DOES SOCIAL AND HUMAN CAPITAL REINFORCE EACH OTHER IN THE CREATION OF KNOWLEDGE? EVIDENCE FROM SPANISH REGIONS

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Abstract

In this paper we check the hypothesis that trust and cooperation between individuals and between them and public institutions may encourage technological innovation and adoption of knowledge. Indeed, people within a trusting society, with vast social networks, and with certain values and civic norms, will share easily information and knowledge with others. Additionally, we will test to what extent the interaction of social capital with human capital and R&D expenditures improves their lonely effect on regional innovation capability. The theoretical underlying hypothesis on this complementarity sets up that innovation inputs such as human capital and innovative efforts could see their influence in the innovation capability reinforced in societies with a high degree of trust and a great spread of social networks. The empirical evidence is given for the Spanish regions through the use of a knowledge production function and longitudinal count data models.

Key words: social capital, human capital, innovation, complementarities

JEL: C21, J24, O33, R11

1. Introduction

According to the Lisbon Strategy launched by the EU members in 2000, Europe has to be “the most dynamic and competitive knowledge-based economy in the world capable of sustainable economic growth with more and better jobs and greater social cohesion by 2010”[1]. This strategy was leaned against innovation as a motor of economic growth and against the learning economy, to cope with the rise of the knowledge-based economy and the ongoing globalisation. In this framework, the study of the determinants of innovation capability of the European regions should be a central point on the empirical economic research in order to provide with suitable policy recommendations. Most literature on the determinants of innovation includes R&D efforts and human capital. Nevertheless, similar innovation technological input endowments have dissimilar results across regions, so there should be something that has not been deeply investigated. For instance, social networks, norms, and trust, in other words, social capital, could enable agents to be more effective in achieving common objectives.

AUDRESTCH (1998, p. 24) stressed that “political scientists and sociologists have long argued that the differences in the culture of a region contribute to differences in innovative performance across regions” which, in turn, is a chiefly force driving economic performance, even holding knowledge inputs such as R&D and human capital constant. And additionally, SAXENIAN (1990) pointed out that the communication between individuals facilitates the transmission of knowledge across agents, aside from high endowments of human capital and knowledge in a given economy.

The seminal work by PUTNAM *et al.* (1993) meant a turning point on the empirical work on social capital: “…social capital (…) refers to features of social organization, such as trust, norms, and networks that facilitate coordination and cooperation for mutual benefit within a society…”. Since then, several scholars have taken into account those social features in producing certain economic outcomes, such as productivity, economic growth, and institutional performance, among others (COLEMAN, 1988; PUTNAM *et al.*,

[1] http://ec.europa.eu/growthandjobs/faqs/background/index_en.htm

1993; HELLIWELL, 1996; KNACK and KEEFER, 1997; HELLIWELL and PUTNAM, 2000; ZAK and KNACK, 2001; SABATINI, 2005; BEUGELSDIJK and VAN SCHAIK, 2005).

In such a setting, the aim of this paper is to analyse the determinants of innovation within Spanish regional economies, focusing our attention in assessing to what extent certain social and cultural features may enhance innovation, and the ways by which it could take place. The idea of social features as cooperation, trust, civic behaviour, and so on, as a source of innovation and, in turn, as a source of competitiveness and growth, is not new. In fact, an important contribution was made by scholars within the marshallian industrial districts literature (BECATTINI, 1979; PORTER, 1990, and the like), whilst the regional and national innovation systems literature (LUNDVALL and JOHNSON, 1994; EDQUIST, 1997; PAVITT, 1998) has widely stressed the influence of external effects such as formal institutions and informal organizations and networks in the innovation processes of a given economy. Thus, most of the research carried out in this topic has approached, either theoretically or empirically, from a case study methodology (SAXENIAN, 1994), being the case study of the influence of social features on innovation in Silicon Valley (aside of the study of Italian and Spanish industrial districts) the most notorious one.

Within the empirical framework given by a knowledge production function (KPF), we test several hypotheses about the possible influence of social capital on innovation, measured by patent applications, in Spanish regions. First of all, we will check the hypothesis that the more the level of social capital, the more the innovation outcomes within a given economy. Moreover, we will test whether social capital exerts its influence on technological progress through certain complementarities with human capital and R&D efforts. Finally, according to some scholars (DURLAUF and FAFCHAMPS, 2004; LYON, 2005; AKÇOMAK and TER WEEL, 2007**;** PÉREZ *et al*., 2005) we follow the idea that the influence of social capital on economic outcomes and innovation is dissimilar concerning the level of development of each economy. So we will test the hypothesis that the ways by which social capital exerts its influence on innovation are different between high-income and low-income regions.

Our main results suggest that there exist an interesting and great enough direct impact of social capital on innovation outcomes, and also a strong effect of this asset through its interaction with other technological inputs such as R&D efforts and, particularly, human capital. Thus, the influence of human capital and R&D efforts on innovation is higher, the higher the level of social capital. Moreover, some additional interesting results arise from our empirical research, that is: there exists an influence of social capital on innovation within low-income Spanish regions directly and by means of enhancing high education R&D returns, but this is not the case within high-income regions. Indeed, within these regions, we have found a greater effect of social capital on innovation outcomes, and a strong complementarity of social capital with human capital –which does not have any influence separately within high-income regions- and with public administrations R&D effort. Hence, the effect of these expenditures on patent applications is larger the larger the amount of social capital of the region.

An additional contribution of this paper is the use of a complex and interesting databank on social capital created by IVIE. Thus, compared to other simpler measures hitherto considered in the literature on social capital, the measure used in this paper tries to overcome some of the empirical problems that commonly arise in this field of research due to an endemic lack of consensus on its definition and, therefore, a chronic deficit of suitable data.

The present paper is organized as follows. Section two reviews related literature on social capital and innovation, sets out the main hypothesis by which social capital and its interactions with other innovation inputs may foster knowledge creation, and presents our empirical model. Section three describes our database, providing some descriptive analysis. Section four highlights our results. Finally, section five concludes.

2. Related literature, theoretical hypothesis and empirical strategy

Social capital in fostering innovation

As COLEMAN (1988, p. 98) stressed, “social capital constitutes a particular kind of resource available to an actor”. Thus, “social capital is defined by its function. It is not a single entity but a variety of different entities, with two elements in common: they all consist of some aspect of social structures, and they facilitate certain actions of actors (…) within the (social) structure. Like other forms of capital, social capital is productive, making possible the achievement of certain ends that in its absence would not be possible." On his side, MASKELL (2000) added that social capital may encourage innovative activity of firms by reducing transaction costs, which have important implications for economic performance. Two ideas highlight from these contributions, that is, social capital allows the achievement of certain ends that in its absence would not be possible, and it does it by means of the reduction of transaction costs. In this framework, we presume that there should exist several ways whereby such social features –trust, networks, shared values, norms, and so on- embedded in social relationships are going to foster creativity and, therefore, innovation creation.

Specifically, networks between individuals embodied in social capital carry complementary ideas, skills and financing. According to KAASA (2007), who performed a KPF where social capital was included at regional level within Europe, the combination of creative ideas leads to unusual results and, moreover, networks help to know whether research projects are being duplicated (KAASA 2007).

On the other hand, seeking to identify the causal nexus between social capital, human capital and innovation, DE CLERCQ and DAKHLI (2003) were the pioneers in setting up an empirical relationship between these capitals and innovative activity at an aggregate level –concretely across 59 countries- within a KPF framework. These authors found strong support for the positive relationship between human capital and innovation and partial support for the positive effect of trust and associational activity on innovation. Thus, according to them, networks foster innovation because they expose individuals to different ideas and provide them with different and useful information sources as well. Indeed, social networks enable individuals to share certain information to know where they can exploit business opportunities, with high degree of technological content, increasing the number of succeed entrepreneurship projects.

Another interesting point stressed by KNACK and KEEFER (1997) when estimating a growth regression including social capital as well, states that the higher the level of social capital within the organization, in the form of trust, the lower the need for rigid controls, so boosting innovation. Indeed, strict controls may diminish creativity, whereas freedom from rigid controls enhances the generation of ideas. Even more, as pointed out by the former authors, higher level of social capital would imply lower monitoring costs from malfeasance and non-fulfilment from other partners, so firms can devote more time and money to other useful things, like innovation.

Furthermore, as KAASA *et al.* (2007) and ACKÇOMAK and TER WEEL (2006) set out, high levels of trust in a given society, would imply that its members are less risk avers, including investors. Thus, they could invest more in R&D, which is usually considered a risky and uncertain activity, producing, indeed, more innovation outcomes.

Again, as KNACK and KEEFER (1997, p.1253) stated, "in low-trust societies, hiring decisions will be influenced more by trustworthy personal attributes of applicants, such as blood ties or personal knowledge, and less by educational credentials", so in high-trust societies, jobs will be for people with appropriate skills, insuring the best human capital for each job, instead of the better contacts individuals have. Thus, it will be a skilled labour force ready to absorb and create innovation (KAASA *et al.* 2007).

Moreover, trust in institutions and in the legal system of a country is important too. Where the legal system is reliable, especially concerning the protection of new innovations (intellectual property rights), inventors and investors have better incentives to innovate and invest in innovation projects, because they know that the results will be better protected (DE CLERCQ and DAKHLI, 2003).

