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3 **Limits of social capital as a driver of innovation: an empirical**
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6 **analysis in the context of European regions**
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Limits of social capital as a driver of innovation: an empirical analysis in the context of European regions

Abstract

Available empirical research referring to different units of analysis supports, in general terms, a linear positive relationship among some components of social capital and innovation. Yet some studies also present controversial results by finding non-significant, negative, diminishing returns and quadratic relationships. Building on the social network theory of innovation, this paper shows that the social capital-innovation relationship has an inverted U-shape. This 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 also has its limits.

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

Classification: Research Paper

JEL classifications: R58, R10, R11, R12

Limits of social capital as a driver of 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 SCHAIK, (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 SCHAIK, 2005a; BARRUTIA and ECHEBARRIA, 2010a). 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 may also exist inside these dimensions).

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; GITTELL 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 to the impact of the various

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2
3 dimensions of social capital on regional performance. In particular, great emphasis has
4
5 been placed on studying and discussing the diverse impact of bridging and bonding on
6
7 regional growth. On the contrary, there is a scarcity of empirical research to contrast the
8
9 social network theories of innovation at a regional level (as exceptions see HAUSER *et*
10
11 *al.*, 2007 and KAASA, 2009). In order to cover this research gap, greater emphasis is
12
13 needed on empirical studies of the relationship between social capital and innovation.
14
15 This is the main aim of this paper.
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19 Empirical studies of other analysis units (such as individuals, teams, business units,
20
21 organizations, small world, and cities and regions) have mostly shown that some
22
23 proxies of the various dimensions of social capital have a positive (and usually linear)
24
25 effect on innovation, as has been conceptually suggested (e.g. COOKE *et al.*, 2005;
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27 DAKHLI and CLERCQ, 2004; LANDRY *et al.*, 2002). Yet, some recent research has found
28
29 a non-significant (e.g. SMITH *et al.*, 2005) or even negative relationship (AHUJA, 2000).
30
31 It has likewise suggested that social capital has its limits and that the social capital-
32
33 innovation relationship might have a diminishing return shape (e.g. VANHAVERBEKE *et*
34
35 *al.*, 2002; MCFADYEN and CANNELLA, 2004) or an inverted U-shape (e.g. UZZI and
36
37 SPIRO, 2005; LEENDERS *et al.*, 2003). The main idea behind these findings is that
38
39 creating new relationships is costly and maintaining existing ties also consumes time,
40
41 energy and financial resources. As tie strength is increased, there is less time left to seek
42
43 out new resources that may lead to good ideas to fuel innovation (ZHENG, 2010). This
44
45 line of reasoning is consistent with the thinking of regional researchers who have
46
47 emphasized the relevance of weak ties for growth (SCHNEIDER *et al.*, 2000;
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49 BEUGELSDIJK and SMULDERS, 2003; FLORIDA, 2003) and have shown the limits of trust
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51 and strong ties.
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3 Building on the social network theory of innovation, this paper seeks to contribute
4 insights to this stream of research, by empirically testing the impact of social capital on
5 innovation in the context of NUTS1 European regions. Our results support the existence
6 of a significant direct and positive effect of social capital on patents (as a measure of the
7 innovation outcomes) up to a tipping point. The social capital-innovation relationship
8 therefore shows an inverted U-shape. This finding might be considered to be relatively
9 surprising, but is consistent with the aforementioned recent empirical research, which
10 was mainly carried out at non-geographical levels of analysis. It also suggests that some
11 sub-constructs of social capital, such as tie strength, involve maintenance and
12 opportunity costs, and that social capital has positive effects but also has its limits.

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

The paper is structured in seven sections. The second and third sections review main concepts and develop first hypotheses. The fourth section refers to empirical evidence regarding the social capital-innovation relationship at different units of analysis and provides additional hypotheses to be tested. The fifth section describes the model and the metrics used. The sixth section presents the results of the empirical analyses. The seventh section concludes with a discussion and avenues for further research.

2. Concepts of Social capital and Innovation

Social capital

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There is a variety of inter-related definitions of social capital (see e.g. LIN, 2001; ADLER and KWON, 2002; BORGATTI and FOSTER 2003 and ZHENG, 2010 for recent works from different focuses). A comprehensive social capital framework was proposed by NAHAPIET and GHOSHAL (1998). Their framework integrated various components of social capital into three dimensions: the structural dimension, the relational dimension and the cognitive dimension. The structural dimension refers to configurations and patterns of connections between people, addressing properties such as network density, connectivity and hierarchy. In the structural dimension, ZHENG (2010) identifies four major sub-constructs: network size (i.e. the total number of contacts an actor has in its network); structural holes (i.e. unique ties to other actors); tie strength (i.e. a combination of the amount of time, emotional intensity, intimacy and collaboration associated with the tie); and, centrality (i.e. large number of contacts, information and power). The structural dimension is closely related to the economic-driven tradition of social capital. From an economic-driven approach, some authors (e.g. BOURDIEU, 1980; COLEMAN, 1990; LIN, 2001; MCFADYEN and CANNELLA, 2004) refer to social capital as investment in social relations with expected returns in the marketplace. Within this approach, the Social Capital Interest Group at the University of Michigan (SCIG, 2001) defines social capital as the product of social relations, which depend on expectations of benefit arising from preferential treatment and co-operation between individuals and groups. This approach is mainly derived from rational choice theory and might not appropriately consider the embeddedness of people in their social context (RUTTEN and BOEKEMA, 2007).

The relational dimension of social capital incorporates the personal relationships that actors have with their contacts developed through past interactions. In the relational dimension, NAHAPIET and GHOSHAL (1998) includes the concepts of: trust (i.e. ‘a

1
2
3 predilection to assume the best when interpreting another's motives and actions', UZZI
4
5 1997, 43), norms (i.e. 'what most people do', CIALDINI *et al.*, 1990), obligations and
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7 expectations (i.e. commitment to undertaking some activities in the future). Major
8
9 concepts in this dimension are respect, friendship, trust, trustworthiness, expectations,
10
11 norms and obligations, and identification (i.e. sense of being part of a group of people).
12
13 The relational dimension of social capital is mainly related to the sociological tradition
14
15 and to the social network concept. From a sociologically driven approach, social capital
16
17 can be measured by the amount of trust and reciprocity in a community or between
18
19 individuals. PUTNAM *et al.* (1993) define social capital as those "features of social
20
21 organisation, such as trust, norms, and networks that can improve the efficiency of
22
23 society by facilitating coordinated actions" (p. 167). They focus on the collective value
24
25 of all social networks and the inclinations that arise from these networks to do things for
26
27 one other. Social capital–innovation research has mostly focused on trust and norms
28
29 (ZHENG, 2010). This research measures social capital by using a composite metric that
30
31 is mainly derived from the sociological tradition and that incorporates trust and, passive
32
33 and active group membership (BEUGELSDIJK and VAN SCHAİK, 2005a).

34
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36 The cognitive dimension of social capital implies shared language, codes, narratives and
37
38 interpretation. NAHAPIET and GHOSHAL (1998) state that this is the dimension that has
39
40 been least considered in social capital and is mainly relegated to the strategy domain.

