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FROM CREATIVENESS TO INNOVATIVENESS: A FIRM-LEVEL INVESTIGATION

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From creativeness to innovativeness: a firm-level investigation

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Abstract

This paper assesses the existence of knowledge externalities in the form of creative human capital spillovers that affect firm innovative performance. Relying on a large sample of Italian manufacturing firms, a knowledge production function is estimated and the residuals regressed on regional creative workforce indicators interacted with spatial agglomeration variables and measures of knowledge transmission mechanisms. The estimates show that regional density of creative human capital has a positive effect on firm innovativeness only after a critical mass is achieved and only after accounting for the presence of local universities, industrial districts and entrepreneurial activities related to knowledge-intensive services.

Keywords: creative human capital; innovativeness; knowledge production function; nonlinearity

JEL: L60; O31; R10; R15

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"[*U*]*ntil very recently it was rare to find innovation research applied to creative industries. We suspect this is due to two factors: first, that they were generally seen as 'frivolous' […]; second, because much novelty is seen to involve aesthetic issues, fashion trends, and the sorts of content discussed at length by media and cultural studies. Determining what is original in aesthetics and content is a minefield which innovation researchers are understandably wary of*" (Miles and Green, 2010, p. 185).

1. Introduction

Does local availability of creative human capital increase incumbent firms' innovative performance? If so, does this effect depend on the regional level of industrial specialization or diversification? And what are the main transmission mechanisms of creativity spillovers? The answers to these questions might be very important for understanding the drivers of regional development, and they are receiving increasing attention in either the quantitative economic geography or (micro)economics of innovation literatures. Following Richard Florida's (2002a), seminal contribution, most studies have focused on estimating the effects of creativity on regional development variables, such as population or employment growth (Marlet and van Woerkens, 2007; McGranahan and Wojan, 2007; Boschma and Fritsch, 2009; Andersen et al., 2011), rate of entrepreneurship (Lee et al., 2004; Wojan and McGranahan, 2007; Boschma and Fritsch, 2009), regional wages (Florida et al., 2008; Mellander and Florida, 2011), total factor productivity (Marrocu and Paci, 2012), on indirect innovation variables such as research and development (R&D) and patents (Andersson et al., 2005; Knudsen et al., 2008; Boschma and Fritsch, 2009) or on providing case study evidence (Stolarick and Florida, 2006). Little research has been devoted to investigating the role of creativity on direct measures of innovation output, which is important for extending our knowledge on the link between human capital and technological change and also for understanding how creativity affects the productivity growth of firms and regions.

According to some scholars (Crépon et al., 1998; Lööf and Heshmati, 2002; OECD, 2008; Johansson and Lööf, 2009; Antonietti and Cainelli, 2011), productivity is not driven so much by innovation inputs, but rather by innovation outputs. That is, the economic success of firms and regions is driven *directly* by their ability to generate and successfully commercialize new products rather than by investment in R&D. This applies particularly to regions where formal R&D activities are relatively less frequent or less important for introducing new products into the market, or where 'territorial creativity' enables the generation and diffusion of new ideas and identifies other innovation models than those based on the 'R&D-invention-innovation' sequence (Camagni and Capello, 2012).

In this paper, I argue that the well established positive effect of innovativeness on firm productivity is explained or mediated by the impact of creative human capital in the first stage of innovation. I propose an innovation-based explanation for the mechanism that allows creativity to impact on firm competitiveness and on aggregate regional development. Existing work, which considers employment, population or productivity growth as the dependent variable, addresses the issue of knowledge spillovers only indirectly. According to Greunz (2004, p. 566), 'a more direct approach consists of testing the impact of spatial environment on new variety, on the capacity of regions to develop new innovations, or on the adjustment of new technology'.

I enrich Florida's theoretical and empirical arguments by providing some econometric evidence of how creative employment and technological innovation are related. In particular, I argue that the relationship between local creativity spillovers and the innovative performance of incumbent firms is indirect since it relates to 'what is left behind' by R&D and other traditional inputs, in the linear model of the innovation process, and is nonlinear since it involves both threshold and interaction effects with local universities, industrial districts and entrepreneurial activities.

Firm-level data allow a more direct and microeconomically robust approach to the assessment of creative human capital externalities, which is based on the estimation of a firm-level knowledge production function rather than on a city-region level of analysis. Consistent with the theoretical framework proposed by Moretti (2004a), if such externalities exist, I should observe that firms located in regions with high density of creative human capital, achieve higher levels of production and commercialization of innovation from the same inputs compared to similar firms in regions with low levels of creative human capital.

The paper is organized as follows. In Section 2, I discuss the motivation for and the conceptual background to the paper by providing some theoretical foundations for creative human capital spillovers (2.1), and focusing on the mechanisms through which creative knowledge spreads across firms and individuals (2.2). In Section 3, I describe the data and the measures of creativity employed (3.1), the innovation variables utilized and the empirical strategy adopted (3.2). In Section 4, I present and comment on the econometric results (4.1), taking account of endogeneity and non-linearity issues (4.2). Section 5 concludes.

2. Conceptual framework

2.1. Creative human capital spillovers and firm innovation

Why should firms located in 'creativity-dense' regions be more innovative than similar firms located elsewhere? Traditionally, the literature on human capital spillovers has focused mainly on the microeconomic foundations underlying the positive externalities of education on productivity. In this perspective, firms in cities and regions endowed with better skilled workforces demonstrate higher productivity for several reasons. First, the local concentration of human capital contributes to knowledge accumulation and sharing, rendering all workers in the area more productive (Moretti, 2004a). This technological externality is shown by the aggregate production function and is due to learning through social interactions (Lucas, 1988) or the complementarity between physical and human capital, in a context of costly job search (Acemoglu, 1996).

Second, human capital increases aggregate economic growth through its effects on reducing crime (Lochner and Moretti, 2004; Machin et al., 2011; Hjalmarsson and Lochner, 2012), enhancing citizens' participation in voting and democratic choice (Milligan et al., 2003; Dee, 2004; Acemoglu et al., 2005), increasing health outcomes (Grossman and Kaestner, 1997; OECD, 2001; Lleras-Muney, 2005; Devaux et al., 2011) and reducing pollution (Appiah and McMahon, 2002). Third, human capital has an impact on consumption and spending in that higher-skilled employees earn higher wages than less skilled ones (Black and Lynch, 1996; Glaeser, 1999).