Finally, according to several scholars, the main source of innovation creation could be knowledge flows between individuals (ROMER, 1986, 1990; AUDRETSCH and FELDMAN, 1996; ANSELIN *et al.*, 1997). In this framework, social capital could foster knowledge flows within a given economy, becoming an important indirect source of innovation through its influence in the former phenomena. As MASKELL (2000) pointed out, the competitiveness of the knowledge-based economy is based not in costs and prices, but in dynamic improvements, creating and, particularly, diffusing knowledge more speedily than its competitors. According to the mentioned author, there exist market failures due to asymmetric information in a knowledge exchange between individuals –like firms-, which only could be overcome whether market relationships are replaced with exchange agreements based on trust. By repeating this exchange of knowledge, trust between individuals increase, doing not only codified knowledge easily transmitted, but also tacit knowledge, which is more difficult to acquire lonely. Further, this bilateral relationship shift into multilateral relationships between individuals and firms who exchange information and knowledge and for who trust betraying is severely punished, and who betrays is deprived of the knowledge flows within a given economy. This combination of incentives and punishments is the mechanism to build up social capital throughout time, including in places, such as Silicon Valley, where nobody knows else's mother.

That being said, and opposite to the neoclassical conception of knowledge as a public good which is transmitted without costs –specially within the economy of new telecommunications-, AUDRESTCH and FELDMAN (1996) pointed out that information transmission costs may not vary with distance, as neoclassical view says, but knowledge transmission depends upon geographical proximity and frequent contacts between individuals. Indeed, information is codified and is easily transmitted within telecommunications, but knowledge is tacit and its transmission requires human interactions (AUDRESTCH, 1998; PAVITT, 1998). Whereas the later tradition has assumed that knowledge flows freely within a given economy and costly between economies, we presume that, not only geography matters, but also the quality of human contacts may influence knowledge transmission (both codified and tacit knowledge) within a given regional economy. As BRESCHI and LISSONI (2001) stressed, knowledge is better endowed in individuals, which, in turn, know and trust others, which meet frequently, and with which exchange certain kind of economic information.

In short, networks (ties between individuals and between them and firms) based in trust relationships help and accelerate the exchange and search for information (KAASA *et al.*, 2007). What is more, trust enhances cooperation between firms and other patenting institutions, which favours not only the adoption of new fabrication procedures, but also the share of confidential information (DE CLERCQ and DAKHLI, 2003). Information share, moreover, which is reinforced by shared values and norms that promote collective interest instead of self interest (LANDRY *et al*., 2000). Given all the arguments above, our first hypothesis is to check empirically whether social capital really enables to obtain higher output incomes at the regional level.

Complementarities between social capital and the inputs of innovation

A second aim of this paper is to check to what extent there exists a complementarity relationship between social capital and the rest of the inputs in a knowledge production function when determining innovation outcomes. Our theoretical underlying hypothesis sets that innovation inputs such as human capital and innovative efforts could see their influence on the innovation results reinforced in societies with a high degree of trust and a great spread of social networks.

On one hand, the above mentioned hypothesis implies that, aside from the direct effect of R&D efforts on innovation outcomes, social capital could reinforce the effectiveness of these expenditures. In such a setting, for a given regional economy, higher levels of social capital facilitates a more effective diffusion of knowledge efforts which spills over from R&D expenditures to firms and other patenting institutions. Meanwhile, such a complementarity could see reinforced again if it yields to a better implementation of public policies and programs, as R&D expenditures of the public administration and higher education sectors (ACKÇOMAK and TER WEEL, 2006). These authors, indeed, investigated the role played by social capital and structural European funds on innovation activity and economic growth by focusing on Objective's 1 European regions between 1990 and 2002. Their investigation suggested that European funding did not influence innovation and economic outcomes, whereas social capital did. Interestingly enough, these authors investigated statistical complementarities between innovation inputs, revealing that regions with higher levels of social capital (among the less developed ones) were more likely to effectively gain from European programmes. Thereby, as the authors suggested, social capital appeared to be an instrument for the effective implementation of government programmes. Certainly, as it was stressed by DURLAUF and FAFCHAMPS (2004) –though concerning to less developed economies- sometimes the Government is not able to organize the efficient delivery of public goods and services, and by extension, public investments and expenditures, so social capital could be a second-best solution in front of a lack of well-functioning legal institutions and public administration.

On the other hand, as it has been pointed out by DE CLERCQ and DAKHLI (2003), higher levels of social capital may enhance opportunities of human capital to promote and value its returns. For SCHULLER (2001), there is a settled consensus about the role of human capital on economic outcomes, whilst social capital success is not as clear as the former one, due to its novelty and, lamentably, to its vagueness. Nonetheless, this author pointed out several useful tools to analyse the interesting relationship between human and social capital in boosting economic outcomes. Thus, social capital has to be understood as a relationship, a property of the group rather than individual's one. As SCHULLER (2001) stressed, individuals and their human capital are not discrete entities that exist separately from the rest of the organisation, or from other social units. Thus, the value of the abilities and skills of individuals depends upon the social context within which they are embedded (*Ibídem*). One important conclusion highlights his analysis, that is, human capital may include both social and technical skills, but social capital encompass social networks and social values through which those human skills are built, deployed and rewarded (SCHULLER, 2001).

Besides, PIAZZA-GEORGI (2002) settled that whereas physical capital was the main source of economic growth for theorists, human and social capitals, and the interactions between them, are nowadays the explanation for better economic outcomes. PIAZZA-GEORGI (2002) asserted that there is a clear relationship between social and human capital. Thus, although social capital may influence economic performance by reducing transaction costs, it could have an indirect effect through abilities realization and entrepreneurship, reducing human capital investment costs. Hence, there exists a complementarity relationship between both forms of capital. Finally, according to the EUROPEAN COMMISSION (2003) although human capital may influence economic performance, needles to say that the knowledge embedded in human beings is acquired in a social process of learning within the family, the school, the workplace, civic social networks, and the like. Thus, according to this report, both social and human capitals reinforce each other and, in turn, may foster economic growth and other economic outcomes.

Econometric specification

As GRILICHES (1979, 1991), JAFFE (1989) and FELDMAN (1994) framed, the empirical knowledge production function is an interesting tool for relating innovation efforts, such as R&D expenditures (RD) and human capital (HK), and some social and structural features of each region (Z), with an innovation output, namely the number of patents (PAT) produced in region i in a time period t:

$$(1) \qquad PAT_{it} = F(RD_{it}, HK_{it}, Z_{it})$$

Specifically, the above mentioned authors proposed a Cobb-Douglas specification for its usefulness,

$$(2) \qquad PAT_{it} = (RD)_{it}^{\beta_1} \cdot (HK)_{it}^{\beta_2} \cdot (Z)_{it}^{\beta_3}$$

It is worth noting that R&D expenditures can include both public and private investments, and the inclusion of the human capital variable may allow us to control for the ability of certain regions to innovate due to the skills and knowledge embodied in individuals (without taking into account the effect of the relationships established between them that may foster innovation also), and to control for their absorptive capability. Z is a set of variables to control for differences on innovation prone between regions due to cultural, social and structural factors. Among them, we have included a social capital indicator (SK), as will be explained below, in order to check the hypotheses mentioned in the section above. Moreover, since working with aggregated data leads to the need of controls for different innovation tendencies in each region, we have included certain variables which are used to capture the composition of the economic activity in each region, since this can determine the effectiveness of innovation in that economy. Concretely, in order to take into account different industry characteristics and MAR-externalities, which are linked to the existence of a pool of specialized labour, the location of customers and suppliers and physical and institutional infrastructures, we have performed a specialization index (SpIn) for each region, as CABRER-BORRÁS & SERRANO-DOMINGO (2007) and LÓPEZ-BAZO *et al*. (2006) did. Additionally, we have included population density[2] (POP) of each region to control for

[2] The specialization index has been built with Gross Added Value (GAV) data from BDMORES databank, and it takes the form of

$$SpIn = \frac{1}{2} \sum_j \left| \frac{GAV_{ij}}{GAV_i} - \frac{GAV_{Nj}}{GAV_N} \right|$$

where i = region, N = nation, and j = economic sector. Data on population have been taken from Eurostat, and data on squared kilometres have been taken from the Spanish Statistical Office.