41 42 43 44 45 46 47 48 **Innovation**

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50 In today's turbulent environment, all organizations are concerned with demands for
51
52 change -both radical and incremental change (DASGUPTA and GUPTA, 2009). Innovation
53
54 is a main target of organizations, countries and regions. As DAVILA *et al.* (2006) suggest
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56 that "companies cannot grow through cost reduction and reengineering
57
58 alone...Innovation is the key element in providing aggressive top-line growth, and for
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3 increasing bottom-line results” (p. 6). Innovation is likewise considered a main driver of
4
5 growth in countries and regions. Recognising the benefits of R&D for growth and
6
7 aware of the rapidly widening gap between Europe’s R&D effort and that of the
8
9 principal partners of the EU in the world, the Barcelona European Council (March
10
11 2003) set the EU a target of increasing R&D expenditure to 3 per cent of GDP by 2010,
12
13 two-thirds of which should come from the business enterprise sector.
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17 Consequently, innovation is a concept studied in various disciplinary contexts and the
18
19 literature, therefore, contains a wide range of approaches to conceptualizing innovation
20
21 (BROWN & ULIJN, 2004). DASGUPTA and GUPTA, 2009 state that “Innovation is
22
23 typically understood as the successful introduction of something new and useful, for
24
25 example, introducing new methods, techniques, practices, or new or altered products
26
27 and services” (p.205).
28
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30
31 Knowledge is a main component in many definitions of innovation. For instance,
32
33 PORTER and STERN (1999) define innovation as ‘the transformation of knowledge into
34
35 new products, processes, and services’ (p. 12). And LUECKE and KATZ (2003) refer to
36
37 innovation as the successful introduction of a new thing or method and the embodiment,
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39 combination, or synthesis of knowledge in original, relevant, valued new products,
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41 processes, or services. DASGUPTA and GUPTA and (2009) suggest that sustainable
42
43 innovation which leads to competitive advantage requires a systemic and effective
44
45 management approach based on knowledge and learning. The ability to absorb and
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47 integrate newly acquired knowledge with existing knowledge leads to the creation of
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49 new knowledge and is the key to improvement and innovation. Knowledge creation is
50
51 an essential part of innovation as any new processes, products and services originate
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53 from new ideas. Scope of innovation is relatively constrained in this study. We refer to
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55 patentable innovations.
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3. 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. In this research, R&D expenditure is viewed as an investment in absorptive capacity (COHEN and LEVINTHAL, 1990) and as a way of obtaining innovation outcomes. As COHEN and LEVINTHAL (1990) put it, previous R&D effort generates related knowledge that 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. GIULIANI (2005) suggests that the actors (a skilled worker, a firm, a cluster of a region) need to continuously performs highly innovative R&D in order to achieve an advance level of absorptive capacity.

So we propose:

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

Social capital

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3 Social capital is a recent yet significant addition to the list of innovation-inducing
4 factors (ZHENG, 2010). Social network theories also echo that the focus of innovation is
5
6 no longer the individual or the firm, but the network in which a firm is embedded,
7
8 which shifts attention to social capital (POWELL, *et al.*, 1996). Knowledge is viewed as
9
10 an intrinsic part of the surrounding social, political and economic context, and
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12 knowledge creation occurs through the integration of resources (COLLINSON, 2000;
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14 BARRUTIA and ECHEBARRIA, 2007, 2011). Knowledge is here embodied in networks
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16 and communities, and social capital becomes an essential ingredient for understanding
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18 innovation. Therefore, a high level of social capital is viewed as having a positive effect
19
20 on regional innovation (STORPER, 1995). It has been argued that social capital prompts
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22 the efficiency and effectiveness of the innovation process. According to MASKELL
23
24 (2001), social capital helps reduce malfeasance, induces the volunteering of reliable
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26 information, causes agreements to be honoured, enables employees to share tacit
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28 information, and places negotiators on the same wavelength. Efficiency, then, is mainly
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30 improved by reducing transaction costs (between firms, and between firms and other
31
32 actors) and the costs of managing the innovation process. Greater effectiveness is
33
34 achieved as a greater (suitable and reliable) quantity and quality of knowledge is
35
36 accessed. Knowledge can more easily be transferred and utilised within a community
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38 made up of firms that understand the same language and share norms and codes
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40 (MASKELL, 2001). On the contrary, a low level of social capital implies lack of
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42 coordination, duplications of effort, and costly contractual dispute (FOUNTAIN and
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44 ATKINSON, 1998).
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54 Regional literature has singularly focused on social capital, although some authors have
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56 also recently suggested that the importance of local networks should not be overstated
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58 (WATERS and SMITH, 2008). Regional economies are viewed as synergy-laden systems
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3 of physical and relational assets (SCOTT and STORPER, 2003). As such, regions are an
4 essential dimension of the innovation process. The spatial proximity of large numbers of
5 firms locked into dense networks of interaction provides the essential conditions for
6 many-sided exchanges of information to occur (SCOTT and STORPER, 2003).
7
8 Furthermore, firms come together in both formal and informal organisations that help to
9 streamline their interactions and accelerate information transfers, to build trust and
10 reputation effects, and to promote their joint interests (BECATTINI, 1990; ASHEIM, 2000;
11 DE PROPRIIS, 2005; ECHEBARRIA *et al.* 2009) inside regional (eco)-systems of innovation
12 (HAMDOUCH and MOULAERT, 2006). Literature shows that social capital and learning
13 have a positive relationship as social capital directly affects the combine-and-exchange
14 process and provides relatively easy access to network resources (NAHAPIET and
15 GHOSHAL, 1998; MCFADYEN and CANNELLA 2004). In the regional arena, regional
16 social capital is viewed as a driver and catalyst of knowledge creation and
17 dissemination. In terms of the influential distinction of POLANYI (1967), knowledge
18 may be tacit and codified. Polanyi's main argument is that the more tacit the
19 knowledge, the harder it is to actually transfer. Codified knowledge is easily
20 transferable in information and can be transmitted through information technologies and
21 infrastructures over long distances and across organisational boundaries. Tacit
22 knowledge, however, cannot be easily transferred as it has not been stated in an explicit
23 form and its transfer is extremely sensitive to social context. Therefore, it is commonly
24 argued that the transfer of tacit knowledge within a region requires face-to-face contact
25 and social capital (SCOTT and STORPER, 2003).

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Previous literature suggests that social capital and intellectual capital are
complementary and it is the co-evolution of social capital and intellectual capital that
underpins organizational advantage. Social capital helps obtain new intellectual capital

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3 and, at the same time, intellectual capital forms the basis from which social system and
4 interactions are formed and takes advantage of social capital (ADLER and KWON 2002;
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6 NAHAPIET and GHOSHAL 1998).
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10 So we propose:

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12 H2: The higher the social capital, the more successful the innovation outcomes
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14 will be.
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17 **Knowledge and learning**

