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The spatial range of university knowledge and the creation of knowledge intensive firms

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Abstract
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how the spatial range of university knowledge depends on the nature (codified knowledge and knowledge embodied in human capital) and the quality of university knowledge. We further distinguish codified knowledge in technological and scientific knowledge (academic patents and publications). Knowledge embodied in human capital stems from teaching activities, resulting in university graduates. After having classified data into geographical units (NUTS 3 level, Italian provinces), according to the location of new KIFs and universities, we estimate negative binomial regression models, where the dependent variable is the number of new KIFs in each Italian province. Results suggest that new KIFs creation in a province is positively related to knowledge generated by universities located in the same province. Moreover, technological knowledge (academic patents) positively affects new KIFs creation in neighbouring provinces, having a spatial range of 200 kilometres. Conversely, the spatial range of scientific knowledge (academic publications) and of knowledge embodied in individuals (graduates) is highly localized, being bounded within the boundaries of the province in which universities are located. Finally, only knowledge produced in high quality universities exerts a significant effect on new KIFs creation, while low quality knowledge does not impact new KIFs creation. These results contribute to policy debate on the design of the national university systems.

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ABSTRACT

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Key-words: university knowledge, university quality, knowledge intensive firms, spatial range, entrepreneurship.

1. Introduction

Conventional wisdom suggests that knowledge produced by universities (hereafter: university knowledge) located in a given geographical area positively affects the creation of new firms at the local level (see Acosta et al. 2011 for a recent review). This holds particularly true for firms operating in knowledge intensive industries (knowledge intensive firms, KIFs). Indeed, geographical proximity to universities allows prospective entrepreneurs to take advantage of the knowledge that universities poured into territories in which they are located (i.e. scientific and technological knowledge, knowledge embodied in university graduates, Santarelli et al., 2012). However, university knowledge might exert an effect on new KIFs creation not only at the local level. Nevertheless, it is reasonable that the impact of university knowledge decreases with distance (for a similar argument applied to exploitation of university knowledge by KIFs see e.g. Laursen et al 2010). In other words, we expect that the effect of university knowledge on new KIFs creation has a limited spatial range, i.e. it is *spatially bounded*.

Several analyses have assessed the spatial range of private and public generated knowledge by studying mainly its effect on innovation by firms in a geographical area (e.g. Jaffe et al. 1993; Anselin et al 1997; Bottazzi & Peri 2003; see Döring & Schnellenbach, 2006 for a survey of this literature). However, while recent studies have analyzed the spatial range of university knowledge (e.g. Belenzon & Schankerman, 2012; Laursen et al., 2011), the literature on new firm creation has received this debate only partially, since just a handful of studies have explicitly taken into account the spatial range of university knowledge when studying new firm creation (Audretsch et al., 2005; Woodwart et al., 2006).

Hence, we add to this emerging literature by speculating and offering empirical evidence on the spatial range of university knowledge as regards to new KIFs creation. These firms have knowledge as their primary value creating asset. Typical examples of KIFs are indeed R&D laboratories, high-tech companies, law and accounting firms, management, engineering and computer consultancy companies (Alvesson, 1995). Therefore, it is reasonable to expect that new

KIFs creation in a geographical area depends on the availability of knowledge in that area. In turn, local knowledge availability is positively related to the presence of universities,[1] which may favor the generation and exploitation of the new entrepreneurial opportunities at the local level (Audretsch and Lehmann, 2005). However, one might expect that the effect of university knowledge is not confined to the area where this knowledge is produced, positively affecting new KIFs creation in neighboring areas as well. In this respect, we argue that the spatial range of university knowledge on new KIFs creation depends on two prominent aspects. First, the *nature* of university knowledge, by distinguishing between *codified* knowledge (e.g., in academic patents and scientific publications) and knowledge *embodied in individuals* (e.g. university graduates). Second, we consider the *quality* of the university where knowledge is produced, that mirrors the quality of the knowledge.

This work advances our knowledge on the spatial range of university knowledge, thus contributing to the design of policies to support regional development. New KIFs play indeed a central role in spawning economic advances, generating positive effects on regional development (e.g. Audretsch and Keilbach, 2004; 2005; for a study on the Italian context see also Piergiovanni et al., 2011). Moreover, we investigate whether and how the spatial range of university knowledge depends on the nature and quality of university knowledge, thus contributing to the policy debate on the design of the national university systems. Specifically, we address the following research questions. Is the spatial range of university knowledge so wide that universities can effectively foster entrepreneurship in peripheral regions? Is high quality knowledge less spatially bounded? Is there, however, a role for knowledge produced in low quality university in fostering new KIFs creation?

