hi-tech sectors presence and human resources in science and technology (0.796) also indicated possible problems when being used together in regression.

Additionally, we checked for normality and linearity and appreciated that social capital-patents relationship seemed to be non-linear. So, it seemed evident that to test a diminishing returns or an inverted U-shape relationship was appropriate. Five observations might be considered as outliers or influential observations. Specifically, the regions of Baden-Wurttemberg, Bayern and Zuid Nederland produced 524, 410 and

612 patents per million of inhabitants, respectively, being the mean of patents 120 and the standard deviation 122. On the other hand, the regions of Oost Nederland and West Nederland presented a social capital index of 100 and 91, respectively, being the mean of the index 36 and the standard deviation 19. It was decided to use all observations and check for consistency with and without these observations.

After preliminary regressions were developed, the Breusch-Pagan/Cook-Weisberg test for heteroscedasticity showed lack of homocedasticity ($\chi^2(1) = 34.36$, $\text{Prob.} > \chi^2 = 0.0000$). This diagnostic was confirmed after plotting the residuals versus the fitted (predicted) values. These problems were mainly related to the non-normality of the outcome variable, which was transformed by using a log function. Table 3 reports standard errors and robust standard errors (Huber-White sandwich estimators). Such robust standard errors can deal with concerns about failure to meet regression assumptions, such as heteroscedasticity, or some observations that exhibit large residuals, leverage or influence (CHEN et al., 2009). They were tested three different models to contrast the social capital-innovation relationship: (1) an increasing linear model; (2) a diminishing returns model and (3) an inverted U-shape model.

Main results are reported in table 3. Specifications 1 to 3 compare the three models and show that the inverted U-shape model offers the best results. The inverted U-shape model and the variables social capital and R&D expenses are highly significant, and R-square is the largest of the three models (0.5843). R-square increasing from specification 1 to 3 is significant. Conclusions are similar whether we use 54 regions as if we remove above reported influential observations. In specifications 1 to 3, only social capital, R&D and intellectual capital (occupation) are reported as predictors. The effect of the education-related proxy for intellectual capital is not reported. A negative relationship with the outcome variable was obtained due to low correlation. Remainder

variables are added to the inverted U-shape model in specifications 4 to 6. The percentage of employees in high-technology sectors adds new useful information and shows predictive validity. Nevertheless, multicollinearity problems arise. The inverted U-shaped relationship between social capital and the outcome variable is robust with respect to the inclusion/exclusion of other variables. Best model is included in specification 6 (R-square = 0.6252). The variable created to incorporate the effect of the social capital-intellectual capital interaction is non-significant (see specification 4). So, hypotheses linked with the main research question of this investigation could not be rejected. Yet, hypothesis regarding interaction effect had to be rejected. These results are discussed below.

Table 3. Social Capital, intellectual capital and R&D as determinants of Innovation Outcomes

	(Spec. 1) Linear model	(Spec. 2) Diminishing returns model	(Spec. 3) Inverted U-shape model	(Spec. 4) Interaction effect (R&D and IC)	(Spec. 5) Inv. U-shape mod. (incl. IC ₁ and H-T)	(Spec. 6) Inv. U-shape mod. (incl. H-T)
Social capital (SC)	0.174 (0.131) [0.111]		0.761** (0.014) [0.011]	0.809*** (0.065) [0.009]	0.823*** (0.006) [0.004]	0.887*** (0.003) [0.001]
SC ²			-0.594*** (0.041) [0.009]	-0.594* (0.151) [0.072]	-0.625*** (0.024) [0.004]	-0.636*** (0.022) [0.002]
SC ^{1/2}		0.237** (0.042) [0.034]				
R&D	0.424*** (0.001) [0.000]	0.410*** (0.002) [0.000]	0.356*** (0.001) [0.006]	0.354*** (0.007) [0.002]	0.186 (0.174) [0.103]	0.230** (0.083) [0.038]
Employees on R&D (IC)	0.276* (0.051) [0.055]	0.245 (0.076) [0.102]	0.269* (0.049) [0.068]	0.308 (0.874) [0.798]	0.15 (0.262) [0.317]	
Employees in High- tech sectors (H-T) R&D* IC				-0.112 (0.277) [0.188]	0.33** (0.013) [0.047]	0.38** (0.003) [0.019]
Constant	1.63*** (0.002) [0.005]	1.25** (0.015) [0.019]	1.14** (0.034) [0.036]	1.00 (0.191) [0.338]	0.77 (0.139) [0.147]	1.11*** (0.012) [0.009]
<i>Regression</i>						
N	54	54	54	54	54	54
F-statistic	20.11***	21.51***	17.22***	13.50***	16.70***	20.44***
R-squared	0.5468	0.5635	0.5843	0.5845	0.6350	0.6252
Adj. R-squared	0.5196	0.5373	0.5503	0.5412	0.5970	0.5946

*** significant at 1%; ** at 5%; * at 10%

Standardized coefficients (beta) are reported for variables.

p values are reported in brackets (std. errors) and square brackets (robust std. errors).

5. Final Discussion and conclusions

The main research question refers to the social capital-innovation outcomes relationship. A sociologically-driven metric is used to measure social capital and empirically contrast the impact of social capital on innovation outcomes. It shows predictive validity to explain innovation outcomes. But research results also show that social capital has its limits. Specifically, in the context of NUTS1 European regions, social capital-innovation relationship shows an inverted U-shape. This finding might be considered as relatively surprising, but is consistent with recent empirical research carried out mainly at non-geographical levels of analysis, and which suggests that some sub-constructs of social capital, such as tie strength or trust, involve maintenance and opportunity costs and that social capital has positive effects, but also has its limits. The underlying idea is that human relations are time consuming and time is not an unlimited resource. If the priority is to build social capital, other targets should be neglected.