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19 A key new insight into social network theories is that knowledge plays an increasingly
20 more crucial role in fostering innovation (LANDRY *et al.*, 2002). Previous literature
21 indicates that the availability of knowledge is a key explanatory variable in innovation
22 and, consequently, in the success of a company or a geographical space (see e.g.
23
24 ROMER, 1986, 1990; JOHANSEN *et al.*, 2001; BARRUTIA and ECHEBARRIA, 2010b). The
25 underlying idea is that knowledge plays an increasingly crucial role in prompting
26 innovation, due to: (1) the continuous expansion of the amount of technical knowledge
27 accumulated over time, and (2) the use of communication technologies that mean
28 knowledge is available on a worldwide scale very rapidly (LANDRY *et al.*, 2002).
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32 Yet knowledge is a non-rival (several people can use it at the same time) and, in the
33 medium/long run, a non-excludable good (EDWARDS, 2007). This is why learning-
34 economy scholars focus on learning. They affirm that it is the capacity to learn
35 continuously that determines success (LUNDVALL, 1992, 1996). Previous knowledge
36 matters, as a key input in producing current knowledge is past knowledge (ROMER,
37
38 1986, 1990; COHEN and LEVINTHAL, 1990). From an isolated perspective, the
39 knowledge and learning capability of a social entity, be it individual, team, organization
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41 or a geographical area, is referred to as intellectual capital (NAHAPIET and GHOSHAL,
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3 1998). NONAKA (1994) suggests that organizations that are able to stimulate and
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5 improve the knowledge of their employees are in a better position to innovate.
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8 So, we propose:

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10 H3: The higher the intellectual capital, the more successful the innovation
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12 outcomes will be.
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15 **Social capital-intellectual capital interaction**

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17 Social capital and intellectual capital has been treated largely as independent predictors
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19 in social capital-innovation studies (MCFADYEN and CANNELLA, 2004; SMITH *et al.*,
20
21 2005). Nevertheless, recent studies have suggested an interaction effect (ZHENG, 2010).
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23 For instance, with regard to structural holes, knowledge workers' diversity of
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25 knowledge and experiences might compensate for the lack of information diversity that
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27 comes from a lack of structural holes. In the same line, VANHAVERBEKE *et al.* (2002)'s
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29 study suggests that the existing technological capital of a firm interacts with a
30
31 dimension of social capital (its network size) in influencing innovation. In PERRY-
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33 SMITH's (2006) study, where non-redundancy and background heterogeneity are
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35 modelled together, non-redundancy turns out to be non-significant. ZHENG (2010)
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37 suggests that future studies need to fill in the empirical gap in verifying this claim in
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39 innovation research.
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45 So we propose:

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47 H4: The higher the interaction social capital-intellectual capital effect, the more
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49 successful the innovation outcomes will be.
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53 **Knowledge spillovers**

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55 European patents show spatial autocorrelation (MORENO *et al.*, 2005). According to
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57 BOTTAZZI and PERI (2003), spatial autocorrelation may be a result of local diffusion of
58
59 non-codified knowledge, embodied in people and spreading via personal contacts (i.e.
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3 knowledge spillovers). This concept of knowledge spillovers is consistent with recent
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5 approaches that focus on interaction and knowledge, such as buzz, learning regions and
6
7 regional learning. STORPER and VENABLES (2004)'s concept of buzz focuses on non-
8
9 codified knowledge. They suggest that transmission of non-codified knowledge is
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11 dramatically favoured by face-to-face contacts and hence embedded in space. The
12
13 concept of learning regions (MORGAN 1997; COOKE and MORGAN, 2000; HASSINK and
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15 LAGENDIJK, 2001; COOKE, 2002) refers to networks driven by policy-making that serve
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17 as regional development tools, in which, according to HASSINK (2005): (1) the main
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19 actors are strongly but flexibly connected with each other and (2) are open to both
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21 intraregional and interregional learning processes. Regional learning refers to more
22
23 spontaneous cooperation between actors in a region through which they learn
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25 (BOEKEMA *et al.* 2000). The potential to reap knowledge spillovers will thus be
26
27 maximised within a region. Nevertheless, some of all this knowledge will spill over
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29 neighbouring regions.
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36 Recent research has focused on the effect of knowledge spillovers between European
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38 regions. Results show that knowledge spillovers seem to exist, but decay with distance.
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40 Thus BOTTAZZI and PERI (2003) analyze 86 European regions between 1977 and 1995
41
42 and find a small but statistically significant influence over a distance of 300 km from
43
44 the source region. A similar analysis is performed by MORENO *et al.* (2005) who
45
46 investigate the innovation outcomes of 175 regions in the EU from 1978 to 2001. They
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48 find a significant influence only if the source is no further than 250 km. RODRIGUEZ-
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50 POSE and CRESCENZI (2008) likewise study EU-25 regions in the 1995-2003 period and
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52 find significant effects of knowledge spillovers on growth to time distances of 180
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54 minutes (200-350 km driving).
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59 So we propose:
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3 H5: The higher the intellectual capital of the neighbouring regions of a specific
4
5 region, the more successful the innovation outcomes of this region will be.
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8 **4. Empirical research about social capital and innovation**

9

10 Studies that address the effect of the different dimensions of social capital and
11 innovation have, in general terms, supported a positive relationship between social
12 capital and innovation, but conflicting evidence has also been found. ZHENG (2010)
13 argues that network size affects innovation by the availability of a large and probably
14 diverse volume of information and resources. It helps the formation of new ideas and
15 the potential availability of innovation resources. Empirical research regarding network
16 size has led to some controversial results. Network size has shown a linear positive
17 impact on innovation at an organizational level (SHAN *et al.*, 1994; SMITH *et al.*, 2005).
18 However, VANHAVERBEKE *et al.* (2002) find a quadratic relationship between a firm's
19 technological alliances and its innovation outcomes. They attribute the diminishing
20 returns to saturation and overembeddedness. At an individual level, MCFADYEN and
21 CANNELLA's (2004) study model finds a diminishing returns relationship between
22 network size and innovation. Their findings suggest that, when a biomedical
23 researcher's co-authors exceed 93 (over the previous five years), they are likely to see a
24 negative return on their publications if they continue to expand their networks. They
25 attribute this diminishing benefit of network size to a potential opportunity cost
26 associated with maintaining and expanding an actor's social network, such as time,
27 money and energy.
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52 The effect of structural holes is to provide exposure to information and power and
53 influence on the actor (ZHENG, 2010). Impact of structural holes (bridging) have also
54 led to some controversial results. At an organizational level, some research work has
55 obtained positive results (HARGADON and SUTTON, 1997; BARRUTIA and ECHEBARRIA,
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3 2007). On the contrary, SMITH *et al.* (2005) find a non-significant relationship and
4
5 AHUJA (2000) obtains a negative effect. Interestingly, UZZI and SPIRO (2005) study the
6
7 Broadway musical industry and find an inverted U-shape relationship. At a regional
8
9 level, FLEMING and MARX (2006) find a positive relationship between increasing
10
11 bridging ties and patents. Likewise at a city level, FLORIDA *et al.* (2002) find a positive
12
13 relationship between weak social ties and innovative activity. In their study, cities are
14
15 compared based on their tolerance towards gays and bohemians (a proxy for structural
16
17 holes and sparse network), and cities that ranked high on these two indexes are found to
18
19 also rank high on innovative activities. Based upon focus group work, FLORIDA (2003)
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21 suggests that the 'creative class' (i.e. people engaged in work whose function is to
22
23 'create meaningful new forms') prefers weak ties. Participants acknowledge the
24
25 importance of community, but they preferred 'quasi-anonymity'. He concludes that
26
27 social structures that historically embraced closeness may now appear restricting and
28
29 invasive and that where strong ties among people were once important, weak ties are
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31 now more effective. Likewise, HAUSER *et al.* (2007) find that the impact of social
32
33 capital on regional innovation processes is significant. However, they also find that not
34
35 all dimensions of social capital exhibit the same explanatory power. Specifically, the
36
37 'associational activity' dimension represents the strongest driving force for patenting
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39 activity. They conclude that their finding contributes empirical evidence for the
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41 significance of weak ties in innovative processes.