In order to address these research questions, we combine data from a number of rich information sources, including the EUMIDA database, containing data on Italian universities, and

[1] The presence of incumbent companies is another important source of local knowledge for new KIFs creation (e.g. Audretsch and Keilbach, 2007; Agarwal et al., 2008).

the MOVIMPRESE directory,[2] from which we extracted the total population of new KIFs established in Italy during 2010. The unit of analysis is the Italian province, which corresponds to level 3 in the Eurostat NUTS (*Nomenclature commune des Unités Territoriales Statistiques*, Nomenclature of Territorial Units for Statistics) classification. We estimate negative binomial regression models, with the number of new KIFs in a province as the dependent variable and types of university knowledge as main explanatory variables. In order to assess the spatial range of university knowledge, we consider both the knowledge produced by universities in the same province (local level) and the university knowledge produced in neighboring provinces. Specifically, we consider different distance intervals (university knowledge produced at the local level, university knowledge produced within a spatial range of 200km and university knowledge produced within a range of 500km), in order to measure the spatial range of university knowledge in fostering new KIFs creation (for a similar approach see Bottazzi & Peri, 2003). Finally, we investigate how university quality affects the spatial range of university knowledge by isolating the effect of knowledge produced in universities which are ranked in the top 40 Italian universities according to the Scimago Institutions Ranking.[3]

In line with the findings of previous studies, we find that new KIFs creation in a province is positively related to knowledge generated by universities located in the same province. Moreover, technological knowledge (academic patents) has a wide spatial range and crosses the boundaries of provinces. Technological knowledge produced by universities indeed positively affects the creation of KIFs in neighbouring provinces, having a spatial range of 200 kilometres. Conversely, the spatial range of scientific knowledge (academic publications) and of knowledge embodied in individuals (graduates) is highly localized, being bounded within the boundaries of the provinces which universities are located. Finally, only knowledge produced in high quality universities exerts

[2] http://www.infocamere.it/movimprese.htm, see section 3 for a detailed description.

[3] http://www.scimagoir.com/

a significant effect on new KIFs creation, while low quality knowledge does not impact new KIFs creation at all.

The paper is organized as follows. Section 2 reviews the extant literature and provides the conceptual background guiding our empirical analysis. Section 3 describes data. Section 4 presents the econometric specification and the variables used in the regressions. Section 5 reports the results of the econometric estimates. The final section offers conclusions and briefly addresses the policy implications.

2. The spatial range of university knowledge and new KIFs creation

The present work grounds on 2 literature streams. First, we refer to studies aimed at assessing the spatial range of public and private generated knowledge. Second, we look at academic contributions focusing on the impact of university knowledge on new firm creation. This paper conveys the debate on the spatial range of university knowledge into the realm of new KIFs creation.

As to the literature on the spatial range of public and private generated knowledge, two main methodological approaches have been used, involving both micro and macro level data (Döring & Schnellenbach, 2006). At the micro level, starting from the seminal work of Jaffe et al. (1993), many scholars used patent citations to demonstrate that knowledge is spatially bounded (for a review see Singh & Marx, 2011). Specifically on university knowledge, Belenzon & Schankerman (2012) analyse the spatial range of academic patents and scientific publications using citations by incumbent firms. They find that the spatial range of citations to academic patents is limited (up to about 100 miles) and strongly constrained by state borders. Moreover, citations to scientific publications have a limited spatial range alike, but they are not constrained by state borders. At the macro level, the extant literature typically assesses the impact of knowledge from private and public generated knowledge on the innovative performance (e.g., patents) of firms located in different geographical areas through the estimation of a knowledge production function (see the seminal paper by Griliches, 1979). Hence, the number of patents by firms in an area is regressed against an array of covariates that may include R&D expenditures by other firms or academic institutions in the same or in neighboring geographical areas. Using regional data on European regions (NUTS2), Bottazzi & Peri (2003) estimate the effect of R&D spending in a region on the number of patents in neighboring regions, finding that a significant positive impact in neighboring regions exist within a spatial range of 300 km. However, the magnitude of the effect in neighboring regions is limited. Indeed, an increase of R&D spending of 100% in a region yields an increase of the number of patents of 80-90% in that region and to an increase of only 2-3% in neighboring regions. As to university knowledge, Anselin et al. (1997) find a significantly positive impact of university research on innovative activities of high-tech firms (US MSA), within a spatial range of 50 miles from the university where research is conducted. Again on US MSA, Varga (2000) shows that the spatial range of academic research is up to 75 miles. The evidence presented here confirms that no consensus has been reached regarding the spatial range of university knowledge.