agglomeration economies, and at the same time to take into account dissimilar regional dimensions. Indeed, in line with GUMBAU-ALBERT and MAUDOS (2007), density of population can be understood as a synonymous of accessibility, and better accessibility may increase the probability of firms and individuals coming into touch with different people and new ideas. Furthermore, a time trend is included in order to capture changes in our patent equation owing to the economic cycle. Hence, the specification we are going to empirically estimate is given by

$$\begin{aligned} PAT_{it} &= \beta_0 + \beta_1 \cdot \ln(RD_{it}) + \beta_2 \cdot \ln(HK_{it}) + \beta_3 \cdot \ln(SK_{it}) \\ &+ \beta_4 \cdot \ln(SpIn_{it}) + \beta_5 \cdot \ln(POP_{it}) + \delta \cdot t + \varepsilon_{it} \end{aligned} \quad (3)$$

with ε_{it} being a random error term. An important issue at this point is the nature of the endogenous variable, which is a count variable (nonnegative integers), so a count model specification is preferable than a linear model, as it has been widely used before (HAUSMAN *et al.* 1984; DEL BARRIO-CASTRO and GARCÍA-QUEVEDO, 2005; GUMBAU-ALBERT and MAUDOS, 2007). The basic model for this estimation is a Poisson regression model which assumes that the dependent variable follows a Poisson distribution. Nevertheless, such a Poisson model, although consistent enough, presumes equality between the conditional mean and the conditional variance of the endogenous variable. Nonetheless, there exist certain symptoms of overdispersion in our dependent variable, that is, the conditional variance exceeds the conditional mean. In such a setting, numerous authors have proposed several alternatives which allow for this overdispersion, being the more usual one the negative binomial model, which arises from a natural formulation of the heterogeneity between observations (GREENE, 2001). The explanatory variables have been taken in logarithms in order to interpret the associated parameter of each variable as elasticities (CAMERON and TRIVEDI, 1998). To our purpose, equation (3) will allow us to assess, through the estimation of this kind of model, the direct effect of social capital on innovation. Nevertheless, in order to check our second hypothesis, we have to include interaction terms in the equation, which will take into account its indirect effect through the parameter of each interaction as follows,

$$PAT_{it} = \beta_0 + \beta_1 \cdot \ln(RD_{it}) + \beta_2 \cdot \ln(HK_{it}) + \beta_3 \cdot \ln(SK_{it}) + \beta_4 \cdot \ln(SpIn)_{it} + \quad (4)$$

$$\beta_5 \cdot \ln(POP_{it}) + \beta_6 \cdot [\ln(SK_{it}) \cdot \ln(HK_{it})] + \beta_7 [\ln(SK_{it}) \cdot \ln(RD_{it})] + \delta \cdot t + \varepsilon_{it}$$

A time lag of one year will be considered for the main explanatory variables in order to infer causality from correlation between these variables and the dependent one. As a matter of fact, concerning R&D expenditures, GRILICHES (1991) pointed out that firms apply for patents in the early stages of their research, so one year lag could be an appropriate length of time.

3. Data and descriptive analysis

Social capital indicators and descriptive analysis

Since the definition of social capital remains elusive and full of vagueness, its measure is almost the most controversial issue in every research work dealing with it. Prior research on social capital has tackled data lack by introducing certain kind of environmental proxies, as crime rates, teenage pregnancy, blood donation, and so on, which has introduced confusion on what social capital is, differently from its outcomes (SABATINI, 2006), and increasing econometric problems concerning every empirical work.

Since PUTNAM's *et al.* (1993) definition was trust, norms, and networks that facilitate coordination and cooperation, an important part of the literature on social capital has been using data of the World/European Values Survey[3], following the way opened by KNACK and KEEFER's (1997) influential work, given that these data fitted very well with the former definition. Thus, empirical literature has focused mainly on one question of this survey, that is: ''Generally speaking, would you say that most people can be trusted or that you need to be very careful in dealing with people?'', responses that have been

[3] The World/European Values Survey was designed to enable a cross-national comparison of values and norms on a wide variety of topics and to monitor changes in values and attitudes across the globe. This data collection contains the survey data from the four waves of the World Values Survey and European Values Survey, carried out in 1981-1984, 1990-1993, 1995-1997, and 1999-2004. Broad topics covered in the integrated file include perception of life, family, work, traditional values, personal finances, religion and morale, the economy, politics and society, the environment, allocation of resources, contemporary social issues, national identity, and technology and its impact on society. The European coordination centre is located in Tilburg University, The Netherlands, whilst the Survey was extended to the world through Ronald Inglehart from the University of Michigan (US).

aggregated to obtain regional or country levels of trust –among other social capital features as well. However, according to some scholars (GLAESER *et al.*, 2000; SABATINI, 2006), this question and the whole survey is not suitable enough at an aggregate level, since responses use to be a micro concept which reflects the particular position of the interviewed, so its aggregation loses historical and social circumstances. Moreover, the variation in responses might be due to numerous reasons, such as "differences in beliefs about the trustworthiness of a common set of people; differences in interpretation of who comprises ''most people;'' differences in the interpretation of what it means to be able to trust someone; or differences in the ability to elicit trustworthy behaviour from other people" (GLAESER et al., 2000; p. 815). Additionally, as KNACK and KEEFER (1997) acknowledged, the World/European Values Survey has several mistakes and presents an overrepresentation of certain social groups. Furthermore, its statistical representation at low levels of aggregation (for instance, at NUTS II level for Europe) is not worthwhile.

Contrarily, we will use a complex and interesting measure proposed by PÉREZ *et al.* (2005). According to the authors, current social capital measures are not a result of a process of investment, as other kind of capitals –namely physical and human capital. Following DURLAUF and FAFCHAMPS (2004) recommendations, who stressed the lack of explicit modelling of the process by which social capital is created within societies, the authors of the PÉREZ *et al.* (2005) database developed one of the most rigorous approaches to the theoretical economic concept of social capital. Indeed, the social capital measure in this database emulates other capital's estimation methodology, as physical capital, since it is based on a model which combines individual trust decisions at a micro level, with the aggregate effect to co-operate being connected within networks in social relationships (PASTOR and TORTOSA-AUSINA, 2007) focusing their analysis on the economic aspects of life (since economic relationships between individuals are the most important sources of interaction and trust creation)[4].

Before further analysis, we must focus our attention to several features that characterized social capital productivity evolution for the Spanish regions. The useful work by PÉREZ *et al.* (2005) provides us with a social capital's databank which supplies

[4] For a detailed explanation of such dataset and its modelling, see PÉREZ *et al*. (2005 and 2006), and for interesting empirical implementations of it, see PÉREZ *et al*. (2006), and PASTOR and TORTOSA-AUSINA, (2007).

with temporal, as well as international and regional quite large data, which constitutes interesting raw material for several analyses[5]. As observed in Figure 1, from minimum levels of social capital occurred in 1985 up to now, this variable has undergone a lingering increase, as a result of the rise of well-being within the Spanish economic performance. Despite the mentioned increasing trend, however, social capital plummet abruptly during the early nineties, coinciding with the recession derived from the Monetary European System crisis. Nonetheless, a vigorous recovery of it was undergone during the second half of the nineties up to the end of our period of analysis.

[Insert figure 1 about here]

Striking enough, social capital differences between Spanish regions are quite stronger than for other forms of capital for the Spanish case (PÉREZ *et al*., 2005). Indeed, as it can be seen in Figure 2, social capital services are large in the north-east and the Mediterranean corridor rather than in the south and west, except, of course, for the case of Madrid.

[Insert figure 2 about here]

Variables and databases. Descriptive analysis

ROGERS (1998) defined innovation as the application of new ideas to the products, processes or any other aspect of a firm activity, concerning with the process of commercialising and extracting value of ideas. In such a setting, patents have been used widely as a measure of innovation. In spite of their caveats since neither all inventions are patented nor they have the same economic impact (GRILICHES, 1991), nor all patents reflect a commercially exploited innovation, they have the minimal standards of novelty, originality and potential profits, hence they could be a good proxy to economically profitable ideas (BOTAZZI and PERI, 2003). We will, therefore, use the

[5] Thus, as a novelty with respect to the literature estimating knowledge production functions with the inclusion of social capital, IVIE's dataset allows us to perform a panel data model. As BALTAGI (2005) summarizes, panel data allow one to control for individual heterogeneity, whilst cross-section and time-series studies do not, taken into account regional time-invariant characteristics within the considered period. Moreover, longitudinal studies "give more information data, more variability, less collinearity among the variables, more degrees of freedom and more efficiency" (BALTAGI, 2005; p. 5) providing with less biased, and more consistent estimations of the relationships between innovative inputs and their output, which could be an important lack in the previous literature on this topic.

information on patent applications provided by the European Patent Office (EPO) at NUTS 2 level[6]. In our period of analysis, 1990-2001, Figure 3 shows an increasing trend in the number of patent applications per capita, which is stressed specially from 1996 up to now. However, not all regions have contributed equally to the level of patenting activity of Spain. Thus, as it can be seen in Table 1, three regions (Catalonia, Madrid, and The Basque Country) accounted for more than 50% of the patents applied in Spain within our period of analysis –Catalonia and Madrid account for more than 50% of patent applications in absolute terms in this period.

[Insert figure 3 about here]

As it has been approached in related literature, we will proxy R&D efforts by means of regional R&D expenditure, both private and public –so including higher education and public administration expenditures. These data are available at the Spanish Statistic Office (INE) in a regional (NUTS 2) disaggregating level from 1987 to 2001 at current prices, so the dataset has been deflated appropriately[7]. Data on human capital are provided by IVIE (Valencian Institute for Economic Research), and the variable has been proxied by the percentage of workers with superior and under-superior education over total workers, as it has been widely used (BARRO and LEE, 1993).

[Insert table 1 about here]

Some interesting features arise from Table 1. Again, the previously mentioned three regions account for almost the 50% of R&D expenditures per capita within the whole period of analysis, which, in turn, spent more than 150 € per capita each of them in 2001 –again, absolute terms data are even more concentrated in Catalonia and Madrid. Thus, as it has been often noted, the Spanish innovative activity –both from inputs and outputs- is strongly concentrated. Nevertheless, since larger cumulative increases of R&D expenses have been occurred in regions aside from Madrid and Catalonia, a

[6] According to some scholars, the difference between patent applications and granted patents is not noteworthy – neither in absolute quantities nor weights between regions and economic branches. What we notice, however, is that between patent applications and granted patents there is a lag of about 2 or 3 years, due to administrative procedures.