If we want to examine the microfoundations of *creative* human capital spillovers, then innovation rather than production, would seem intuitively to be the obvious focus since 'creativity involves thinking that aims at producing ideas or products that are relatively novel and that are, in some respect, compelling' (Sternberg 2006, p. 2) and also 'it is a matter of sifting through data, perceptions and materials to come up with combinations that are new and useful' (Florida 2002a, p. 35).

The microeconomic approach to assessing the magnitude of human capital spillovers (Moretti, 2004a, b) which considers that greater regional endowment of more skilled individuals increases marginal productivity of labour and capital inputs simultaneously. Similarly, I assume that local creative human capital positively affects the innovative performance of incumbent firms by increasing the marginal productivity of all innovative inputs - R&D, information and communication technology (ICT) and internal human capital - simultaneously. In other words, firms in locations with a larger supply of workers will produce more innovations from the same amount of R&D capital as firms located elsewhere, or will produce the same amount of innovative output as other firms, but with the use of fewer R&D resources.

Borrowing from elements of standard human capital theory, it can be shown that this can occur through social connections and learning, that is, through weak ties that develop in social networks that are rooted in places where culture – in its various forms - is produced and consumed. This a mechanism is described by Currid, 2007, p. 71: [p]eople talked. They compared notes. They changed jobs. And when one engineer or designer meets with another to talk about how a new co"mputer's design will fit with the hardware inside, or whether a particular fabric will work with a designer spring collection, chances are they exchange a lot of ideas […] The exchange of knowledge ended up translating into new ideas and product innovations". Currid (2007, p. 84) goes on to say that: 'firms have to know where to find the skills they need, and the potential employees have to make themselves known. Social networks are simply the best and most efficient way to do this'.[1]

Another approach is to examine the complementarity between regional creative human capital and the firm's ICT endowment. For instance, the efficiency of use of software programs, web applications and network technologies increases if the firm interacts with creative programmers and developers, or creative communities and customers. Local availability of skilled workers renders ICT capital more productive, which reduces the marginal costs of innovation and increases the size of the market for ICT assets. Higher productivity of ICT capital can also be a source of attraction for talent (Florida, 2002a, b), which increases regional endowment of creative human capital and the generation of knowledge spillovers across incumbent firms.

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[1] A recent development in work on social interaction the phenomenon of collaborative design or crowdsourcing (Amabile, 1996; Howe, 2006): innovative firms can delegate creative work to a group of strangers assembled to perform a task. 'Crowd' members communicate through the designs they produce: one crowd generates ideas, another evaluates these ideas and a third selects among and combines existing ideas. Creative ideas and, thus, potential innovations, emerge through this evolutionary process (Yu et al., 2012).

A third source of advantage is the formal or informal connections between firms' R&D resources and external research or university facilities. Consistent with the 'open innovation model' (Chesbrough, 2003; Laursen and Salter, 2005), firm R&D activities may benefit from interactions with external sources of creative knowledge or local creative knowledge-intensive services, which make intra-mural R&D more efficient or less relevant for the development of new ideas. Advertising and design are one of the knowledge-intensive business services (KIBS) that typically interacts with innovative manufacturing activities. Formal interactions between innovative firms, and KIBS that employ creative workers, may help the former to create new products or successfully commercialize existing ones, for instance, through web applications, customized high-skill services, or creative consultancy and marketing. For the Montréal region case, Stolarick and Florida (2006) provide evidence that the primary linkage between innovative firms and creative people is via design. For Europe, Hollanders and van Cruysen (2009, p. 5) provide cross-country evidence on the interplay between creativity, that is, the generation of new ideas, design, that is, the shaping of new ideas into new products, and innovation, that is, the exploitation of ideas through the successful marketing of new products. In addition, Ciriaci (2011) finds that design has a strong positive impact on firms' innovative performance, regardless of the size of the firm. For Italy, Bertacchini and Borrione (2012) show that the design industries are highly relevant sectors of the creative economy, especially in non-urbanized areas.

2.2. Mechanisms for transmitting knowledge spillovers

How are creativity spillovers transmitted across firms and individuals? The literature on the geography of innovation identifies three main knowledge transmission channels, which apply also to the case of creative knowledge (Audretsch and Feldman, 2004).

The first is local presence of research laboratories and universities. According to Jaffe (1989), Mansfield (1995), Audretsch and Feldman (1996), Anselin et al., (1997), Feldman and Audretsch (1999), Varga et al. (2000) and Schiller and Revilla Diez (2010), knowledge created in university laboratories spills over and contributes to the generation of commercial innovations by private enterprises, or materializes in the creation of new enterprises and knowledge-based start-ups (Abramovsky et al., 2007; Baptista and Mendonça, 2010; Acosta et al., 2011). Since knowledge spillovers are limited by distance (Basile et al., 2012), the benefits from academic research accrue to the nearest firms. If we assume that universities and research organizations are the main developers and employers of talent and creative human capital, I would expect that proximity to a university would the matching and the mutual transmission of ideas between creative workers and innovative firms.

The second mechanism is social capital and the existence of relational networks. Innovation does not occur in isolation, but is facilitated by the establishment of inter-organizational networks (for a recent review see Tranos, 2013), or, in other words, by the underlying *social milieu* (Currid and Williams, 2010). The literature on industrial districts (Becattini, 1990; Cainelli and De Liso, 2005; Cainelli et al., 2007), *milieux innovateurs* (Camagni, 1991) and collective learning (Capello and Faggian, 2005) emphasizes that the transmission of technological knowledge is driven not just by physical proximity, but also by cognitive and relational proximity (Basile et al., 2012). It relies on shared values, reciprocal trust, local embeddedness, cooperation mechanisms and the presence of intermediate social institutions which reduce uncertainty and transaction costs.