As to the literature on the impact of university knowledge on new firm creation, recent studies focused on this issue, relating university knowledge to new firm creation at the local level (for a survey see Acosta et al. 2011). In creating their ventures, prospective entrepreneurs can indeed take advantage from knowledge produced by universities. Specifically, the impact of different types of university knowledge have been assessed. However, evidence from these studies is far from being conclusive. When looking at academic research, recent studies find a positive effect of R&D expenditures by universities on new firm creation at the local level (e.g. Harhoff, 1999; Woodwart et al., 2006; Kirchhoff et al., 2007). However, when academic research is measured by scientific publications, the evidence is mixed (Audretsch et al. 2005; Acosta et al. 2011, Bonaccorsi et al 2012). The same holds when using academic patents in order to measure the effect of technological knowledge (Acosta et al. 2011; Bonaccorsi et al. 2012). Finally, university knowledge embedded in individuals as measured by university graduates or students may engender a positive effect on new firm creation at the local level, but, again, the evidence is mixed (e.g. Acosta et al., 2011; Armington & Acs, 2002; Baptista & Mendonça, 2010, Piva et al., 2011).

Despite the rising of studies trying to assess the effect of university knowledge at the local level, the issue of the spatial range of university knowledge in shaping new firm creation has gone rather under-remarked in the literature. An exception is Woodwart et al. (2006). Using data at US County level, they show that R&D expenditures of universities exert a positive influence on new high-tech firm creation, up to approximately 145 miles. However, only R&D expenditures are considered as a measure of university knowledge, while in the present study we focus on different types of university knowledge.[4]

Specifically, in this paper we convey the debate on the spatial range of private and public generated knowledge into scholarly conversations on the impact of university knowledge on new firm creation. Specifically, we assess the spatial range of university knowledge as regards to new KIFs creation considering the *nature* of university knowledge. We distinguish between i) *codified* knowledge, stemming from university R&D, resulting in *technological* knowledge (as measured by academic patents) and *scientific* knowledge (as measured by scientific publications) and ii) knowledge *embodied in individuals*, stemming from teaching activities (as measured by university graduates). Furthermore, we consider the *quality* of the university producing this knowledge, which mirrors the quality of generated knowledge.

Let us turn first attention to knowledge codified in documents, such as patents and publications. One might expect that codified knowledge is not spatially bounded, as documents can be easily sourced at long distance. Accordingly, one might expect that codified university knowledge has a wide spatial range as regards to new KIFs creation. However, although codified knowledge is potentially accessible from everywhere, its effective use (i.e. assimilation) is shaped by geographical proximity to the knowledge source. Knowledge assimilation depends indeed on the ability of the recipient (i.e. the prospective entrepreneur) to use available knowledge (Cohen and Levinthal, 1990). Geographical proximity to the university helps to assimilate university knowledge

[4] Note that Audretsch et al. (2005) consider distance from university and the new firm as the dependent variable. Results show that new firms tend to locate close to universities to access university knowledge. However, this study considers only knowledge developed by the university which is closest to the new firm (see also Laursen et al. 2011 for a similar approach when studying university-industry collaborations).

codified in academic patents and publications as it enables direct interactions with academic personnel. Academic personnel (who authored publications and patents) possesses embodied knowledge that can be accessed only through direct interactions (Morgan, 2004) and that is crucial to assimilate university codified knowledge. Here we also distinguish between scientific knowledge (publications), which is mainly science-based and technological knowledge (patents), which is mainly technology-based. Scientific and technological knowledge may differ when considering their spatial range. Cohen et al. (2002) investigate how public research from university impacts industrial R&D, finding that direct interactions tend to complement scientific publications in favoring the assimilation of university knowledge. This not happen in case of academic patents. A possible explanation is that scientific publications codify knowledge that is still fluid and partially formed, while patents describe knowledge in an advance stage of development and usable for commercialization. Fluid knowledge requires more direct interactions to be assimilated (Storper and Venables, 2004). Hence, one could expect that spatial range of scientific knowledge is limited.

Let us now turn attention to knowledge embodied in individuals stemming from teaching activities, i.e. university graduates. Knowledge-intensive entrepreneurship at the local level can benefit from university knowledge, which is embodied in individuals (see e.g., Piva et al., 2011 for a recent discussion of this issue). University graduates can found new KIFs (Astebro et al., 2011) or be involved in new ventures by prospective entrepreneurs who take them on board as partners or hire them as employees (see Rosenkopf and Almeida, 2003, on the process of knowledge acquisition through mobility of skilled workers). We envisage that the spatial range of university embodied knowledge is more limited than that of codified knowledge. Individuals are indeed little mobile across space (undoutfully less mobile than documents). This holds particularly true in Italy (see Addario & Vuri, 2010 for a discussion on the low mobility of workers in Italy).[5] Hence, it is

[5] According to ISTAT (ISTAT, 2003) in Italy more than 80 percent of individuals with alive parents lives in the same area as their mothers or fathers, about 7 percent of the people resides within 16 km from their parents, and only 8.2 percent lives abroad or at a distance greater than 50 km.

reasonable to expect that the spatial range of this type of knowledge in determining new KIFs creation is particularly limited.