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43 Overall, tie strength has also shown a positive impact on innovation at an organizational
44
45 level (ROWLEY *et al.*, 2000; DAKHLI and CLERCQ, 2004; SMITH *et al.*, 2005). Strong ties
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47 have a positive influence on innovation by helping to establish trust and cohesion inside
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49 the network (ZHENG, 2010). Nevertheless non-significant, diminishing and inverted U-
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51 shape results have also been obtained. Interestingly, LANDRY *et al.* (2002) find a non-
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3 significant impact of tie strength with radicalness of innovation. And, LENDERS *et al.*
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5 (2003) and MCFADYEN and CANNELLA (2004)'s data draw a quadratic relationship at a
6
7 team and individual level respectively. MCFADYEN and CANNELLA (2004) suggest that
8
9 peak knowledge creation for biomedical researchers occurs with about 1.56
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11 collaborations with the same co-author over a five-year period. More interactions seem
12
13 to bring diminishing benefits. These results are due to the fact that tie strength involves
14
15 maintenance and opportunity costs. LEENDERS *et al.* (2003) also found an inverted U-
16
17 shape of the relationship between tie strength inside a team and team creativity. They
18
19 suggest that a very low or very high level of interaction frequency impedes team
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21 creativity, while creativity is the highest when interaction frequency is moderate .
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27 Overall, trust is shown to be a contributing factor to innovation. It has shown a positive
28
29 impact on innovation at an organizational level (DAKHILI and de CLERCQ, 2004;
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31 LANDRY *et al.*, 2002; LEE and CHOI, 2003; COOKE *et al.*, 2005), and at a business unit
32
33 level (TSAI and GHOSAL, 1998). For instance, COOKE *et al.* (2005) find that innovative
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35 firms tend to make greater use of collaboration and information exchange, to be
36
37 involved in higher trust relationships, and to make greater use of non-local networks.
38
39 DAKHLI and CLERCQ (2004)'s research find positive effect of trust and associational
40
41 activity on innovation. However, in their study regarding European regions, HAUSER *et*
42
43 *al.* (2007) interestingly find a non-significant relationship between trust and patents.
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45 Norms have also shown a positive relationship with innovation outcomes at an
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47 organizational level (DAKHILI and CLERCQ, 2004; SMITH *et al.*, 2005).
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53 The results of these investigations link with the interesting debate that is taking place
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55 within regional literature (and other related fields) around the impact of tie strength in
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57 regional GDP, i.e. bonding (exclusive, closed social capital with strong ties) and
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59 bridging (inclusive, open social capital characterised by weak ties) (GITELL and VIDAL,
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3 1998; PUTNAM, 2000). Bonding social capital is linked to family or primary friendship
4 relationships. Bridging social capital is linked with weak ties and can be generalised to
5
6 people who are strangers. ZHENG (2010) echoes the bonding vs. bridging debate,
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8 suggesting that tie strength involves maintenance costs, and so a quadratic or
9
10 diminishing returns relationship between tie strength and innovation is worth further
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12 attention.
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17 So we propose three H2 variants:
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20 H2a: The social capital-innovation relationship will be direct, linear and positive.
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23 H2b: The social capital-innovation relationship will be direct, positive and with
24
25 diminishing returns.
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28 H2c: The social capital-innovation relationship will be direct and have an inverted
29
30 U-shape.
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32 **5. Data and metrics**

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34 The main objective of this research is to empirically validate social network theories of
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36 innovation in the context of the European regions, by focusing on social capital, R&D
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38 effort and knowledge spillovers as the main drivers of innovation. The variable
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40 'presence of hi-tech sectors' is also considered as a control variable. Table 1 includes a
41
42 summarized description of the variables used in this research.
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45
46 (Insert Table 1)
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49 Variable 'R&D expenditure in Purchasing Power Standards (PPS) as a percentage of
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51 GDP' is proposed to proxy learning effort and absorptive capacity. The underlying
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53 concept, which is sometimes misunderstood, "comprises creative work undertaken on a
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55 systematic basis in order to increase the stock of knowledge, including knowledge of
56
57 man [sic], culture and society and the use of this stock of knowledge to devise new
58
59 applications" (OECD, 2002, p.63). This is a simple and robust metric, which measures
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3 the relative real effort in terms of actual cost expended for the generation of new
4 marketable knowledge or learning. Furthermore, it is a structural metric that, within the
5 European context, moves slowly and with a generally upward trend and, therefore,
6 makes it possible to proxy the knowledge that has accumulated within a particular
7 geographical area and its absorptive capacity.

8
9
10 There is no consensus on how to measure social capital. Previous literature has
11 concentrated on describing the concept of social capital and its implications. Following
12 a sociologically driven approach, and using data from the European Value Studies
13 (EVS) (see www.europeanvalues.nl), a regional measure of social capital has been
14 proposed: the BEUGELSDIJK and VAN SCHAİK (2005a)'s social capital index, which uses
15 the Eurostat NUTS1 definition of regions. These authors' index considers indicators of
16 trust, and active and passive group membership (respondents who are members of a
17 particular association but do not perform voluntary work for that body).

18
19
20 An experience-related variable is used to proxy intellectual capital: the stock of human
21 resources in science and technology as a percentage of the population in the age group
22 25-64. As was suggested by NONAKA (1994), after studying innovation at an
23 organizations level, what matters is the practice, the doing, the embodiment of
24 knowledge. He suggests that the creation of organizational knowledge begins with
25 subjective tacit knowledge, that flow of information which individuals have created and
26 proven in their own committed, effective, embodied actions.

27
28
29 To measure knowledge spillovers, the longitude and latitude of the centroid of each
30 region is incorporated into the dataset and a matrix generated based on the Euclidean
31 distances between regions. Median and maximum distances are respectively 9.5 and
32 39.4. A threshold distance of 3 is then defined, such that pairs with distances less than 3
33 are considered as neighbours and pairs with distances greater than 3 are not. This

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3 threshold distance is consistent with the results of previous research that limits the effect
4 of knowledge spillovers to neighbouring regions. On the basis of the Euclidian distances
5 between regions, knowledge spillovers are calculated as explained in Table 1.
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10 The outcome variable considered is the number of patent applications to the European
11 Patent Office (EPO) per million inhabitants. Eurostat summarizes the main weaknesses
12 that are usually attributed to this metric: (1) not all inventions are patented and not all
13 patents have the same value; (2) the value distribution of patents is skewed as many
14 patents have no industrial application; (3) inventions that are protected by other means
15 or inventions, whose value does not warrant the costs of patenting, are not patented; (4)
16 the propensity to patent differs across countries and industries; and (5) changes in patent
17 law and regulations result in lower comparability over time. Despite these limitations
18 the number of patent applications is the best metric available to measure innovation as
19 has been suggested by GRILICHES (1995) and TRAJTENBERG (1990), among others.
20 Specifically, the number of patents seems to be a good proxy for measuring the most
21 relevant innovation outcomes, as it includes the most radical and long term profit-
22 impacting innovations (i.e. innovations that are new to the firm and the world). Most
23 investigations use the number of patents granted as the innovation outcome (see for
24 example, SHAN *et al.*, 1994; AHUJA, 2000; VANHAVERBEKE, *et al.*, 2002). Previous
25 literature suggests that the propensity to patent depends on the sector. For instance,
26 ARUNDEL and KABLA (1998) found that 80% of innovations were patented in the
27 pharmaceutical sector while the figure for the textile sector only stands at 8%.
28 Therefore, the presence of Hi-tech sectors in the region is included as a control variable.
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58 **6. Models to be tested and Empirical Results**