The third mechanism involves entrepreneurship, that is, the creation and growth of new enterprises. According to the knowledge spillovers theory of entrepreneurship (Audretsch and Keilbach, 2004, 2007), a start-up venture serves as a conduit for knowledge spillovers, through the commercialization of ideas. Therefore, a context with more advanced knowledge will likely provide more entrepreneurial opportunities. Pfirrmann (1994) shows that the innovative activity of small and medium firms is higher in regions with a higher endowment of knowledge resources. Lee et al. (2004) provide support for this finding, showing that social diversity and creative human capital are positively correlated with new firm formation and regional patenting production in the US.

A final aspect is the type of industrial structure that is considered more conducive to innovation. Scholars in regional economics have long debated whether firms' innovative capacity is favoured more by a specialized or diversified industry environment, but has not reached a consensus (Beaudry and Shiffauerova, 2009). According to this literature, both inter-industry Marshall-Arrow-Romer (MAR) externalities, and intra-industry Jacobs externalities facilitate knowledge spillovers across firms. For instance, Feldman and Audretsch (1999) consider local variety to be a driver of industrial innovation, while Ejermo (2005) finds a positive and significant role for specialization. At the same time, Shefer and Frenkel (1998), Paci and Usai (1999), van Oort (2002), Greunz (2004) and van der Panne (2004) among others, find that both MAR and Jacobs externalities have a positive effect on regional innovativeness, while Massard and Riou (2002) find a negative effect for specialization and no effect for diversification.

Against this background, I would expect firms located in regions with high concentrations of creative human capital to show better innovative performance than firms located elsewhere. In addition, I would expect this relationship to be particularly strong in regions with a high presence of university and research facilities, higher levels of social and relational capital, and an environment conducive to entrepreneurship. I would also expect creativity spillovers to be greater in a more diversified environment compared to a specialized one since creative activity often requires the recombination of heterogeneous knowledge.

In line with the findings from spatial agglomeration studies, I expect the creativeness-innovativeness relationship to be nonlinear. This nonlinearity can be caused by congestion costs or, and more likely, the need for a critical mass of creative human capital for knowledge to diffuse throughout the region.

Finally, since innovation clusters around knowledge externalities which reduce the costs of scientific discovery and commercialization, innovative firms tend to be located in areas where there is an accumulation of resources based on previous innovation success (Audretsch and Feldman, 2004). Similarly, since creative human capital tends not to be randomly distributed across regions, but to be concentrated in high technology areas with better amenities, cultural opportunities and openness (Florida, 2002a, b, c; Andersson et al., 2005), I expect that firm innovativeness and regional creativity endowment to be endogenous.

3. Data and empirical methodology

3.1. Data and creativity variables

The data come from the 10th survey of manufacturing firms administered by the Unicredit banking group (formerly Mediocredito Centrale and Capitalia). It provides information on a representative sample of 5,137 Italian manufacturing firms during 2004-2006. Firms with more than 500 employees are fully represented; firms employing between 11 and 500 employees are selected on the basis of region of location, employment size and sector of economic activity. The survey responses provide information on firms' innovative activities, labour force composition and internationalization modes, and the market relationships between firms, the banks, customers and competitors.

The data were cleaned to remove non-manufacturing firms, inconsistencies and missing observations in the variables of interest, yielding a final sample of 3,197 companies.

Table 1 shows their distribution by employment size, macro-area (NUTS1 region) and industry.

Data on the local creative workforce come from the Census of Population and Housing carried out by the Italian Statistical Office (ISTAT) in 2001. Following Florida, I define a creative human capital employment measure, at the level of the Italian NUTS3 regions, corresponding to 103 Adminisrative Provinces in 2001.[2] This index includes the number of technical, scientific, organizational and intellectual occupations with high levels of qualification or specialization, that is, tertiary level of education. I call this the Creative Graduates (CG) variable; it includes various types of knowledge-based occupations. In order to distinguish between the roles played by education and creativity (as suggested by Glaeser, 2005), following Marrocu and Paci (2012), I define a variable computed as the difference between the regional stock of university graduated workers (irrespective of their actual occupation) and the stock of graduates employed in creative work. This provides a measure of Non-Creative Graduates (NCG), that is, tertiary educated employees not engaged in creative jobs[3].

For each category, I calculate an absolute density measures of creativity, given by the (log) number of creative workers per square kilometer of NUTS3 land area: DenCG and DenNCG. Figure 1 depicts the distribution of these creative human capital variables across the Italian provinces. The rationale for using density variables is that it enables better accounting for the effect of spatial proximity on innovativeness (Carlino et al., 2007): as

[2] According to Boschma and Fritsch (2009), this spatial level is particularly relevant for analysing the relationship between the creative class and regional economic development, since place of residence and place of work are usually in same region. Bertacchini and Borrione (2012) argue that NUTS3 regions enable a reasonable balance between descriptive accuracy and statistical noise regarding province specialization in creativity.

[3] As suggested by Marrocu and Paci (2012), since the local creative workforce and local graduate workforce measures are highly correlated (0.9), they should not be included together in the estimates.

density increases, so does the probability of firms to find creative workers. Therefore, I would expect the innovation performance of firms to increase with location in creativity-denser regions compared to location elsewhere.

3.2. Empirical strategy

In order to estimate the existence and magnitude of creative human capital externalities, I rely on the knowledge production function (KPF) approach. The KPF is a relationship linking innovation inputs to measures of innovation output (Griliches, 1979). Following the accounting framework developed by Mairesse and Mohnen (2001, 2002), I identify two indicators of innovation output. The first is the expected share of innovative sales in total firm turnover, that is, the percentage of innovative sales that can be expected when controlling for a number of explanatory variables that affect innovation activity. This variable is a sales weighted measure of the number of innovations, and is explained by an explicit econometric model or accounting framework. Table 2 shows the sample distribution by firm size, area of localization and two digit industry.