[7] Despite our preferred aggregation level of analysis is the Spanish province (corresponding to NUTS3), since is an appropriate unit of analysis within both innovation and knowledge diffusion literature (RONDÉ and HUSSLER, 2005; ANSELIN *et al*., 1997; ACS *et al*., 2002), our analysis will be performed at NUTS2 level due to data lack concerning R&D expenditures.

process of technological spread within the Spanish geography should be noticed. Finally, as it can be seen in Table 1, certain regions as Madrid, The Basque Country, Navarre, Aragon, Castille and Leon or Catalonia show the highest levels of human capital.

4. Results

Using the empirical model described above, in this section we will present the results of the negative binomial model estimations of the effects of social capital on innovation outcomes –patents. We also expect that there might be important interactions between innovation inputs. It could be argued, as it has mentioned before, that social capital affects innovation outcomes primarily and perhaps exclusively, through the interaction with other technological inputs. Hence, if the estimated coefficient on the interaction between social and human capital is positive, the effect of human capital on innovation would be larger the larger the amount of social capital in a given regional economy. Similarly, the effect of social capital on innovation would be larger the larger is the amount of human capital. The same applies for the interaction between social capital and R&D efforts.

Our main results are presented in Table 2 –and subsequent ones. We have presented our results starting by the simplest specification, column (i), without including interaction terms, which are included afterwards step by step. Moreover, we have performed the Hausman test (HAUSMAN, 1978) in all our estimations, and the null hypothesis that the individual effects are uncorrelated with the independent variables must be rejected, so the fixed effects model estimation is consistent.

The results in column (i) show a positive and strong significant effect of both R&D efforts and human capital on innovation, with elasticities of 54.7% and 75.3% respectively. The value of the former is consistent with prior research, since it is slightly high than the results reported in MORENO *et al.* (2005) -20%- for the European regions, CABRER-BORRÁS and SERRANO-DOMINGO (2007) -33%- and DEL BARRIO-CASTRO and GARCÍA-QUEVEDO (2005) -40%- for the Spanish regions. Meanwhile, human capital elasticity is in line with CABRER-BORRÁS and SERRANO-DOMINGO (2007) -75%-, and GUMBAU-ALBERT and MAUDOS (2007) -85%- for the Spanish case, RONDÉ and

HUSSLER (2005) -60%- for the French regions, or BOTAZZI and PERI (2003) -92%- for the European regions. As for the controls, the parameter of the specialization index is significant, although only at 10%, and it presents the expected positive sign, indicating that highly specialised regions tend to further innovate. The time trend shows a positive and significant parameter, whilst population density is not. As GUMBAU-ALBERT and MAUDOS (2007) argued, this variable has little temporal variability, so its effect could be captured by the fixed effect of each region. Interestingly, the elasticity of patent applications with respect to social capital productivity (or services) is positively significant, and strongly at 1%. Thus, it could be concluded that social capital exerts a positive influence on innovation, at the same level of significance than other inputs, and with an elasticity of 64,7%, comparable with the importance of human capital, as it has been stressed before (HAUSER *et al.*, 2007).

However, as it has been mentioned, social capital exerts an indirect impact on innovation reinforcing the effect of human capital, in other words, one possible way by which social capital positively affects innovation outcomes is by means of the social valuation of human capital. With this idea in mind, in the second specification, the interaction between social and human capital has been included. Although innovation inputs are significant, the interaction term is not, but in order to assess accurately the importance of the interactions between inputs, we report total semi-elasticities in equations with interactions terms -adding, thus, the complementarity effect to the direct effect. With the aim of assess the significance of the inclusion of interactions we have tested the joint significance of both parameters –the direct effect and its indirect effects through its interaction. Standard errors for the total semi-elasticitates have been calculated using the delta method (SERFLING, 1980). In such a setting, since the covariance of the parameter of each variable and the parameter of their interactions is negative, the total semi-elasticities of each innovation input could be significant even though the initial parameters are not significant. As it can be observed in column (ii) of Table 2, the total semi-elasticity of patents with respect to social capital remains statistically significant at 1%, and more than 10 points greater than in the first specification. Moreover, the total semi-elasticity on innovation with respect to human capital, which remains strongly significant, makes a step forward, from a value of 75.3% to 83.7%. Such an interesting result lead us to corroborate our hypothesis concerning the complementary roles between human and social capital, as it has been stressed by several authors (SCHULLER, 2001; PIAZZA-GEORGI, 2002). Thus, human capital returns on innovation could be stronger in a high social capital environment which reinforces human capital's valuation in a given regional economy.

The specification in column (iii) includes the interaction term between R&D efforts and social capital, whereas the one in column (iv) includes both interaction terms at the same time. Albeit the significance of all parameters is obvious –R&D efforts, human capital and social capital- the total semi-elasticities have been calculated again. As a result, both human and social capital show significant values and enhanced total semi-elasticities -specially the former- whilst the total semi-elasticity of R&D, although always strongly significant, is not enhanced enough.

In front of this set of results we can conclude that features such as trust, social networks and relationships, shared values and the like, exert an important and strong effect on the generation of innovation within a given regional Spanish economy. Moreover, there is strong evidence that social capital reinforce the effect of human capital, although this is not the case for R&D given that social capital does not seem to enhance the effectiveness of R&D expenditures. In short, we had the hypothesis that social capital could reinforce R&D returns on innovation, since it could enhance R&D expenditures which spill over to other patenting organizations, although empirical evidence is not obtained at first sight. Despite this initial result, certain theoretical arguments lead us to think that, since sometimes the Government is not able to organize the efficient delivery of public goods and services, and by extension, public investments and expenditures, social capital appeared to be an instrument for the effective implementation of them (DURLAUF and FAFCHAMPS, 2004; ACKÇOMAK and TER WEEL, 2006), so it could exert its influence only through public R&D expenditures, and not through private ones.

[Insert Table 2 about here]

With this idea in mind, in Table 3 we show the regression results entering business, high education, and public administration R&D efforts separately. By doing so, we are able to explore whether there is an additional effect of social capital by means of improving the effectiveness of public investments and expenditures –so high education and public administration efforts. First of all, the results of our estimations show a higher effect of human capital on innovation outcomes through its direct influence in relation to the first specification in Table 2, whilst social capital remains significant. Interestingly enough, the effect business and public administration R&D efforts are separately significant, whereas the significance of high education is slightly lower. This is consistent with previous literature, as it is shown in DEL BARRIO-CASTRO and GARCÍA-QUEVEDO (2005), and BILBAO-OSORIO and RODRÍGUEZ-POSE (2004) for the European peripheral regions. In fact, as it was pointed out in the later paper, one should bear in mind that high education R&D is often linked to basic research, which may have a less direct link with the number of patent applications.

The main conclusions after the introduction of the interactions are as in Table 2, although some slight differences should be noted. Firstly, the reinforcement of the effect of human capital on innovation when the interaction term with social capital is included is again strong enough. On the other hand, the effect of the interactions with business and public administrations R&D efforts, as before, is not important enough. Nonetheless, social capital does achieve an improvement on the influence of high education R&D expenditures on innovation outcomes, since both its level of significance and its value are increased, from an 11% to even a 17% when all the interactions are included. Thus, our former suggestions could be partially accepted, at least for high education expenditures. Concretely, regions with higher levels of social capital are more likely to effectively gain from high education R&D expenditures. It would seem, then, that university expenses devoted to R&D could be better implemented if certain social features (in such a case, chiefly trust and networks) are high and, for instance, more collaborative scientific projects could be carried out –which is an essential source of knowledge diffusion and creation.

[Insert Table 3 about here]

At this point, we are interested in checking whether the impact of social capital is related with the level of development achieved in a given economy. There are two different hypotheses with this respect. On the one hand, according to several scholars (LYON, 2005; AKÇOMAK and TER WEEL, 2006), social capital may act as a substitute for the lack of such kind of inputs that foster innovation and other economic outcomes. Thus, in certain economies, with low levels of R&D expenditures and certain lack of human skills, social capital might have larger impact than in those more developed economies with better endowments of innovative efforts and human capital. On the other hand, some other authors (PÉREZ, *et al.*, 2005) have highlighted that potential gains from transaction costs reduction due to better social capital endowments will be more significant in developed regions, technically and technologically complex, where uncertainty and strategic interaction are higher, so there exist large incentives to trust others. With the aim of checking which hypothesis is taken place in the Spanish case, we present the results in Table 4. Our empirical strategy will consist on dividing our sample into two sub-samples containing, each of them, high-income regions and low-income regions respectively. By doing so, we are able to check the above mentioned hypotheses, and at the same time, by including both public and private R&D efforts in our regressions, we will be able to check whether social capital may play different roles in the complementarities with each kind of expenditure, according to the level of development of each region. Thus, the sample has been divided according to the per capita Gross Added Value, so those regions with a per capita GAV over the national mean will belong to the high-income sample[8]. According to table 4, a strong effect of social capital on innovation outcomes is observed both in high-income and low-income regions. Nevertheless, the value of its elasticity is more than ten points greater in the former kind of regions than in the later, initially corroborating the hypothesis which relates better social capital returns with more developed regions.