59 **Models**

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Empirical models include the factors that may affect patents for region in five categories as explanatory variables: (1) R&D on PPS as a percentage of GDP (R&D_i); (2) Social Capital (in advance, SC_i); (3) Intellectual Capital (IC_i); (4) Knowledge spillovers (KS_i); and (5) High-Tech sectors presence (H-T_i). The outcome variable is patents per million of inhabitants (P_i). Models to be tested are:

(1) Linear model:

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

(2) Diminishing returns model:

$$P_i = \alpha + \beta_1 R\&D_i + \beta_2 [(SC_i)^{1/2} \text{ or } \log(SC_i)] + \beta_3 IC_i + \beta_4 H-T_i + \beta_5 (SC_i * IC_i) + \beta_6 KS_i + \varepsilon_i$$

(3) Inverted U-shape model:

$$P_i = \alpha + \beta_1 R\&D_i + \beta_2 SC_i + \beta_3 (SC_i)^2 + \beta_4 IC_i + \beta_5 H-T_i + \beta_6 (SC_i * IC_i) + \beta_7 KS_i + \varepsilon_i$$

Empirical Results

The Stata 10 statistical software was used to analyse the data. Preliminary analysis identified a high correlation between the 'human resources in science and technology' variable and the Hi-tech sectors presence control variable (0.623), that indicated possible problems when being used together in regression. Other variables showed also high correlation (see table 2). Additionally, we checked for normality and linearity and appreciated that social capital-patents relationship seemed to be non-linear. So, it seemed obviously appropriate to test for diminishing returns or an inverted U-shape relationship.

(Insert Table 2)

After preliminary regressions were developed, the Breusch-Pagan/Cook-Weisberg test for heteroscedasticity showed lack of homocedasticity (chi2 (1) = 34.36, Prob.>chi2 = 0.0000). This diagnostic was confirmed after plotting the residuals versus the fitted (predicted) values. Consequently, we used robust regressions and report robust standard

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3 errors (Huber-White sandwich estimators). Such robust standard errors can deal with
4 concerns about failure to meet regression assumptions, such as heteroscedasticity, or
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6 some observations that exhibit large residuals, leverage or influence (CHEN *et al.*, 2009).
7
8 Five observations may be considered as outliers or influential observations.
9
10 Specifically, the regions of Baden-Wurttemberg, Bayern and Zuid Nederland produced
11
12 524, 410 and 612 patents per million of inhabitants, respectively, being the mean of
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14 patents 120 and the standard deviation 122. On the other hand, the regions of Oost
15
16 Nederland and West Nederland presented a social capital index of 100 and 91,
17
18 respectively, with the mean of the index 36 and the standard deviation 19. We tested
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20 hypothesis 1 to 6 by using 54 and 49 observations respectively. The three different
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22 models proposed above were tested. Two variants of the diminishing return model were
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24 tested. One of them considered a log transformation of social capital and the other a
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26 square root transformation.
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34 (Insert Table 3)

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36 The main results are reported in Tables 3, 4 and 5. In Table 3, Specifications 1 to 8
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38 compare the three baseline models (which include R&D and social capital as dependent
39
40 variables) and show that the inverted U-shape model obtains the best results by using 54
41
42 and 49 regions respectively. The model and the social capital and R&D expenses
43
44 variables are highly significant, and the adjusted R-square is the largest of the three
45
46 models (0.4209 and 0.4081 with 49 and 54 observations respectively). Conclusions are
47
48 similar whether or not 54 regions are used. However, the coefficients and the tipping
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50 point are clearly affected by the presence of these singular observations (see Table 3 and
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52 Figures 1 and 2).
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57 (Insert Figures 1 and 2)

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3 In Table 4, Specifications 1 to 13 include the results obtained after incorporating the
4 remaining variables to the diminishing return and the inverted U-shape models. Both
5 models are tested as the difference is small in the adjusted R-square between them in the
6 baseline specifications. The square root transformation of social capital is used as it
7 offers better results than the log transformation in the baseline model. 49 observations
8 are considered.
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17 (Insert Tables 4 and 5)
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19 After including the remaining variables, results confirm that the best model is the
20 inverted U-shape model. The adjusted R-square is higher in the U-shape models than in
21 the diminishing return models and the social capital variable and its transformation,
22 square social capital, are consistently significant at a 5% level. On the contrary, the
23 behaviour of the variable square root of social capital, included in the diminishing
24 return model, is less consistent. The inverted U-shaped relationship between social
25 capital and the outcome variable is robust with respect to the inclusion/exclusion of
26 other variables.
27

28 Specifications 1 and 2 show that intellectual capital seems to add new and useful
29 information. This variable is significant at a 5% level and its incorporation improves the
30 adjusted R-square. On the contrary, Specifications 3 and 4 show that the variable
31 created to incorporate the effect of the 'social capital-intellectual capital interaction' is
32 not significant and does not improve the predictive power of the model. Specifications 5
33 and 6 incorporate the control variable, employees of hi-tech sectors. This variable
34 slightly improves the adjusted R-square. However, intellectual capital and employees on
35 hi-tech sectors are non significant in these specifications.
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37 In the remaining specifications, the behaviour of R&D is robust. However, intellectual
38 capital is not significant when the variable knowledge spillovers and intellectual capital
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3 are jointly considered in the regression. Table 5 shows the variance inflation factor
4 (VIF) of the variables considered in the 13 specifications presented in Table 4. After
5
6 including other variables, the intellectual capital VIFs range from 2.23 to 3.01.
7
8 Specifications 7 and 8 show the effect of the control variable, employees in hi-tech
9 sectors, when the variable intellectual capital is removed. This variable improves the
10 adjusted R-square slightly, but it is not significant.

11
12 We used the residuals of the regressions included in Specifications 1 to 13 to calculate
13 Moran's I (see Table 4). Moran's I is a traditional measure of spatial autocorrelation.
14
15 The results show that, prior to including the variable knowledge spillovers
16 (Specifications 1 to 8), we can not reject the null hypothesis that there is zero spatial
17 autocorrelation present in the residuals at alpha equal to 0.05. Specifications 9 to 13
18 include the results obtained after incorporating this variable. The proxy for knowledge
19 spillovers consistently improves the adjusted R-square, is significant, and eliminates the
20 residual spatial autocorrelation between neighbouring regions. The model included in
21 Specification 13 offers the largest adjusted R-square (0.4945) and its predictors are
22 significant. It is a parsimonious model in which the independent variables are the main
23 traditional predictor of patents (R&D effort), social capital and knowledge spillovers.
24 Table 4 also includes the tipping point in the different regressions. In Specification 13
25 the tipping point occurs at a social capital level of 38.84.