Considering I as the share of innovative sales for firm i at time t and L_R, K_R and K_{ICT} as the variables, respectively, for R&D labour, R&D investment and ICT investment (Hall et al., 2012), I estimate the following standard Cobb-Douglas version of the KPF:

$$(1)\ I_{it} = A_i L_{Rit}^{\alpha} K_{Rit}^{\beta} K_{ICTit}^{\gamma} .$$

The second innovation output variable, A, represents the firm's 'extent of innovative ability or capacity' (Mairesse and Mohnen, 2002, p. 226), or its 'innovativeness'. While innovative sales can be considered the expected output of innovation activity, as explained by the underlying innovation model, innovativeness can be taken as the unexplained or unexpected part of the actual observed share of innovative sales, not unaccounted for by the model. According to Mairesse and Mohnen (2001, 2002), innovativeness is to innovation what total factor productivity (TFP) is to output: both account for omitted performance factors, such as technological, organizational, cultural, environmental, or social factors not captured by the respective innovation or production function. Mairesse and Mohnen (2001, p. 8) state that: 'both also correspond to other sources of misspecification and errors in the underlying model of the innovation or production function, and could be rightly viewed as measures of our ignorance'. Therefore, firm innovativeness is computed as the residual in a model that explains innovation performance as a function of a series of variables for firm size, sectoral specialization, organizational structure and innovation input, according to the microeconometric literature on the determinants of innovation. Table 3 summarizes the sample distribution based on firm size, area of firm location and the two digit industry. On average, innovativeness is higher for small-sized firms located in the North East and South of Italy, and belonging to the scale intensive and supplier dominated sectors, which include most of the 'Made in Italy' industries.

Since creativity spillovers are not directly observable by the firm, I assume that they impact on the innovative performance indirectly through the term *A*, similar to how standard agglomeration economies increase firm productivity through their impact on TFP (Martin et al., 2011).[4] Hence, firm innovativeness *A* depends on a firm-level component *U*, and on a set of variables characterizing the surrounding environment, including DenGC and DenNCG:

(2.1) $A_{i,t} = U_{i,t} \cdot DenCG_{C,R,t-1}^{\delta} \cdot \mathbf{X}_{R,t-1}^{\eta}$,

(2.2) $A_{i,t} = U_{i,t} \cdot DenNCG_{C,R,t-1}^{\delta} \cdot \mathbf{X}_{R,t-1}^{\eta}$

[4] The use of a two-stage approach also provides a simpler way to test for endogeneity.

Log-linearizing expression 2.1 and 2.2, I obtain:

(3.1) $a_{it} = \delta DenCG_{\mathrm{C,R,t\text{-}1}} + \eta \mathbf{X}_{R,t-1} + u_{it}$,

(3.2) $a_{it} = \delta DenNCG_{\mathrm{C,R,t\text{-}1}} + \eta \mathbf{X}_{R,t-1} + u_{it}$

Relying on the literature surveyed in Section 2, the variables included in vector **X** should capture: nonlinear terms in the density variables; industry composition of the region; regional endowment of universities; level of social capital and relational networks; regional level of entrepreneurship; and the interaction between creative human capital and its transmission mechanisms.

Potential congestion or threshold effects are measured including the squared terms of the two creative human capital variables (DenCG^2 and DenNCG^2). The degree of local specialization (Spec) and sectoral variety (Var), are given, respectively, by the regional share of employment in the two digit sector *s* in region *R* (E_{sR}/E_R), and by the the inverse of the Herfindahl concentration index calculated at the three-digit level ($1\Big/\sum_{s=1}^{S} p_s^2$, where p_s denotes the employment share of the three-digit sector *s*). The presence of universities is given by the number of athenaeums in the NUTS 3 region (University) in 2001, as provided by the Italian Ministry of Education and Research.

Social capital, defined as a set of rules and social behaviours (including trust, civic sense and propensity for cooperative behaviour) that favour coordination of individual actions (Putnam, 1993), is measured by a set of five alternative indicators. The first is an index of provincial 'districtization' (District); it is provided by De Arcangelis and Ferri (2005) and is computed on Census data for year 1991. It is manufacturing employment in all the local labour systems belonging to an industrial district area in each province, over total manufacturing employment in the province. The District index ranges between 0 and 1, and measures the importance of district employment in the region: the higher the index, the higher the weight of industrial districts in the NUTS 3 region. This proxy should capture the interplay between local division of labour, propensity to cooperate, propensity to establish relational contracts and level of common values and norms. It encompasses a mix of production and social aspects.

The other four indicators are from Arrighetti et al. (2003) and Arrighetti and Lasagni (2011). The first is a measure of civic capital similar to that provided by Putnam (1993), and corresponds to a standardized index (based on principal component analysis) of three elements: provincial share of literate population in 1965, political preferences expressed in the 1963 national elections, and turnout in the 1974 referendum on divorce. The second is a measure of negative social capital, given by a standardized index of the number of official complaints concerning promissory notes and banking cheques plus the number of not accepted bills per 1,000 inhabitants in 1996, and the number of crimes against the national heritage, economy, industry and trades (that resulted in a formal court case) per 1,000 inhabitants in 1996. This index aims at capturing the propensity of the local population to act opportunistically in managing market transactions. The third is a measure of the local activism of intermediate institutions, given by a standardized index based on the following: the importance of local banks; the degree of embeddedness of the local Chambers of Commerce; engagement of local public administration in financing provision of local public goods (e.g. justice, police, education, infrastructures); and degree of technical and vocational education with respect to the level of industrialization in 1951. The fourth is given by a standardized index of the local propensity to create economic associations in 1982, based on the average number of economic and cultural associations per 100,000 inhabitants.[5]

Finally, relying on publicly available data extracted from Infocamere's Movimprese dataset (http://www.infocamere.it/movimprese), I compute regional entrepreneurship in two ways: first, as the (log) number of new firms established in each province (Entrep); second, as the (log) number of new KIBS firms ($Entrep^{KIBS}$), identified by NACE codes 72-74, which include computer and related activities, R&D and other technical and professional services such as management consulting, architectural and engineering activities, advertising and design.

All these variables are interacted in the estimates with creative and non-creative human capital in order to capture potential complementarity effects. A positive and statistically significant effect of the interaction terms signals that the effect of creativity on firm innovativeness is mediated by the presence of a set of regional level knowledge transmission mechanisms.