Likewise, in the first part of the table (high-income regions, column (i)), significant parameters for business and high education R&D efforts are not observed, in line with CABRER-BORRÁS and SERRANO-DOMINGO (2007) results. Nevertheless, there exists a strong –around 30%- and significant effect of public administrations R&D efforts, which is slightly reinforced when the interactions between this input and social capital are included. Such an expenditure is characterized by including, among others, public autonomous organisms expenses (except public firms and universities), like the great public investigation organisms (OPIS), which we presume are mostly concentrated in certain more developed regions, so its importance is clear within these regions. In such a setting, the interesting complementarity found between these expenditures and social

[8] The high-income region sample includes Aragon, Balearic Islands, Catalonia, Madrid, Navarre, the Basque Country and La Rioja, whilst the low-income region sample includes Andalusia, Asturias, the Canary Islands, Cantabria, Castille and Leon, Castille-La Mancha, Community of Valencia, Extremadura, Galicia and Murcia.

capital could be explained in the same terms as the complementary effect between high education R&D and social capital found in table 3, that is, an improving of knowledge transmission between research groups and individuals.

Contrarily, in low-income regions, a great value –around 31%- and strong significance is observed for high education R&D expenditures, coinciding with a considerable expansion and regional redistribution of the university network that took place during the nineties in Spain (DEL BARRIO-CASTRO and GARCÍA-QUEVEDO, 2005). This is, in turn, reinforced owing to substantial complementarities with social capital –almost 6 points- so repeating the results obtained for the whole sample. Meanwhile, this is not the case for business and public administration expenses. In the meantime, interactions between such R&D expenditures and social capital in those regions improve clearly the explanatory power of the later between 13 and 18 points, but this is not the case for high-income regions.

For the case of human capital, it seems to be unimportant in high-income regions at first sight, since its elasticity is not significant. These results are in line with LÓPEZ-BAZO *et al.* (2006), although they examined the effect of human capital on TFP rather than on patents. However, quite interestingly, the interaction between social and human capital reinforce the explanatory power of the later, since it turns from an insignificant parameter into a significant one –at 10% level- and from a value of 82% to a value higher than 100%. Meanwhile, the significance and the value of social capital remain unalterable –at around 88%. Concerning low-income regions, several results arise from the second part of Table 4. Contrary to rich regions, human capital is strongly significant and high now, and the interaction between such an input and social capital enhances slightly the explanatory power of human capital, although social capital total semi-elasticity remains practically unaffected. This opposite result lead us to think that again the complexity of more developed regions induce social capital to value human capital returns on innovation that would be almost negligible in its absence, whilst the simplest organization of low-income regions lead them to value human capital returns for themselves.

In a nutshell, interesting conclusions may arise from the analysis of Table 4. First of all, social capital fosters innovation and knowledge diffusion directly, both in high and low-income regions, although its intensity is higher for high-income regions. However, within these regions, complementarities between social capital and R&D efforts are negligible, though an interesting complementary effect between social capital and public administrations R&D effort within these regions is observed. Moreover, a strong complementary effect of social capital through its interaction with human capital is observed as well. In other words, the effect of human capital and public administrations R&D efforts is reinforced in rich regions when there is a high level of social capital.

On the other hand, within low-income regions, social capital exerts a direct effect on innovation, but at lower levels than for high-income regions. Additionally, high education R&D efforts and social capital reinforce strappingly each other in foster innovation creation. On its side, human capital, which has the highest explanatory power, does not see its influence on innovation reinforced due to complementarities with social capital. Thus, within poor regions, social capital may play an interesting role directly and by complementing the effect of high education efforts on innovation. Nevertheless, when a region reaches a minimum threshold of development, social capital may get better technological outputs by means of its direct effect on patenting activity and by its relationship with human capital and public administration R&D efforts.

[Insert Table 4 about here]

5. Concluding remarks

Throughout previous pages, the aim of this paper was to analyse the role played by certain social features within a given Spanish regional economy, such as its level of trust, its social networks and the strength of its social ties, its shared values and norms, and the like, in the process of knowledge creation within those regional economies. Specifically, we have estimated a knowledge production function with the inclusion of social capital as a source of innovation. As a proxy for social capital, we have considered an interesting and complex measure of social capital, provided by IVIE, that tries to overcome some of the problems that characterizes social capital empirical research, which have questioned the validity of nearly every finding in this research field due to the lack of suitable data and, therefore, due to the lack of consistency in the estimations that have been carried out up to now. What is more, the main features of this dataset –chiefly, their level of desegregation and time range- and the characteristics of the dependent variable –a nonnegative integer- have allowed us to carry out a negative binomial regression within a panel data model at NUTS2 level of regional desegregation, adding, hence, consistency to our findings. According to our empirical approach, we observe that such social features might exert a strong influence on innovation outcomes, thus confirming the hypothesis that the more the level of social capital, the more the innovation outcomes.

Additionally, we have analysed the mechanisms through which social capital may foster knowledge creation. By introducing interaction terms between social capital and human capital, and between social capital and R&D efforts, we concluded that such innovation inputs could see their influence on the innovation output reinforced in societies with a high degree of trust and a great spread of social networks. In fact, we have obtained strong evidence for the former complementarity, since social capital fosters human capital returns on innovation, and low or not worth mentioning evidence for the latter. These results might have important policy implications, since they would reject those policy streams that focus on individuals to obtain certain economic outcomes, and refuse collective learning and relational development.

Likewise, we have tried to understand the low or almost inexistent complementary effect between R&D expenses and social capital, and by introducing separately business, high education, and public administration R&D efforts, we have made a step forward in our initial results. We confirm the idea suggested in the literature (DURLAUF and FAFCHAMPS, 2004; ACKÇOMAK and TER WEEL, 2006), that the more the social capital in a given economy, the more the effectiveness of public expenditures. Concretely, we have found evidence of an interesting complementarity between social capital and high education R&D expenditures, while it is not the case for business and public administration R&D expenses. Thus, sieving in our initial results, we must conclude that, although complementarities between social capital and R&D expenditures are not striking enough, the former intangible asset may play a reinforcing role by fostering high education R&D returns on innovation, due to the existence, we presume, of an improved knowledge transmission between research groups and individuals, and stronger links between universities and firms.

On the other hand, we have checked the hypothesis that social capital may have different effect concerning the level of development of each region. We have analysed either whether in less developed economies social capital may act as a substitute of certain technological inputs or whether social capital may play a larger role in high developed regions due to their larger technical and technological complexity. Our findings suggest that social capital fosters innovation and knowledge diffusion directly, both in high–income and low-income regions. However, within low-income regions, social capital direct effect on innovation is lower than for high-income regions. Additionally, the complementarities between social capital and the rest of factors are completely different. Within high-income regions, complementarities between social capital and R&D efforts are negligible, though an interesting complementary effect between social capital and public administrations R&D effort within these regions is observed. Moreover, a strong complementary effect of human capital through its interaction with social capital is observed as well. On the other hand, within low-income regions, high education R&D efforts and social capital reinforce strappingly each other in foster innovation creation. Possible explanations of this fact are both that social capital could be a second best solution to the effectiveness of public expenditures delivery and investment in regions where the institutional and legal frameworks are also less developed, and that this interaction improves knowledge transmission between research groups and individuals, and between universities and firms –whereas an spread of the university network took place in Spain during the nineties throughout less developed regions. On its side, human capital, which has the highest explanatory power within low-income regions, does not see its influence on innovation reinforced due to complementarities with social capital.

Thus, social capital exerts a positive impact on innovation in both more and less developed regions, although the mechanisms through which it operates differ according to the level of development. Indeed, within low-income regions, social capital may play an interesting role directly and by complementing the effect of high education efforts on innovation. Nevertheless, when a region reaches a minimum threshold of development, social capital may get better technological outputs by means of its direct effect on patenting activity and by its relationship with human capital and public administration R&D efforts.

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References

ACS, Z.; ANSELIN, L.; VARGA, A. (2002) Patents and innovation counts as measures of regional production of new knowledge *Research Policy* 31, 1069–1085

AKÇOMAK, I.S. and TER WEEL, B. (2006) How does social capital and government support affect innovation and growth? Evidence from the EU regional support programmes UNU-MERIT Working Papers 1871-9872

ANSELIN, L.; VARGA, A.; ACS, Z. (1997) Local Geographic Spillovers between University Research and High Technology Innovations *Journal of urban economics* 42, 422-448

AUDRETSCH, D. B. (1998) Agglomeration and the location of innovative activity *Oxford review of economic policy*, vol. 14, no. 2

AUDRETSCH, D. B. and FELDMAN, M. P. (1996) R&D Spillovers and the Geography of Innovation and Production *The American Economic Review*, Vol. 86, No. 3, 630-640

BALTAGI, B. H. (2005) *Econometric analysis of panel data*, third edition, John Wiley & Sons, Ltd, Sussex

BARRO, R. J. and LEE, J. W. (1993) International comparisons of educational attainment *Journal of Monetary Economics*, vol. 32(3), 363-394,

BECATTINI, G. (1979) Dal «settore» industriale al «distretto» industriale. Alcune considerazioni sull'unità di indagine dell'economia industriale *L'Industria. Rivista di economia e politica industriale*, n.º 1, 7-21.