26
27 Therefore, hypotheses linked with the main research question of this investigation could
28 not be rejected. Social capital is shown consistently to have a significant effect on
29 patents. This effect has an inverted U-Shape (hypothesis 2c). Likewise, R&D effort and
30 knowledge spillovers are shown to be robust and relevant predictors of patents
31 (hypotheses 1 and 5). Yet, hypothesis regarding interaction effect have to be rejected
32 (hypothesis 4). Intellectual capital is also shown to have an impact on patents, but this
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3 variable shares information with other variables such as R&D, the control variable
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5 (employees on hi-tech sectors) and knowledge spillovers and its behaviour is shown to
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7 be less robust (hypothesis 3). A main component of R&D expenses is the R&D
8
9 remuneration of employees that work in R&D activities (i.e. R&D expenses incorporate
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11 information regarding intellectual capital). As we consider knowledge spillovers to be a
12
13 result of people interactions (mainly R&D employees), the intellectual capital of the
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15 neighbouring regions is used to proxy knowledge spillovers.
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22 **7. Final Discussion and conclusions**

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24 The main research question refers to the relationship between social capital and
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26 innovation outcomes. A sociologically-driven metric is used to measure social capital
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28 and empirically contrast the impact of social capital on innovation outcomes. It
29
30 indicates predictive validity to explain innovation outcomes. But the research results
31
32 also show that social capital has its limits. Specifically, the social capital-innovation
33
34 relationship in the context of NUTS1 European regions is seen to have an inverted U-
35
36 shape. This finding might be considered as relatively surprising, but is consistent with
37
38 recent empirical research carried out mainly at non-geographical levels of analysis.
39
40 This suggests that some sub-constructs of social capital, such as tie strength or trust,
41
42 involve maintenance and opportunity costs and that social capital has positive effects,
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44 but also has its limits. The underlying idea is that human relations are time consuming
45
46 and time is not an unlimited resource. If the priority is to build social capital, other
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48 targets could be neglected.
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55 These conclusions are also implicit in bridging-bonding debate in regional literature.
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57 The bridging-bonding debate focuses, in essence, on two ideas: (1) the cost and limits of
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59 bonding and, on the contrary, (2) 'the strength of weak ties' (GRANOVETTER, 1973) to
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3 prompt regional growth. SCHNEIDER *et al.*, (2000), when extending Putnam's research
4 to Europe, indicates that: in regions where horizontal social networks seem well
5 developed, (1) growth rates exceeding the average are experienced, and (2) trust in
6 compatriots does not seem to support economic performance. BEUGELSDIJK and
7 SMULDERS (2003) also show that bridging social capital is empirically good for growth,
8 while strong emphasis on family ties is negatively related to growth. Likewise,
9 SAFFORD (2009) highlights that the structure of social relationships facilitate
10 interaction—and mobilization—across social, political and economic divisions is more
11 important than network density. When studies more closely related to this research
12 (those using data from EVS) are analysed in detail, previous results can be seen to
13 likewise reveal some limitations of social capital as a predictor of growth and
14 innovation. Specifically, this research uses BEUGELSDIJK and VAN SCHAİK (2005a)'s
15 social capital index. They study the social capital-GDP relationship and find a
16 significant positive effect. Nevertheless, BEUGELSDIJK and VAN SCHAİK (2005b) use the
17 indicators integrated in its index separately in another study and find that although
18 active membership of associations implied an increase in GDP, trust and passive group
19 membership did not. HAUSER *et al.* (2007) likewise use different constructs to measure
20 social capital and only associational activity is shown to be a significant predictor of
21 innovation (at 0.5% level). Friendship ties and trust are not significant. Nevertheless,
22 these studies do not analyse (or at least do not report) an inverted U-shape relationship.
23
24 When jointly considered, the above arguments and findings suggest that when measures
25 are built on proxies related with strong ties and trust, the inverted U-shape seems to be
26 more appropriated than the linear relationship, particularly given the potential costs of
27 strengthening social ties. It seems reasonable to consider that the benefit of increasing
28 tie strength and trust initially grows as previously weak social ties are strengthened and
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3 the regional actors have easier access to resources and knowledge. However, the benefit
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5 does not go up indefinitely. A tipping point exists where there is nothing to gain from
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7 additional interaction with certain people or organizations. Furthermore, as tie strength
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9 is increased, there is less time left for other research activities and opportunity costs
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11 increase. Therefore, an inverted U-shape relationship seems to be more realistic
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13 modelling than a linear relationship.
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17 R&D effort is shown to be a relevant predictor of innovation outcomes. However,
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19 investment effort in R&D is not in itself enough to achieve innovation outcomes in
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21 regions with low levels of social capital. R&D input should be accompanied by an effort
22
23 to prompt social capital. Some Italian regions (such as Sicilia or Ambruzzo-Molise) are
24
25 good examples of the low impact of R&D investment input on innovation outcomes,
26
27 due to the almost or total absence of social capital. Likewise, emphasis on a step-by-
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29 step absorptive capacity might be considered as bad news for some EU politicians (and
30
31 also some countries and regions politicians) who searching for shortcuts in the race for
32
33 R&D expenditure. EU politicians should consider that even if the R&D spending levels
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35 of USA or Japan are achieved, that innovation outcomes may also be lower due to the
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37 absorptive capacity concept. In addition, excessive speed might run the risk of
38
39 precipitating wrong decisions. Investment rankings, which are very popular in political
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41 circles, should therefore be used with care. This research confirms the importance of
42
43 proximity for the transmission of knowledge. The results highlight that knowledge
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45 flowing from neighbouring regions improves regional innovation outcomes.
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49 The results of this research might be influenced by the use of NUTS1 level of
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51 aggregation. Results could be tighter at a lower degree of aggregation. NUTS1 seems to
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53 imply that there is a need to create some artificial debatable conglomerates. Moreover,
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55 average data could hide important disparities between NUTS2 regions. And, as
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3 explained by LORENZEN (2007), for instance, social capital seems to be formed on small
4 scales. Unfortunately, social capital data at a NUTS2 level are not available. The patents
5 granted in a region cover an important part of the whole innovation market-led effort
6 and the results of the region and propensity to patent are increasing. Nevertheless, we
7 are aware that some forms of innovation are not included in this research.

8
9
10 The index of social capital used in this research considers some components of social
11 capital. It is not a fully comprehensive measure of social capital as it does not include
12 all relational, structural and cognitive dimensions of social capital. Concrete proposals
13 to measure social capital from a multidimensional perspective are scarce. And when
14 these metrics have been developed, they have been based on the adaptation of secondary
15 sources (for instance, BJORNSKOV, 2006, uses the World Values Survey; BEUGELSDIJK
16 and VAN SCHAİK, 2005a, and HAUSER *et al.*, 2007, use the European Values Study and
17 KAASA, 2009, the database of the ESS-European Social Survey). An ad-hoc scale of
18 measurement should be developed in keeping with the academic concepts of social
19 capital. The comprehensive framework proposed by NAHAPIET and GHOSHAL (1998)
20 might be used as a theoretical foundation to develop the different constructs that make
21 up social capital and the set of items to measure them. Definitive conclusions regarding
22 the social capital-innovation relationship cannot be obtained until we have more
23 comprehensive and robust metrics.