The first-stage dependent variable measures actual innovation output, computed as the share of sales from new products. This variable has two features which make standard ordinary least square (OLS) estimates unreliable: first, it is bounded between 0 and 1; second, it has a left-skewed distribution. Thus, I estimate the KPF following the standard microeconometric literature on innovation (Crépon et al., 1998; Mairesse and Mohnen, 2001, 2002; OECD, 2008) and apply logit transformation to the share of innovative sales. The logit share of innovative sales (I), then is defined as $\ln[I/(1-I)]$; in this case, all the zero values are excluded from the computation, so that the number of observations is reduced to 1,397. Since

[5] As a robustness check, I included a fifth social capital indicator (Social), based on Cartocci (2007), which is given by an average standardized index of: local diffusion of newspapers in 2000-2001; electoral participation between 1999 and 2001; blood donation in 2002; participation in sports associations in 1999-2002.

not all firms are innovative, and there is potential selection bias, I specify the KPF in terms of a generalized Tobit model (hereafter Heckit) through two equations: the first accounts for the propensity to innovate, measured by a dummy variable which takes the value 1 if the firm records a positive share of innovative sales; the second accounts for innovation intensity, measured by the logit share of innovative sales.

Following the approach in OECD (2008), in the selection equation I use the following variables as regressors: firm size (*Size*), given by the log of average turnover in 2004-2006;[6] group membership (*Group*), given by a dummy equal to 1 for firms belonging to a business group or a consortium; a dummy for firms engaged in exporting activities (*Export*); a dummy that is equal to 1 if the firm benefited from tax relief in 2004-2006 (*Tax reliefs*); three variables for cooperative activities, given by the share of financial contribution to extra-mural R&D expenditure respectively from universities and research centres (*Coop Univ/Res*), other firms (*Coop firm*), and other organizations (*Coop other*), on trade fairs, associations, conferences, exhibitions and so on.[7] I also include 22 two-digit industry-specific dummies to control for technological conditions and sector-specific effects.

In the outcome equation, I exclude the tax reliefs[8] dummy and include in the set of regressors the following variables: log share of white collar workers (i.e. top and middle

[6] Due to the presence of numerous missing values, I do not include the traditional variable of (log) employment.

[7] The data exploited here (unlike Community Information Survey data) do not provide information on the factors hampering innovation activities.

[8] Tax reliefs are excluded in order to make second stage estimates robustly identified. This assumes that benefiting from tax relief may significantly improve the probability that the firm will introduce a new product, without necessarily affecting the degree of its market success. The partial correlation between tax reliefs and the propensity to innovate is 0.104 (significant at 1% level), whereas that between tax reliefs and the logit share of innovative sales is 0.004 (and not statistically significant), which supports this assumption.

managers, executives, clerks) as a proxy for firm human capital (*HC*);[9] the log value of average innovation input expenditures, including R&D, design and training (*Input*); and the log value of average expenditures in ICT (*ICT*). Appendix Table A1 present the results of the Heckit estimate for this basic specification of the KPF, where all variables show the expected sign. The residuals of the outcome equation are then extracted and used to compute firm innovativeness a_i.

4. Estimation results

4.1. The impact of creativity on firm innovativeness

Tables 4 and 5 present the results of the OLS estimates of the effect of DenCG and DenNCG respectively, on innovativeness. Columns (1) and (2) show that, when the squared terms are excluded, the estimated coefficients are never statistically different from zero. If the squared terms are included there is a strongly significant threshold effect. Firms become more innovative only after achievement of a critical mass of local creative human capital. In particular, I find a minimum threshold of 14.55 CG and 5.54 NCG per km^2, which are well above the mean and median values of DenCG and DenNCG respectively. Until these values are achieved, a higher density of creative workers may be detrimental to firm innovativeness. This may be due to: increased search and matching costs for both firms and creative workers; insufficiently competitive market for creative ideas, which increases the price of creative services; or, for incumbent creative workers, lack of networking opportunities for knowledge exchange and cross-fertilization of ideas. Following Jacobs (1969), it seems that a critical mass of creativity is crucial since: 'the concentration of creativity leads to greater chances of

[9] Since it includes many creative occupations, this variable also measures the firm's creative human capital stock. Its inclusion in the first-stage equation avoids potential double counting and allows better capture of spillovers effects by the coefficients of the local creative density variables in the second stage.

more creativity happening', so that '[t]he number of creative people lends itself to great possibilities for new innovations, artistic collaborations, and possibilities of discovery of new types of music, fashion, and art' (Currid, 2007, p. 91).

Column (3) in Table 4 and Table 5 show that creativity spillovers complement the degree of industrial variety in the region, whereas there is no significant effect of interaction with local specialization. A higher density of creative human capital increases firms' innovativeness as the regional industry composition becomes more diversified. Note also that this effect is slightly higher for DenCG than DenNCG, the difference being significant at the 10% level. This result is in line with Spencer's (2012) simulation exercise, from which it emerges that individuals tend to be more creative in larger and more diverse places.

Column (4) in Table 4 and Table 5 shows the estimation results for the interaction between local creative workforce and the three main channels of transmission for knowledge spillovers. In relation to its effect on firm innovativeness, creative human capital is complementary with the number of universities and the 'districtization' of the region. There is no effect for the other four social capital variables (results not reported here for reasons of space) or for the Entrep variable. I interpret these results as follows. The condition for local creativeness positively affecting firm innovativeness depends less on civic sense and reciprocal trust building and more on local social capital combined with the industry make-up and a productive environment characterized by high division of labour, particularly among small firms. Again, this combines production and social aspects.

Column (5) in Table 4 and Table 5 shows a positive and significant effect for DenCG interacted with the rate of local entrepreneurship in KIBS activities, but no significant effect for regional level of KIBS entrepreneurship and DenNCG. This shows that creative human capital tends to support incumbent manufacturing activities via the provision of skill-intensive services.

The results in Column 6 in Table 4 and Table 5, where both the squared terms and the interaction terms are included, confirm most of the previous results, and include all the variables.[10] The exception is the interaction between DenNCG and the District variable: when the squared term of the former is included, the interaction term becomes statistically insignificant.

To sum up, higher density of creative human capital increases firms' innovativeness after: a regional critical mass of creative workers is achieved in a highly diversified regional industrial environment, with several regional universities and high regional entrepreneurial participation in KIBS. With respect to non-creative human capital spillovers, the results are weaker: overall, the main transmission mechanism is the number of universities in the province in which the firm is located.