BEUGELSDIJK, S. and VAN SCHAIK, T. (2005) Differences in social capital between 54 Western European regions *Regional Studies*, Vol. 39.8, 1053–1064

BILBAO-OSORIO, B. and RODRÍGUEZ-POSE, A. (2004) From R&D to Innovation and Economic Growth in the EU *Growth and Change* Vol. 35 No. 4, 434-455

BOTTAZZI, L.; PERI, G. (2003) Innovation and spillovers in regions: Evidence from European patent data *European Economic Review* 47, 687 – 710

BRESCHI, S. AND LISSONI, F. (2001) Knowledge spillovers and local innovation systems: A critical survey, Luic Papers nº 84, *Serie Economia e Impresa*, 27

CABRER-BORRÁS, B. and SERRANO-DOMINGO., G. (2007) Innovation and R&D spillover effects in Spanish regions: A spatial approach *Research Policy* 36, 1357–1371

CAMERON, A. C. and TRIVEDI, P. K. (1998) *Regression analysis of count data* Econometric Society Monographs No. 30, Cambridge University Press, Cambridge

COLEMAN, J. S. (1988) Social capital in the creation of human capital *The American Journal of Sociology*, Vol. 94, 95-120

DE CLERCQ, D.; DAKHLI, M. (2003) Human capital, social capital, and innovation: A multi-country study. *Vlerick Leuven Gent Working Paper Series* 2003/18

DEL BARRIO-CASTRO, T. and GARCÍA-QUEVEDO, J (2005) Effects of University research on the geography of innovation *Regional Studies*, Vol. 39.9, 1217-1229

DURLAUF, S. N. and FAFCHAMPS, M. (2004) Social capital NBER *Working Paper Series* 10485 National Bureau of Economic Research

EDQUIST, C. (ed.) (1997) *Systems of innovation: technologies, institutions, and organizations,* London ; Washington

EUROPEAN COMMISSION (2003) Building the knowledge society: social and human capital interactions, Commission Staff Working Paper

FELDMAN, M. P. and AUDRETSCH, D. B. (1999) Innovation in cities: Science-based diversity, specialization and localized competition *European Economic Review* 43, 409-429

FELDMAN, M. (1994) *The Geography of innovation*, Kluwer Academic Publishers, Dordrecht

GARCÍA-QUEVEDO, J. (2002) Universidades e infraestructura tecnológica en la localización de las innovaciones, *Economía Industrial*, nº 346

GLAESER, E. L.; LAIBSON, D. I. ; SCHEINKMAN, J. A. ; SOUTTER, C. L. (2000) Measuring trust *Quarterly Journal of Economics*, Vol. 115, 3, 811-846

GUMBAU-ALBERT and MAUDOS (2007) Patents, technological inputs and spillovers among regions *Applied Economics*, 99999:1, 1 - 14

GREENE, W. H. (2001) *Análisis econométrico*, 3ª edición, Prentice Hall, Madrid

GRILICHES, Z (1979) Issues in Assessing the Contribution of Research and Development to Productivity Growth *The Bell Journal of Economics*, Vol. 10, No. 1, 92-116.

GRILICHES, Z (1991) The search for R&D spillovers NBER Working Paper No 3768, National Bureau of Economic Research

GRILICHES, Z. (1991) Patent Statistics as Economic Indicators: A Survey, NBER Working Papers 3301, National Bureau of Economic Research

HAUSMAN, J.A.; HALL, B.H.; GRILICHES, Z. (1984) Econometric models for count data with an application to the patent-R&D relationship *Econometrica*, Vol. 51, Nº 4

HAUSMAN, J.A. (1978) Specification test in econometrics *Econometrica*. 46: 1251-1271

HAUSER, C., TAPPEINER, G. AND WALDE, J. (2007) The Learning Region: The Impact of Social Capital and Weak Ties on Innovation *Regional Studies*, 41:1, 75 - 88

HELLIWELL, J. F. (1996) Economic growth and social capital in Asia NBER Working Paper 5470

HELLIWELL, J.F. and PUTNAM, R. D. (2000) Economic growth and social capital in Italy, in *Social Capital: A Multifaceted Perspective*, P. Dasgupta and I. Seragilden (eds.), Washington DC: World Bank, 253-266

JAFFE, A. B. (1989) Real effects of academic research *The American Economic Review,* Vol. 79, No. 5., pp. 957-970

KAASA, A. (2007) Effects of different dimensions of social capital on innovation: evidence from Europe at the regional level, Working Paper Series of the University of Tartu, Estonia

KAASA, A.; KALDARU, H.; PARTS, E. (2007) Social capital and institutional quality as factors of innovation: evidence from Europe, Working Paper Series of the University of Tartu, Estonia

KNACK, S. and KEEFER, P. (1997) Does social capital have an economic pay-off? A cross country investigation *Quarterly Journal of Economics* 112, 1251-1288

LANDRY, R.; AMARA, N.; LAMARI, M. (2000) Does social capital determine innovation? To what extend? Paper prepared for presentation at the *4th International Conference on Technology Policy and Innovation*. Brazil

LÓPEZ-BAZO, E; REQUENA, F.; SERRANO, G. (2006) Complementarities between local knowledge and internationalization in regional technological progress *Journal of Regional Science*, Vol. 46, No. 5, 901-929

LUNDVALL, B.Å. AND JOHNSON, B. (1994) The Learning Economy *Journal of Industry Studies*, Vol. 1, No. 2, Dec. 1994, 23-42.

LYON, T. P (2005) Making capitalism work. Social capital and economic growth in Italy, 1970-1995. *Fundazione Eni Enrico Mattei*, Nota di Lavoro 70.2005

MASKELL, P. (2000) Social Capital, Innovation and Competitiveness, in Baron, S. (ed), *Social Capital: Critical Perspectives*, Oxford, Oxford University Press

MORENO, R.; PACI, R; USAI, S. (2005) Geographical and sectoral clusters of innovation in Europe *Annals of Regional Science* 39, 715–739

PAVITT, K. (1998) The social shaping of the national science base *Research Policy* 27, 793-805

PASTOR, J. M.; TORTOSA-AUSINA, E. (2007) Social Capital and Bank Performance. An International Comparison for OECD Countries. Documento nº 4/2007 Fundación BBVA

PÉREZ, F.; SERRANO, L.; MONTESINOS, V.; FERNÁNDEZ, J. (2006) Measurement of social capital and growth. An economic methodology. Documento nº 4/2006 Fundación BBVA

PÉREZ, F.; MONTESINOS, V.; SERRANO, L.; FERNÁNDEZ, J. (2005) *La medición del capital social: una aproximación económica* Fundación BBVA and IVIE

PIAZZA-GEORGI, B. (2002) The role of human and social capital in growth: extending our understanding *Cambridge Journal of Economics*, 26, 461-479

PORTER, M. (1990) *The Competitive Advantage of Nations*, Mc-Millan, London

PUTNAM, R., LEONARDI, R. AND NANETTI, R. (1993) *Making Democracy Work: Civic Traditions in Modern Italy*, Princeton, Princeton University Press.

RODRÍGUEZ-POSE, A. (1999) Innovation prone and innovation averse societies: economic performance in Europe *Growth and Change*, vol. 30, 75-105

ROGERS, M., (1998) The definition and measurement of innovation. Melbourne Institute of Applied Economic and Social Research. Working Paper no. 10798. University of Melbourne

ROMER, P. M. (1990) Endogenous Technological Change *Journal of Political Economy*, vol. 98(5), S71-102

ROMER, P. M. (1986) Increasing Returns and Long-run Growth *Journal of Political Economy*, vol. 94(5), 1002-37

RONDÉ, P. AND HUSSLER, C. (2005) Innovation in regions: What does really matter? *Research Policy,* 34, 1150–1172

SABATINI, F. (2006) The Empirics of Social Capital and Economic Development: A Critical Perspective, Fondazione Eni Enrico Matei, Nota di Lavoro 15.2006

SABATINI, F. (2005) The Role of Social Capital in Economic Development. Investigating the Causal Nexus through Structural Equations Models, University of Rome La Sapienza, Department of Public Economics, mimeo.

SAXENIAN, A. (1994) *Regional Advantage. Culture and Competition in Silicon Valley and Route 128* Cambridge MA: Harvard University Press.

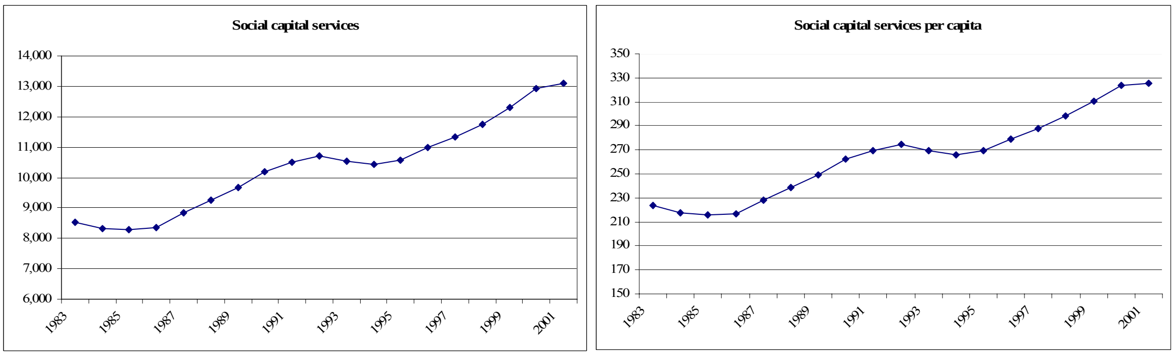
SAXENIAN, A. (1990) Saxenian, A. (1990) Regional Networks and the Resurgence of Silicon Valley *California Management Review*, 33, 89–111

SCHULLER, T. (2001) The Complementary Roles of Human and Social Capital, in *The Contribution of Human and Social Capital to Sustained Economic Growth and Well-Being*, International Symposium Report edited by the OECD and HRDC

SERFLING, R. J. (1980) *Approximation theorems of mathematical statistics* New York: Wiley, cop.