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Figure 1. Patents vs. social capital (54 regions)

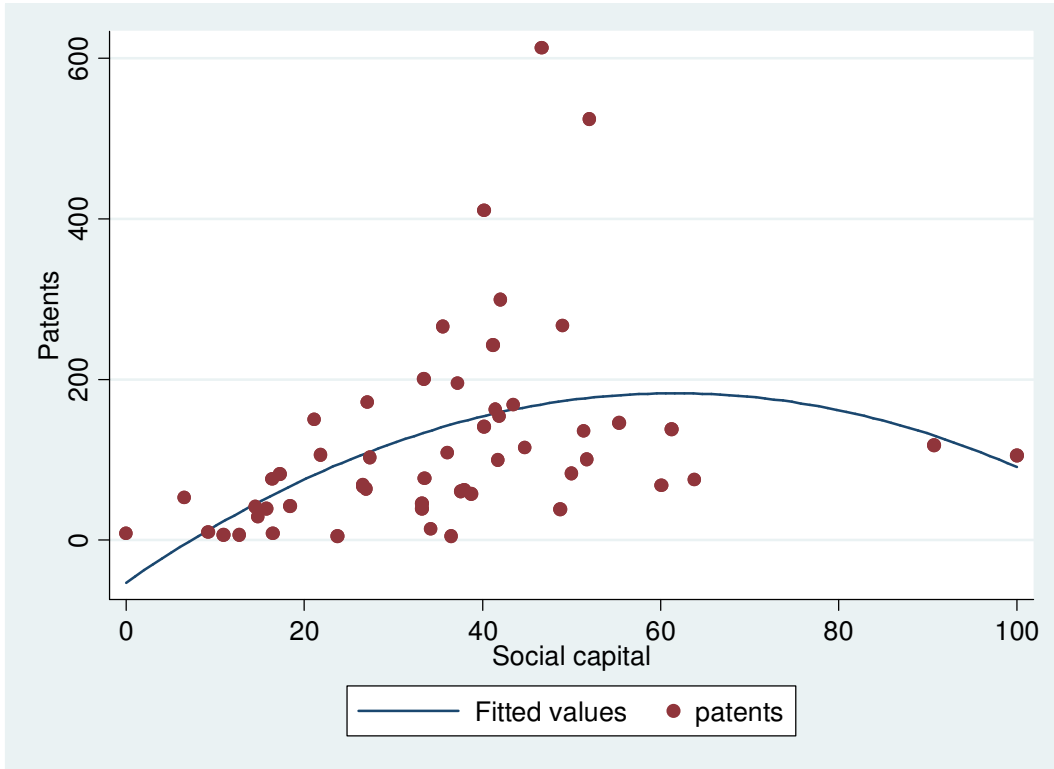


Figure 2. Patents vs. social capital (excluding influential observations)

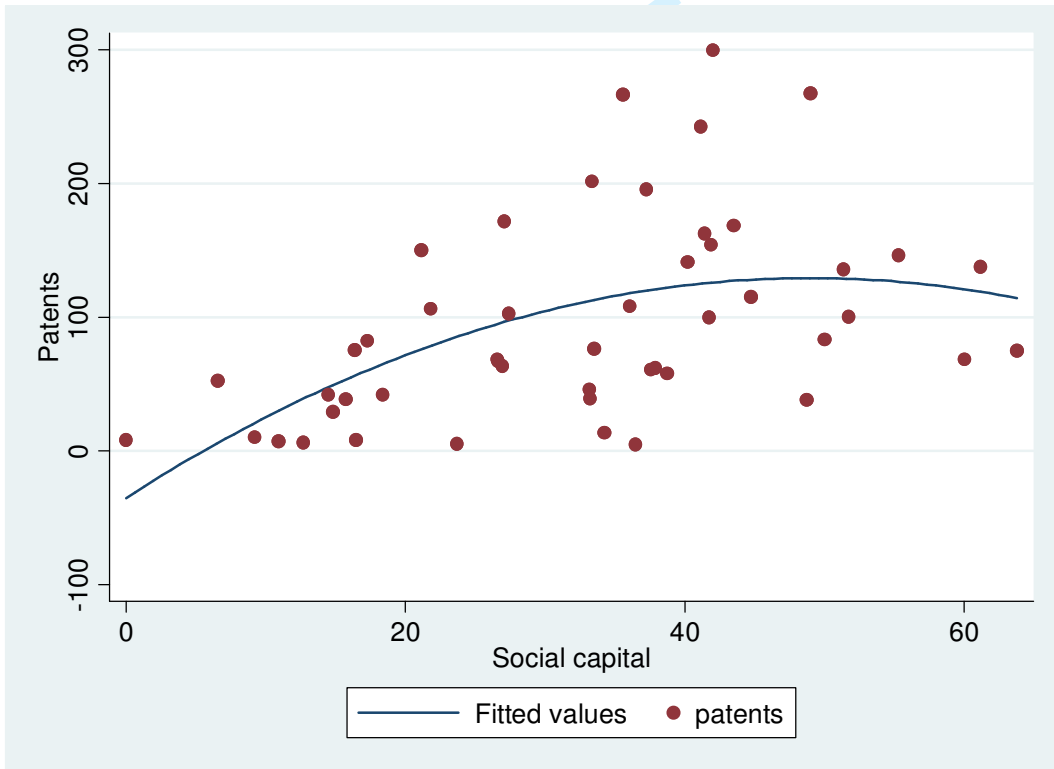


Table 1. Variable Coding in the Analysis

Concept	Variable	Description	Source
<i>Innovation Outcomes</i>			
Patents (P)	Number of patent applications to the European Patent Office (EPO) per million inhabitants	Includes 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)	R&D expenditure in Purchasing Power Standards as a percentage of GDP	Includes 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) (doing)	Human resources in science and technology (HRST) as a percentage of the population in the age group 25-64	A person is defined to be a member of HRST if s/he is employed in an science and technology (S&T) occupation for which education at the third level in a S&T field of study is normally required	European Union Labour Force Survey (LFS). Eurostat
Knowledge spillovers (SP _r)	Knowledge spillovers obtained from the neighbouring regions (Euclidean distance <= 3)	$SP_r = \sum_{j=1}^n \frac{1}{d_{rj}} \frac{1}{n} IC_j$ where: SP _r = knowledge spillover effect on region r; d _{rj} = Euclidean distance between r and j = square root of [(longitude _r - longitude _j) ² + (latitude _r - latitude _j) ²]; n = number of neighbouring regions; IC _j = % of employees on R&D in the region j	Calculated for this research

Table 2. Summary Statistics and correlations

	Obs.	Mean	Std. Dev.	Min.	Max	Correlations				
						Patents	R&D	H-T	IC	SP
Social Capital	54	35.90	18,93	0	100	0.330	0.373	0.284	0.546	0.417
Patents	54	119.9	121.9	4.83	524.6	1	0.642	0.482	0.515	0.501
R&D	54	1.64	0.88	0.52	3.96		1	0.692	0.646	0.303
Hi-Tech	54	4.44	1.43	1.73	7.75			1	0.623	0.366
Intel. Cap.	54	24.9	6.01	13.2	39				1	0.622
Spillovers	54	14.5	9.3	0	46.1					1

Regions: BE1 Bruxelles, BE2 Vlaanderen , BE3 Wallonie, DE1 Baden-Wurttemberg, DE2 Bayern, DE3 Berlin, DE5 Bremen, DE6 Hamburg, DE7 Hessen, DE9 Niedersachsen, DEA Nordrhein-Westfalen, DEB Rheinland-Pfalz, DEC Saarland, DEF Schleswig-Holstein, ES1 Noroeste, ES2 Noreste, ES3 Madrid, ES4 Centro, ES5 Este, ES6 Sur, ES7 Canarias, FR1 Ile-de-France, FR2 Bassin Parisien, FR3 Nord Pas de Calais, FR4 Est, FR5 Ouest, FR6 Sud-ouest, FR7 Centre-Est, FR8 Mediterranee, IT1 Nord Ovest, IT2 Lombardia, IT3 Nord Est, IT4 Emilia Romagna, IT5 Centro, IT6 Lazio, IT7 Ambruzzo-Molise, IT8 Campania, IT9 Sud, ITA Sicilia, ITB Sardegna, NL1 Noord Nederland, NL2 Oost Nederland, NL3 West Nederland, NL4 Zuid Nederland, UK1 North, UK2 Yorkshire and Humberside, UK3 East Midlands, UK4 East Anglia, UK5 South East, UK6 South West, UK7 West Midlands, UK8 North West, UK9 Wales, UKA Scotland.