4.2. Endogeneity and nonlinearity

It is typical of agglomeration studies that the relationship between output and density is potentially endogenous (Ciccone and Hall, 1996). This endogeneity may be due to: (i) simultaneity between the dependent variable and the covariates; (ii) unobservable factors that affect (innovation) output without being strictly related to local (creative workforce) density.

In the absence of panel data, the first cause can be overcome by establishing a five year time lag between the innovation output and creativity measures: the former is measured in 2006 and the latter in 2001. Assuming that local creative workforce remains stable over a five-year time span, this should avoid the possibility that positive or negative shocks in firms' innovative outcome might be affecting the capability of the region to attract talent. The second issue is dealt with by re-estimating equation (3) using a two-stage least squares (2SLS)

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[10] I included all the variables because the Ramsey RESET test in Columns 4 and 5 in Table 4 and Table 5 rejects the null hypothesis of no omitted variables.

instrumental variables procedure. Following Boschma and Fritsch (2009), as an instrument I use a cultural opportunity index (COI), given by the share of the workforce active in cultural and recreational activities, such as restaurants, bars, film and video, radio and television, other entertainment, libraries, museums and sports (NACE codes 553, 554 and 921-926), computed for each province in year 1991 from ISTAT Census data. This assumes that the creative workforce is attracted not only, or not completely, by a high-income area, but rather by the 'cultural attractiveness' of regions with high degrees of openness, diversity and tolerance[11] (Florida, 2002a, b, c; UNCTAD, 2010; Simonton, 2011).

Column (1) in Tables 4 and 5, shows the corresponding Durbin-Wu-Hausman endogeneity test for each 2SLS estimate. Results are reported in the last row in Tables 4 and 5. The estimated linear coefficients of both DenCG and DenNCG are not statistically significant. Looking at the goodness of fit of the 2SLS approach, I note a strong association with the instrument: the estimated coefficient of the COI is highly significant, the first-stage adjusted R^2 is above 0.9, the F statistic is highly above the rule-of-thumb value of 10, and the reported minimum eigenvalue statistic from the Stock and Yogo test is well above the critical value (16.38) for not rejecting the null hypothesis of weak instruments. Also, looking at the p-value of the Durbin-Wu-Hausman test, I observe that the null hypothesis of exogeneity is never rejected, so these variables should be taken as exogenous and the OLS estimates considered consistent.

In addition to endogeneity, the presence of nonlinearities can be a problem. If congestion effects occur, the relationship between innovative output and creativity will be inverted U-shaped; if a threshold effect occurs, the relationship between creativity and innovation will be U-shaped.

[11] As a robustness check, as an instrument in the 2SLS estimates I use the Tolerance index provided by Florida and Tinagli (2005). The results were qualitatively unchanged.

As already explained, to test for the presence of nonlinear effects I introduce the squared terms of the density variables in the OLS estimates.[12] In addition, I test also for the strength of these nonlinear effects by separately estimating a set of generalized additive models (GAM) of innovativeness on DenCG and DenNCG, where a penalized log likelihood function is minimized. The smoothness of the resulting estimated function is given by the specified 'equivalent degrees of freedom', in this case 2 (Hastie and Tibshivani, 1990). The presence of a second order curvilinear effect is given by the magnitude and statistical significance of the so called 'gain' statistic, which corresponds to the difference in the normalized deviance between the GAM and a model with a linear term for density of creative workers: the larger the gain and the higher its significance, the higher the non-linearity associated with that variable.

Table 6 presents the results of the GAM estimates. The magnitude and level of significance of the gain statistic shows that true non-linearity emerges only for the two density variables; for all other covariates a linear specification is preferred. Combined with the results of the Ramsey test for omitted variables, this confirms the need to account for non-linear effects in the creativeness-innovativeness relationship.

5. Conclusions and policy implications

In this paper I assessed the existence of knowledge externalities in the form of creativity spillovers affecting firms' innovation performance. I exploited rich data on Italian manufacturing firms and show that, after controlling for R&D, ICT and human capital inputs, firm innovativeness is positively affected by the regional density of creative human capital.

However, this relationship is highly non-linear: positive externalities arise only after a critical mass of creative workers is reached, and only if the local presence of a creative

[12] In unreported estimates, I included the cubic terms, but they were never statistically significant.

workforce is linked to a diversified industry grouping, to the presence of universities, to the level of 'districtization' of the region, and to a high rate of entrepreneurship related to knowledge-intensive business service activities. This is evidence that creative ideas do not diffuse automatically across space, but are transmitted to incumbent firms through formal channels. These results complement existing evidence which demonstrate the existence of a positive relationship between urban density and technological innovation (Andersson et al., 2005; Carlino et al., 2007; Knudsen et al., 2008), since "density helps to drive the formation of these connections by enabling more frequent interactions which occasionally give rise to these innovation-generation connections" (Stolarick and Florida, 2006, p. 1814). Moreover, these results are in line with previous studies in social psychology and evolutionary economic geography, which show that larger and diversified locations are the best environment for generating creative economies of scale (Spencer, 2012).

These results have also two policy implications. The first is that increasing the local availability of creative jobs can foster firm capability to generate and successfully commercialize new ideas, especially in the absence of or as an alternative to large R&D facilities. In this respect, my results are in line with the findings in the *innovative milieux* literature, which show that social learning helps to explain the processes of knowledge creation and diffusion within and between small and medium-sized firms. However, the presence of critical mass effects suggests that, in order for knowledge externalities to emerge, cities or regions must be sufficiently large or sufficiently dense: external benefits from creative knowledge accrue only in the densest cities-regions, which have institutions that allow creative workers to meet, exchange ideas, and find jobs and information on salaries. In this sense, there may be a potential selection effect related to larger and more urbanized areas (Andersen et al., 2011).

The second implication is that, in order to promote sustainable economic development, regional innovation policies should provide finance for R&D activities and also focus on improving the capabilities of cities and regions to attract talented and high-skilled workers. This could be particularly important in the European Union context, and in relation to the Europe 2020 agenda and the smart specialization strategy (Foray et al., 2009; European Commission, 2010; McCann and Ortega-Argilés, 2011) aimed at building regional competitive advantage in R&D and innovation. While support for basic and industrial research activities will promote development in core regions, support for entrepreneurship, creativity, product and industry variety, establishment of university-firm linkages and building of a cognitive and social spaces for territorial creativity should be components of an alternative 'smart innovation policy' (Camagni and Capello, 2012) which would favour the development of peripheral regions.