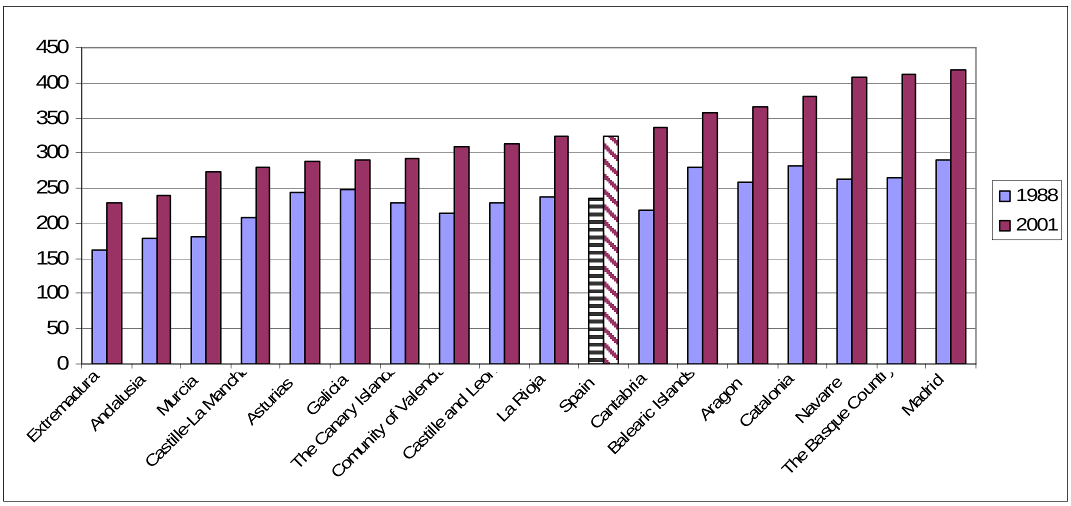
ZAK, P. J. and KNACK, S. (2001) Trust and growth *The Economic Journal,* 111, 295-321

Figure 1. Evolution of social capital services in 1995 constant €. Spain.



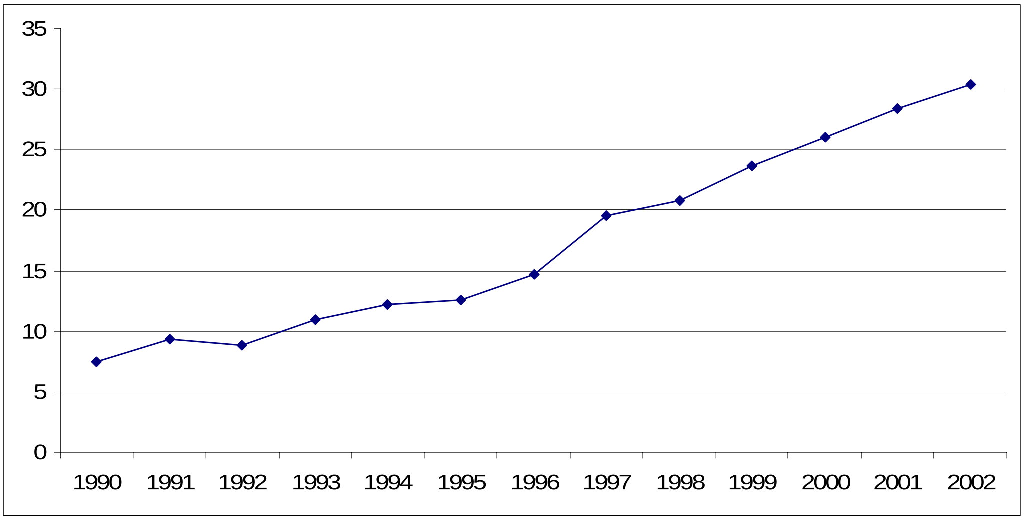
Source: IVIE

Figure 2. Regional distribution of social capital services per capita. Spain.



Source: IVIE

Figure 3. Spanish evolution of patent applications per capita (1990-2001)



Source: European Patent Office (EPO)

Table 1. Description of main variables in the analysis

	Patents pc	Social capital services pc		R&D expenditures pc			Human capital	
	Regional distribution	Social capital	Social capital growth	R&D pc	R&D pc growth	R&D regional distribution	HK	HK growth
	1990-2001	2001	1990-2001	2001	1990-2001	1990-2001	2001	1990-2001
Andalusia	6.86	239.78	1.92	55.21	6.53	3.72	17.67	4.14
Aragon	4.41	366.05	2.32	87.11	5.43	5.96	20.61	4.82
Asturias	1.50	287.14	0.91	67.97	6.52	4.40	17.69	4.57
Balearic Islands	1.05	356.93	1.90	32.69	10.41	1.82	14.22	3.40
The Canary Islands	1.99	291.71	1.81	57.29	11.87	3.53	15.22	1.88
Cantabria	0.45	335.85	3.23	64.71	4.76	4.42	15.53	2.41
Castille and Leon	3.20	312.76	1.98	89.04	7.87	4.73	19.55	5.04
Castille-La Mancha	12.98	280.44	1.76	30.73	9.45	2.27	15.77	5.36
Catalonia	20.17	379.77	1.62	153.86	5.90	10.05	19.45	4.21
Valencian Comunity	1.79	309.41	2.42	82.01	9.44	4.61	17.52	4.92
Extremadura	0.80	228.91	1.97	46.37	9.40	2.15	17.00	4.65
Galicia	2.34	290.23	0.93	65.27	11.15	3.30	15.27	6.57
Madrid	27.40	418.05	2.44	280.49	2.95	21.12	30.29	4.35
Murcia	1.44	273.01	2.83	62.49	6.27	3.97	18.25	4.95
Navarre	3.92	407.40	3.29	145.62	11.80	8.65	24.02	4.71
The Basque Country	9.32	412.40	3.16	195.02	6.39	12.00	23.55	3.87
La Rioja	0.39	322.82	2.31	60.52	14.41	3.30	18.38	4.09
Total	**100**	**325.23**	**1.99**	**113.89**	**5.63**	**100**	**19.94**	**4.53**

Note: Growth rates are calculated as accumulative annual growth rates

Table 2. Regression results for the negative binomial model with fixed effects. Dependent variable: number of patents

	(i)	(ii)	(iii)	(iv)
Constant	-9.053	-13.247	-13.146	-14.083
	*1.185****	*3.272****	*4.026****	*4.094****
ln (RD)	0.547	0.479	0.878	0.619
	*0.114****	*0.124****	*0.332****	*0.428*
ln (HK)	0.753	2.204	0.745	1.944
	*0.342***	*1.108**	*0.336***	*1.341*
ln (SK)	0.647	1.353	1.323	1.487
	*0.206****	*0.552***	*0.666***	*0.678***
ln(SK)*ln(HK)		-0.225		-0.185
		0.164		*0.201*
ln(SK)*ln(RD)			-0.057	-0.022
			0.053	*0.064*
ln (SpIn)	0.584	0.515	0.586	0.528
	*0.323**	*0.325*	*0.323**	*0.327**
ln (POP)	-0.053	0.009	-0.008	0.016
	0.165	*0.171*	*0.169*	*0.172*
Time trend	0.053	0.060	0.058	0.061
	*0.016****	*0.016****	*0.016****	*0.016****
Total semi-elasticity with respect to				
RD	0.547	0.479	0.532	0.487
$[\beta^{RD} + \beta^{RD\,SK}\ ln(SK)]$	*0.114****	*0.124****	*0.118****	*0.126****
HK	0.753	0.837	0.745	0.819
$[\beta^{HK} + \beta^{HK \cdot SK}\ ln(SK)]$	*0.342***	*0.344***	*0.336***	*0.346***
SK	0.647	0.754	0.680	0.747
$[\beta^{SK} + \beta^{RDSK}\ ln(RD) + \beta^{HK \cdot SK}\ ln(HK)]$	*0.206****	*0.219****	*0.208****	*0.219****
Pseudo-R^2	*0.149*	*0.150*	*0.149*	*0.151*
AIC	*1588.898*	*1588.994*	*1589.732*	*1590.877*
Schwartz BIC	*1612.125*	*1615.539*	*1616.277*	*1620.740*
Log-likelihood	-787.449	-786.497	-786.866	-786.438
Wald test	772.500	753.470	744.430	745.950
Prob	0.000	0.000	0.000	0.000

Notes: Fixed effects model with several levels of significance: 1%***; 5%**; 10%*
Standard errors are presented in italics below each associated parameter
The average values to calculate the semi-elasticities are: lnR&D=11.28; lnHK=2.66; lnSK=6.07

Table 3. Regression results for the negative binomial model with fixed effects. Public and private R&D efforts. Dependent variable: number of patents