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Table 3. Determinants of innovation: results of the baseline models*

Specification	(1) Linear	(2) Dimin. return (SC ^{1/2})	(3) Dimin. return (Log)	(4) Inverted U-shape	(5) Linear	(6) Dimin. return (SC ^{1/2})	(7) Dimin. return (Log)	(8) Inverted U-shape
Variables	Sample size = 54				Sample size = 49			
Social capital (SC)	0.104 (0.167)			0.531** (0.010)	0.233** (0.030)			0.911*** (0.006)
SC ²				-.433*** (0.008)				-.689** (0.027)
SC ^{1/2} (or Log)		0.121* (0.070)	0.126* (0.062)			0.251*** (0.009)	0.236** (0.015)	
R&D	0.602*** (0.000)	0.588*** (0.001)	0.589*** (0.001)	0.550*** (0.001)	0.517*** (0.000)	0.508*** (0.000)	0.522*** (0.000)	0.488*** (0.000)
Constant	-41.35 (0.111)	-88.64** (0.022)	-88.64** (0.015)	-79.67** (0.013)	-13.98 (0.377)	-41.95** (0.043)	-61.73** (0.038)	-54.17** (0.020)
F-statistic	11.34***	12.89***	13.31***	8.42***	17.94***	20.19***	18.83***	13.78***
R-squared	0.4217	0.4259	0.4255	0.4416	0.4259	0.4328	0.4282	0.4571
Adj. R-sq.	0.3990	0.4033	0.4030	0.4081	0.4010	0.4081	0.4033	0.4209
Mean VIF ¹	1.16	1.21	1.20	6.99	1.23	1.23	1.23	10.99
SC VIF (SC ^{1/2} /Log)	1.16	1.21	1.20	10.27	1.23	1.23	1.23	16.22
SC ² VIF				9.41				15.49
R&D VIF	1.16	1.21	1.20	1.30	1.23	1.23	1.23	1.25
Turning point				58.07				44.62
Conf. Int.				(28.4, 87.7)				(31.7, 57.6)
*Standardized coefficients (beta) are reported for variables; p values are reported in brackets (robust std. errors); *** significant at 1%; ** at 5%; *at 10%								
¹ VIF = Variance Inflation Factor								

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Specification	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Social capital (SC)		0.782 (0.021)		0.809 (0.017)		0.803 (0.023)		0.906 (0.009)		0.826 (0.026)		0.809 (0.023)	0.844 (0.014)
SC ²		-.634 (0.037)		-.644 (0.034)		-.640 (0.040)		-.682 (0.030)		-.711 (0.031)		-.709 (0.026)	-.734 (0.020)
SC ^{1/2}	0.170 (0.113)		0.190 (0.075)		0.181 (0.094)		0.246 (0.019)		0.141 (0.175)		0.130 (0.211)		
R&D	0.348 (0.008)	0.338 (0.010)	0.306 (0.022)	0.291 (0.029)	0.274 (0.064)	0.252 (0.085)	0.358 (0.013)	0.331 (0.020)	0.337 (0.022)	0.322 (0.026)	0.404 (0.001)	0.392 (0.001)	0.438 (0.000)
Employees on R&D (IC)	0.293 (0.043)	0.270 (0.050)	0.300 (0.037)	0.294 (0.037)	0.242 (0.107)	0.231 (0.113)			0.086 (0.603)	0.057 (0.712)	0.123 (0.463)	0.097 (0.546)	
Employees in High-tech sectors					0.154 (0.386)	0.162 (0.344)	0.227 (0.19)	0.233 (0.161)	0.133 (0.441)	0.137 (0.404)			
R&D* IC			0.064 (0.614)	0.062 (0.625)									
Knowledge spillovers									0.237 (0.062)	0.260 (0.039)	0.247 (0.047)	0.272 (0.027)	0.314 (0.006)
Constant	-89.31 (0.007)	-105.7 (0.004)	42.47 (0.154)	23.64 (0.403)	-100.6 (0.002)	-116.8 (0.003)	-70.75 (0.002)	-84.40 (0.004)	-73.16 (0.035)	-94.73 (0.025)	-62.23 (0.063)	-84.43 (0.030)	-68.75 (0.011)
F-statistic	15.99	11.76	11.97	9.49	13.82	11.05	16.65	10.45	11.95	10.31	15.99	10.66	13.00
R-squared	0.4756	0.4982	0.4785	0.5010	0.4875	0.5111	0.4612	0.4871	0.5195	0.5492	0.4756	0.5400	0.5366
Adj. R-squared	0.4406	0.4525	0.4311	0.4429	0.4409	0.4543	0.4253	0.4405	0.4636	0.4848	0.4406	0.4865	0.4945
Turning point		41.66		42.42		42.35		44.79		39.21		38.52	38.84
Confidence Int.		(29.2, 53.9)		(30.1 54.3)		(30.2, 54.4)		(26.6, 62.9)		(30.3, 48.1)		(29.1, 47.9)	(29.9, 47.7)
Moran's I	2.448 (0.007)	2.221 (0.013)	2.582 (0.005)	2.358 (0.001)	2.369 (0.009)	2.091 (0.018)	2.514 (0.006)	2.196 (0.014)	1.068 (0.143)	0.624 (0.266)	1.115 (0.132)	0.717 (0.237)	0.410 (0.341)
* n = 49; standardized coefficients (beta) are reported for variables; p values are reported in brackets (robust std. errors); variables R&D and IC were centered (specifications 3 and 4).													

Table 5. Variance inflation factors (VIF) of the specifications included in Table 4

Specification	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Mean VIF	1.74	8.90	1.85	7.58	1.98	7.68	1.69	8.89	2.13	6.87	1.98	7.69	8.47
SC VIF (or $SC^{1/2}$)	1.38	16.42	2.43	16.19	1.39	16.46	1.23	16.02	1.44	16.47	1.43	16.44	16.07
SC ² VIF	n.a.	15.35	n.a.	15.38	n.a.	15.35	n.a.	15.28	n.a.	15.48	n.a.	15.48	15.30
R&D VIF	1.83	1.84	2.02	2.44	2.30	2.33	1.82	2.07	2.42	2.45	1.92	1.93	1.28
IC VIF	2.01	2.00	1.52	2.02	2.23	2.23	n.a.	n.a.	2.99	3.01	2.83	2.85	n.a.
H-T VIF	n.a.	n.a.	n.a.	n.a.	2.02	2.03	1.82	1.82	2.03	2.04	n.a.	n.a.	n.a.
R&D*IC VIF	n.a.	n.a.	1.42	1.4	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Spillovers VIF	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1.76	1.78	1.75	1.77	1.24