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Table 1. Sample distribution by size, area and industry

Size	Clean	Original
11-20	32.22	33.50
21-50	30.50	30.66
51-250	29.87	27.66
251-500	4.00	4.57
> 500	3.41	3.60
NUTS-1 region		
North West	41.26	42.88
North East	29.97	29.04
Centre	16.86	16.24
South	11.92	11.84
Pavitt sector		
Supplier dominated	49.36	49.74
Scale intensive	18.89	18.96
Specialized suppliers	27.49	26.75
Science based	4.25	4.56
Industry (NACE)		
DA – Food and beverages	8.16	8.12
DB – Textile	9.85	9.46
DC – Leather	3.66	3.47
DD – Wood	2.56	2.73
DE – Paper, publishing, printing	6.29	6.18
DF – Coke	0.41	0.37
DG – Chemicals	3.88	4.77
DH – Rubber and plastics	5.29	5.16
DI – Mineral products	7.38	6.83
DJ – Metal products	18.95	19.08
DK – Machinery and equipment	14.54	14.52
DL – Electrical equipment	9.36	9.08
DM – Transport equipment	2.47	2.61
DN – Other manufacturing	7.19	6.40
Num. obs.	**3197**	**5137**

Table 2. Average innovative sales by size, area and industry

Size	**Full sample**	**Innovative sales >0**
11-20	9.61	27.66
21-50	10.30	24.68
51-250	13.36	26.05
251-500	11.68	23.36
> 500	17.84	24.94
Small	9.95	26.07
Medium	13.36	26.05
Large	14.51	24.23
NUTS-1 region		
North West	10.89	26.11
North East	11.52	24.92
Centre	14.10	29.36
South	8.26	21.70
Pavitt sector		
Suppl. Dominated	11.05	26.70
Scale intensive	9.02	25.24
Special. Suppliers	12.30	24.47
Science based	17.98	28.43
Average %	11.31	25.88
Num. obs.	**3197**	**1397**

Table 3. Firm innovativeness by size, area and industry

Size	Absolute	Relative
11-20	2.079	0.308
21-50	1.877	0.092
51-250	1.626	-0.131
251-500	1.280	-0.507
> 500	1.071	-0.653
Area		
North West	1.853	0.100
North East	1.679	-0.054
Centre	1.675	-0.130
South	1.886	0.020
Pavitt		
Suppl. Dominated	1.861	-0.020
Scale intensive	2.093	0.080
Special. Suppliers	1.524	-0.042
Science based	1.504	0.164
Average	1.768	1.31e-08

Note: the 'relative' measure of innovativeness is computed as the difference from two-digit industry mean.

Table 4. The impact of local creative workforce on firm innovativeness

	(1)	(2)	(3)	(4)	(5)	(6)
DenCG	0.023	-0.482***	-0.881***	-3.026	-1.480*	-2.417**
	(0.040)	(0.178)	(0.295)	(2.293)	(0.808)	(0.977)
DenCG (2SLS)	0.031					
	(0.043)					
$DenCG^2$		0.090***				0.119*
		(0.028)				(0.070)
Var			-0.293			
			(0.175)			
Spec			-1.608			
			(3.607)			
DenCG*Var			0.250***			
			(0.083)			
DenCG*Spec			1.417			
			(1.364)			
University				-0.252***	-0.372***	-0.281**
				(0.076)	(0.120)	(0.126)
District				-0.960**	-0.852*	-0.594
				(0.398)	(0.426)	(0.443)
Entrep				2.193		
				(1.706)		
$Entrep^{KIBS}$					-0.484*	-0.679**
					(0.273)	(0.300)
DenCG*University				0.082***	0.127***	0.093**
				(0.022)	(0.044)	(0.046)
DenCG*District				0.439**	0.432**	0.331*
				(0.169)	(0.181)	(0.181)
DenCG*Entrep				-0.980		
				(0.833)		
$DenCG*Entrep^{KIBS}$					0.173*	0.258*
					(0.123)	(0.129)
Num. obs.	1397	1397	1397	1397	1397	1397
R^2	0.02	0.06	0.06	0.11	0.12	0.14
RESET test (p-value)	0.030	0.751	0.841	0.035	0.033	0.117
1^{st} stage Adj. R^2	0.926					
Robust regression F test	6709.05					
Instrument (DenCOI)	1.053***					
Endogeneity test (p-value)	0.440					
Min. eigenvalue	17389.7					

Notes: clustered-robust (industry-NUTS3 region) standard errors are reported in brackets. *Significant at 10%; **significant at 5%; ***significant at 1%. All the estimates also include a constant term.

Table 5. The impact of non creative graduates on firm innovativeness

	(1)	(2)	(3)	(4)	(5)	(6)
DenNCG	0.024	-0.274***	-0.789***	-3.026	-1.189	-1.903**
	(0.037)	(0.118)	(0.290)	(2.450)	(0.757)	(0.857)
DenNCG (2SLS)	0.030					
	(0.041)					
$DenNCG^2$		0.080***				0.108
		(0.026)				(0.071)
Var			-0.021			
			(0.116)			
Spec			0.069			
			(2.404)			
DenNCG*Var			0.223***			
			(0.081)			
DenNCG*Spec			1.297			
			(1.414)			
University				-0.155***	-0.220***	-0.172*
				(0.058)	(0.079)	(0.086)
District				-0.484*	-0.393	-0.187
				(0.244)	(0.268)	(0.290)
Entrep				1.096		
				(0.945)		
$Entrep^{KIBS}$					-0.258*	-0.363**
					(0.153)	(0.170)
DenNCG*University				0.069***	0.106**	0.077*
				(0.019)	(0.041)	(0.044)
DenNCG*District				0.391**	0.385**	0.234
				(0.168)	(0.187)	(0.187)
DenNCG* Entrep				-1.006		
				(0.897)		
$DenNCG*Entrep^{KIBS}$					0.138	0.232
					(0.119)	(0.126)
Num. obs.	1397	1397	1397	1397	1397	1397
R^2	0.02	0.06	0.06	0.11	0.11	0.13
RESET test (p-value)	0.045	0.575	0.866	0.034	0.034	0.158
1^{st} stage Adj. R^2	0.939					
Robust regression F test	5640.96					
Instrument (DenCOI)	1.104***					
Endogeneity test (p-value)	0.564					
Min. eigenvalue	21586.4					