These conclusions are also implicit in the regional literature bridging-bonding debate. BEUGELSDIJK and VAN SCHAİK (2005a)'s metric focuses mainly on bonding (trust and associations membership) and the bridging-bonding debate focuses, in essence, on two ideas: (1) the cost and limits of bonding and, on the contrary and (2) 'the strength of weak ties' (GRANOVETTER, 1973) to prompt regional growth. For instance, SCHNEIDER et al. (2000), when extending Putnam's research to Europe, indicated that: in regions where horizontal social networks seem well developed, (1) growth rates exceeding the average were experienced, and (2) trust in compatriots did not seem to support economic performance. BEUGELSDIJK and SMULDERS (2003) also showed that bridging social capital was empirically good for growth, while strong emphasis on family ties was negatively related to growth. And FLORIDA (2003) suggested that the 'creative

class' (i.e. people engaged in work whose function is to 'create meaningful new forms') prefers weak ties. Participants acknowledged the importance of community, but they preferred 'quasi-anonymity'. He concluded that social structures that historically embraced closeness may now appear restricting and invasive and that where strong ties among people were once important, weak ties are now more effective. These remarks are consistent with the literature dealing with concepts of regional innovation systems, learning regions and regional learning which emphasize relatively weak (professional) ties as explanatory factors of successful innovation.

When studies more closely related to this research (those using data from EVS) are analysed in detail, it can be seen that previous results also revealed some limitations of social capital as a predictor of growth and innovation. Specifically, this research use BEUGELSDIJK and VAN SCHAIK (2005a)'s social capital index. They studied the social capital-GDP relationship and find a significant positive effect. Nevertheless, BEUGELSDIJK and Van SCHAIK (2005b) used the indicators integrated in its index separately in another study and found that although active membership of associations implied an increase in GDP, trust and passive group membership did not. HAUSER et al. (2007) likewise used different constructs to measure social capital and only associational activity show to be a significant predictor of innovation (at 0.5% level). Friendship ties and trust were not significant. Nevertheless, these studies did not analyse (or at least did not report) an inverted U-shape relationship.

When jointly considered, the above arguments and findings suggest that when measures are built on proxies related with strong ties and trust, the inverted U-shape seems to be more appropriated than the linear relationship, particularly given the potential costs of strengthening social ties. It seems reasonable to consider that the benefit of increasing tie strength and trust initially grows as previously weak social ties are strengthened and

the regional actors have easier access to resources and knowledge, but the benefit does not go up indefinitely. A tipping point exists where there is nothing to gain from additional interaction with certain people or organizations. Furthermore, as tie strength is increased, there is less time left for other research activities and opportunity costs increase. Therefore, an inverted U-shape relationship seems to be more realistic modelling than a linear relationship.

Although a broad conceptual evidence to support the relevance of education-related intellectual capital to explain innovation outcomes is available, our data do not allow this view to be supported. Level of education attained, being secondary or tertiary levels, is sometimes considered as a good metric of knowledge needed to innovate. Nevertheless, these metrics show a low correlation with innovation outcomes. Capabilities of knowledge workers lie in their education background and professional experience (learning by doing). So, educational metrics only approach a dimension of these capabilities and it is possible that the knowledge that matters to innovation may be the knowledge acquired by doing, and that this knowledge is better measured by using metrics such as R&D, as absorptive capacity might largely lie on continuous and step-by-step R&D effort, human resources on R&D and on Hi-tech sectors. As was suggested by NONAKA (1994), after studying innovation at an organizations level, what matters is the practice, the doing, the embodiment of knowledge. He suggested that the creation of organizational knowledge begins with subjective tacit knowledge, that flow of information which individuals have created and proven in their own committed, effective, embodied actions. Emphasis on a step-by-step developed absorptive capacity might be considered as bad news for EU politicians (and also countries and regions politicians) who are trying to look for shortcuts in the race for R&D expenditure. EU politicians should consider that even if the R&D spending levels of USA or Japan are

achieved, it may also be probable that innovation outcomes are lower due to the absorptive capacity concept. Additionally, excessive running might be associated with the risk of making wrong decisions due to precipitation.

The results of this research might also be influenced by the use of NUTS1 level of aggregation. Results could be tighter at a lower degree of aggregation. NUTS1 seems to imply the need for creating some artificial debatable conglomerates. Moreover, average data could hide important disparities between NUTS2 regions. And, as explained by LORENZEN (2007), for instance, social capital seems to be formed on small scales. Unfortunately, social capital data at a NUTS2 level are not available.

The patents granted in a region cover an important part of the whole innovation market-led effort and the results of the region and propensity to patent is increasing. Nevertheless, we are aware that some forms of innovation are not included in this research. Nor is social innovation included in our approach. Future research might include market-led and social-led indicators to consider a more multidimensional measure of innovation, as was recently suggested (see MOULAERT and NUSSBAUMER, 2005). Shortcomings regarding social capital metrics need to be addressed. A comprehensive measure of social capital needs to be developed. Definitive conclusions regarding the social capital-innovation relationship cannot be obtained until we have more robust metrics.

Finally, other suggestion for politicians emerges from this study. Investment effort in R&D is not in itself enough to achieve innovation outcomes in regions with low levels of social capital. R&D input should be accompanied by effort to prompt social capital. Some Italian regions are good examples of the low impact of R&D investment input on innovation outcomes, owing to the almost or total absence of social capital. Investment rankings, which are very popular in political circles, should therefore be used with care.

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