	(i)	(ii)	(iii)	(iv)
Constant	-9.132	-13.724	-12.885	-15.094
	*1.238****	*3.22****	*4.009****	*4.202****
ln $(RD)_{business}$	0.188	0.145	0.102	-0.165
	*0.061****	*0.065***	*0.439*	*0.45*
ln $(RD)_{high\ education}$	0.111	0.104	-0.018	-0.132
	*0.065**	*0.067*	*0.263*	*0.261*
ln $(RD)_{public\ adms.}$	0.299	0.282	0.926	0.899
	*0.099****	*0.098****	*0.564**	*0.55**
ln (HK)	1.136	2.705	1.133	3.22
	*0.34****	*1.071***	*0.339****	*1.297***
ln (SK)	0.600	1.377	1.16	1.5
	*0.206****	*0.544***	*0.673**	*0.696***
ln(SK)*ln(HK)		-0.249		-0.335
		0.161		*0.201**
ln(SK)*ln$(RD)_{business}$			0.015	0.052
			0.074	*0.074*
ln(SK)*ln$(RD)_{high\ educ.}$			0.024	0.049
			0.052	*0.052*
ln(SK)*ln$(RD)_{public\ adms.}$			-0.103	-0.103
			0.092	*0.089*
ln (SpIn)	0.715	0.65	0.738	0.693
	*0.319***	*0.323***	*0.324***	*0.326***
ln (POP)	-0.035	0.013	0.019	0.049
	0.168	*0.17*	*0.171*	*0.174*
Time trend	0.037	0.047	0.039	0.045
	*0.016***	*0.017****	*0.016***	*0.017****
<u>Total semi-elasticity with respect to:</u>				
RD business	0.188	0.145	0.193	0.148
$[\beta^{RDbus} + \beta^{RDbusSK} \ln(SK)]$	*0.061****	*0.065***	*0.062****	*0.066***
RD high education	0.111	0.104	0.125	0.166
$[\beta^{RDh.e.} + \beta^{RDh.e.SK} \ln(SK)]$	*0.065**	*0.067*	*0.088*	*0.091**
RD public administrations	0.299	0.282	0.302	0.274
$[\beta^{RDp.a.} + \beta^{RDp.a.SK} \ln(SK)]$	*0.099**	*0.098****	*0.100****	*0.098****
HK	1.136	1.196	1.133	1.185
$[\beta^{HK} + \beta^{HK\cdot SK} \ln(SK)]$	*0.340****	*0.340****	*0.339****	*0.341****
SK	0.600	0.715	0.586	0.661
$[\beta^{SK} + \beta^{RDSK} \ln(RD) + \beta^{HK\cdot SK} \ln(HK)]$	*0.206****	*0.218****	*0.222****	*0.227****
Pseudo-R^2	*0.149*	*0.150*	*0.150*	*0.151*
AIC	*1592.210*	*1591.798*	*1596.499*	*1595.714*
Schwartz BIC	*1622.074*	*1624.979*	*1636.317*	*1638.850*
L-L	-787.10523	-785.89887	-786.24973	-784.85702
WALD	767.55	745.60	773.26	780.57
Prob	0.0000	0.0000	0.0000	0.0000
Sample size	204	204	204	204

Notes: Fixed effects model with several levels of significance: 1%***; 5%**; 10%*
Standard errors are presented in italics below each associated parameter
The average values to calculate the semi-elasticities are: $\ln RD_{bus}$=10.16; lnRDh.e.=10.11; lnRDp.a.=9.39;lnHK=2.66; lnSK=6.07

Table 4. Regression results for the negative binomial model with fixed effects. Dependent variable: number of patents. Public and private R&D efforts, and high and low income regions

High-income regions sub-sample

	(i)	(ii)	(iii)	(iv)
Constant	-7.096	-12.801	-15.365	-18.995
	1.672***	5.219**	5.000***	6.219***
ln (RD)$_{business}$	0.162	0.099	0.032	-0.336
	0.107	0.118	0.661	0.737
ln (RD)$_{high\ education}$	0.075	0.068	-0.006	-0.025
	0.061	0.063	0.351	0.344
ln (RD)$_{public\ adms.}$	0.301	0.317	1.365	1.513
	0.131**	0.131**	0.735*	0.721**
ln (HK)	0.819	2.671	0.796	2.752
	0.552	1.702	0.512	2.111
ln (SK)	0.879	1.653	2.007	2.376
	0.354**	0.756**	0.806**	0.883***
ln(SK)*ln(HK)		-0.275		-0.288
		0.239		0.3
ln(SK)*ln(RD)$_{business}$			0.023	0.075
			0.11	0.119
ln(SK)*ln(RD)$_{high\ educ.}$			0.012	0.018
			0.073	0.072
ln(SK)*ln(RD)$_{public\ adms.}$			-0.17	-0.194
			0.117	0.116*
ln (SpIn)	1.360	1.138	1.158	0.874
	0.603**	0.609*	0.734	0.779
ln (POP)	-0.267	-0.121	-0.051	0.083
	0.317	0.33	0.358	0.374
Time trend	0.042	0.052	0.053	0.058
	0.024*	0.025**	0.026**	0.026**
Total semi-elasticity with respect to:				
RD business	0.162	0.099	0.171	0.120
$[\beta^{RDbus} + \beta^{RDbusSK}\ln(SK)]$	0.107	0.118	0.108	0.117
RD high education	0.075	0.068	0.068	0.084
$[\beta^{RDh.e.} + \beta^{RDh.e.SK}\ln(SK)]$	0.061	0.063	0.115	0.119
RD public administrations	0.301	0.317	0.335	0.336
$[\beta^{RDp.a.} + \beta^{RDp.a.SK}\ln(SK)]$	0.131**	0.131**	0.124***	0.123***
HK	0.819	1.003	0.796	1.005
$[\beta^{HK} + \beta^{HK\cdot SK}\ln(SK)]$	0.552	0.567*	0.512	0.556*
SK	0.879	0.884	0.788	0.745
$[\beta^{SK} + \beta^{RDSK}\ln(RD) + \beta^{HK\cdot SK}\ln(HK)]$	0.354**	0.342***	0.391**	0.376**
Pseudo-R2	0.166	0.168	0.171	0.172
AIC	742.060	742.744	744.177	745.261
Schwartz BIC	763.937	767.052	773.347	776.861
L-L	-362.02996	-361.372	-360.08838	-359.63028
WALD	467.80	459.08	493.71	506.01
Prob	0.0000	0.0000	0.0000	0.0000
Sample size	84	84	84	84

Notes: Fixed effects model with several levels of significance: 1%***; 5%**; 10%*
Standard errors are presented in italics below each associated parameter
The average values to calculate the semi-elasticities are: $\ln RD_{bus}$=10.72; lnRDh.e.=9.78; lnRDp.a.=9.32;lnHK=2.79; lnSK=6.06

Low-income regions sub-sample

	(i)	(ii)	(iii)	(iv)
Constant	-9.924	-8.42	4.09	2.901
	2.525***	6.065	11.397	11.76
ln (RD)$_{business}$	0.089	0.094	0.809	0.955
	0.092	0.093	0.757	0.843
ln (RD)$_{high\ education}$	0.313	0.314	0.934	1.267
	0.149**	0.148**	1.191	1.454
ln (RD)$_{public\ adms.}$	0.074	0.061	-2.849	-2.877
	0.269	0.274	1.732	1.755
ln (HK)	1.1	0.591	1.115	-0.241
	0.532**	1.939	0.533**	3.34
ln (SK)	0.772	0.545	-1.348	-1.144
	0.334**	0.893	1.739	1.807
ln(SK)*ln(HK)		0.084		0.23
		0.308		0.559
ln(SK)*ln(RD)$_{business}$			-0.121	-0.144
			0.127	0.141
ln(SK)*ln(RD)$_{high\ educ.}$			-0.093	-0.147
			0.191	0.235
ln(SK)*ln(RD)$_{public\ adms.}$			0.465	0.466
			0.273*	0.276*
ln (SpIn)	0.32	0.357	0.61	0.575
	0.559	0.574	0.607	0.612
ln (POP)	-0.037	-0.033	-0.055	-0.052
	0.288	0.289	0.293	0.293
Time trend	0.049	0.047	0.041	0.038
	0.03	0.031	0.031	0.032
Total semi-elasticity with respect to:				
RD business	0.089	0.094	0.076	0.078
$[\beta^{RDbus} + \beta^{RDbusSK}\ln(SK)]$	0.092	0.093	0.093	0.093
RD high education	0.313	0.314	0.371	0.373
$[\beta^{RDh.e.} + \beta^{RDh.e.SK}\ln(SK)]$	0.149**	0.148**	0.154**	0.153**
RD public administrations	0.074	0.061	-0.025	-0.046
$[\beta^{RDp.a.} + \beta^{RDp.a.SK}\ln(SK)]$	0.269	0.274	0.262	0.269
HK	1.100	1.101	1.115	1.153
$[\beta^{HK} + \beta^{HK\cdot SK}\ln(SK)]$	0.532**	0.532**	0.533**	0.543**
SK	0.772	0.761	0.904	0.913
$[\beta^{SK} + \beta^{RDSK}\ln(RD) + \beta^{HK\cdot SK}\ln(HK)]$	0.334**	0.335**	0.357**	0.354**
Pseudo-R2	0.142	0.142	0.146	0.146
AIC	859.0560	860.9810	861.9250	863.7550
Schwartz BIC	884.1430	888.8560	895.3750	899.9920
L-L	-420.52798	-420.49072	-418.96257	-418.8774
WALD	314.8100	317.0400	327.3300	327.0600
Prob	0.0000	0.0000	0.0000	0.0000
Sample size	120	120	120	120

Notes: Fixed effects model with several levels of significance: 1%***; 5%**; 10%*
Standard errors are presented in italics below each associated parameter
The average values to calculate the semi-elasticities are: $\ln RD_{bus}$=9.77; lnRDh.e.=10.33; lnRDp.a.=9.43;lnHK=2.56; lnSK=6.07