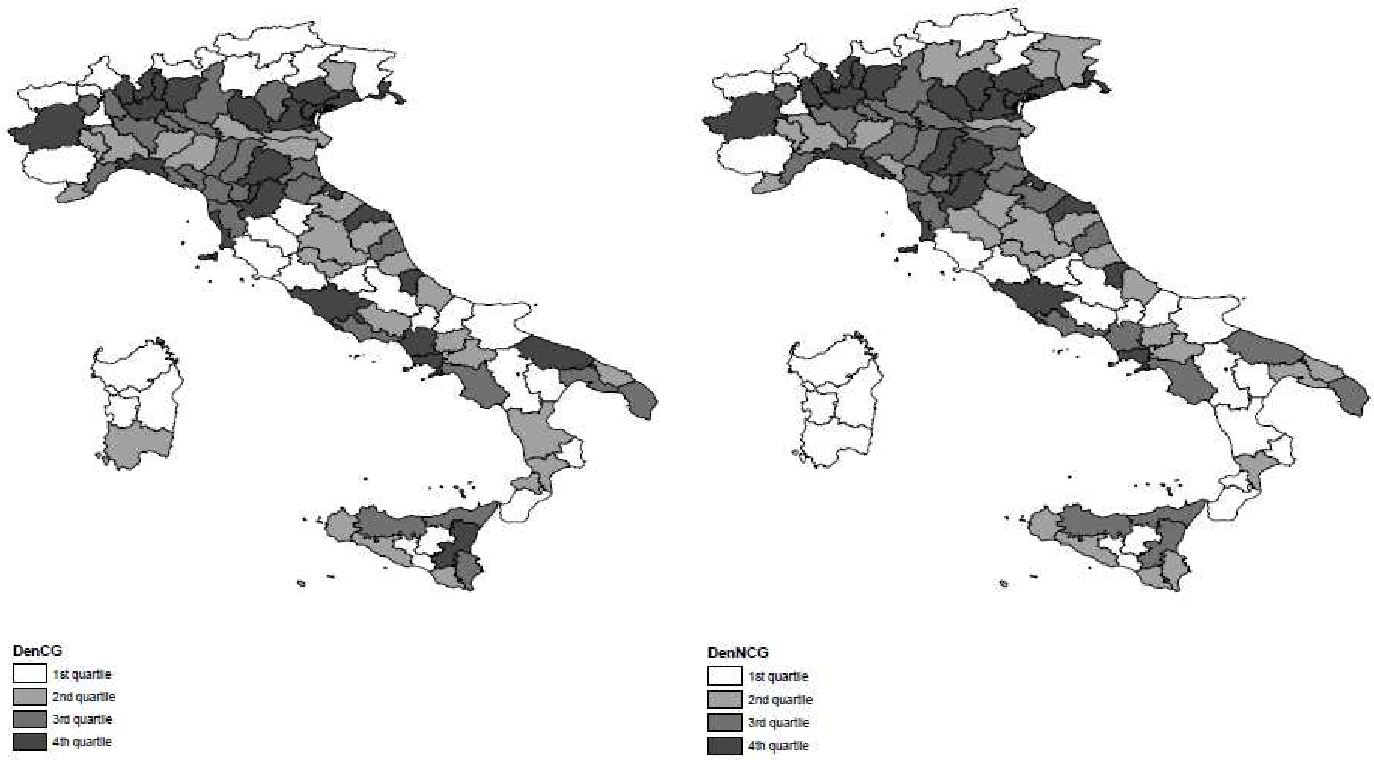
Notes: clustered-robust (industry-NUTS3 region) standard errors are reported in brackets. *Significant at 10%; **significant at 5%; ***significant at 1%. All the estimates also include a constant term.

Table 6. Generalized additive model estimates: quadratic specification

	(1)	(2)	(3)	(4)	(5)	(6)
DenCG	7.750***	5.679**	9.180***			
DenNCG				7.270***	5.415**	8.802***
Var		1.415			1.316	
Spec		0.718			0.705	
University			1.050			0.971
District			1.295			1.030
$Entrep^{KIBS}$			1.349			1.317
Average Gain	7.750***	7.812**	12.874**	7.270***	7.436**	12.121**

Note: cells report the 'gain' statistic, which is the difference in the normalized deviance between the GAM and a model with a linear term for that predictor. A large gain indicates a lot of nonlinearity, at least as regards statistical significance. The associated p-value is based on a chi-square approximation to the distribution of the gain if the true marginal relationship between that term and the dependent variable was linear.

Figure 1. The density distribution of creative and non-creative human capital in Italy (2001)



Source: Author's elaborations from Census of Population and Housing (ISTAT, 2001).

Appendix

Table A1. Knowledge production function: Heckit estimate

	Selection		Outcome
Group	0.040		0.076
	(0.053)		(0.120)
Size	0.122***		0.150***
	(0.020)		(0.046)
Export	0.128***		0.303***
	(0.037)		(0.115)
Tax Reliefs	0.088**		
	(0.039)		
Coop Univ/Res	0.181*		-0.099
	(0.102)		(0.212)
Coop Firm	0.065		0.133
	(0.173)		(0.441)
Coop Other	0.504***		0.741***
	(0.087)		(0.171)
HC	0.026*		0.037
	(0.016)		(0.034)
Input			0.545**
			(0.227)
ICT			1.687*
			(0.920)
Industry dummies	Yes		Yes
Area dummies	Yes		Yes
Num. obs.	3197		1397
Log pseudo LL		-4482.27	
Lambda		2.144***	
Rho		0.952***	

Notes: all the standard errors are clustered by industry and NUTS3 region. A constant term is also included in the estimates.
* significant at 10%; ** significant at 5%; *** significant at 1%.