Finally, we investigate whether university quality affects the spatial range of the abovementioned types of university knowledge. An useful work in this respect is that of Laursen et al. (2011), showing how firms' decisions to collaborate with universities are influenced by both geographical proximity and university quality. Specifically, they find that the first choice for firms is to collaborate with a local (within 100 miles from the firm), top-tier university; in the absence of a high quality university nearby, the second-best choice is to collaborate with a distant university. In other words, firms appear to prefer university quality to geographical proximity, since the benefits of accessing high quality knowledge might overcome the cost of accessing that knowledge even at long distances. However, the study of Laursen et al. (2011) focuses on incumbent firms. As regards to new KIFs creation it reasonable to expect that high quality universities are likely to exert a stronger effect on new KIFs creation at the local level, since they fertilize territories in which they are located with high quality knowledge that can be used for new KIFs creation. Moreover, due to the crucial role that knowledge play for KIFs, perspective entrepreneurs in these industries value knowledge from high quality universities, despite of distance (according to Laursen et al. findings). Then, we expect that the spatial range of high quality knowledge is higher than that of low quality knowledge.

3 Data and descriptive evidence

In order to assess the spatial range of university knowledge in fostering new KIFs creation, we use data collected from several sources and classified into 103 geographical units (Italian provinces, equivalent to the Eurostat NUTS 3 level),[6] according to the localization of the new KIF and of the university.

Data on Italian KIFs have been extracted from the MOVIMPRESE database, which gathers information on all new firms established in Italy every year and on the population of incumbent firms. Data includes the industry of activity (NACE rev. 2 classification at 2-digit level) and the firm location at the NUTS 3 level. Using the industry of activity we first defined knowledge intensive industries.[7] Then, we extracted data for new KIFs in 2010 and for incumbent KIFs in 2009. During 2010, 4,761 new KIFs have been established in Italy.

Data on universities have been collected from three sources. First, we extracted the information on university graduates and academic patent applications as in 2008 from the EUMIDA database. This database has been developed under a European Commission tender and it is based on official statistics produced by National Statistical Authorities in all 27 EU countries plus Norway and Switzerland (for details see European Commission, 2010). It contains information on 2,457 European universities. Of these, 1,364 are defined as research active universities. The *research active* label implies that research is considered by the university as a constitutive part of its institutional activities and it is organized with a durable perspective.[8] To our purposes, we considered information on all 80 research active universities located in Italy. Second, data on scientific publication have been hand-collected from the ISI Web of Knowledge database. For each

[6] It is worth noting that during the period 2005-2009, 7 new provinces were created (Olbia-Tempio, Ogliastra, Medio Campidano, Carbonia-Iglesias, Monza-Brianza, Fermo and Barletta-Andria-Trani). Therefore, the current number of Italian provinces is actually 110. Nevertheless, data on new KIFs and on territorial characteristics are not available for these new provinces.

[7] See Appendix A1 for the list of industries included in the sample.

[8] Criteria for inclusion were the following: the existence of research units institutionally recognised; the existence of an official research mandate; the presence of regular PhD programs; the consideration of research in the strategic objectives and plans; and the regular funding for research projects either from public agencies or from private companies.

research active university, we collected all publications on scientific journals from 2000 until 2008.[9] Third, in order to assess university quality, we collected information from the Scimago Institutions Ranking as in 2010. The 2010 edition includes 2,833 research-devoted institutions from around the world grouped into institutional sectors and world regions. The ranking includes 4 key performance indicators to evaluate institutions' research outcomes, in terms of research size, performance, impact and internationalization (Scimago, 2010). We considered as high quality universities those ones belonging to the top 40 Italian universities in the Scimago Institutions Ranking as in 2010.[10]

To build control variables, information on new KIFs and on universities has been combined with data on an array of territorial characteristics of Italian provinces. First, we used databases of the Italian National Institute of Statistics (ISTAT) to extract the total population, the area in square meters, the unemployment rate, and the value added in thousands euro as in 2008 for each Italian province. Second, we downloaded the list of Italian science parks and business incubator centers from the website of the Association of Italian Science and Technology Parks (APSTI).[11]

In order to gain some preliminary insights on the distribution of new KIFs across Italian provinces, maps in Figure 1 report the geographical distribution of new KIFs per mln. inhabitants (map 1, on the left) and the geographical distribution of Italian universities across provinces (map 2, on the right). Map 1 reveals a high concentration of new KIFs per mln. inhabitants in the North of Italy. In Map 2 the darkest areas, where there are more than 3 universities, refer to the province of Roma, Milano and Napoli, with 8, 7 and 4 universities, respectively. This is hardly surprising since these provinces are also the most populated (4.15, 3.96 and 3.08 mln. inhabitants, respectively). A part from these 3 top provinces, Figure 1 show a quite uniform distribution of the number of universities across Italian provinces (in 51 out of 103 provinces there is at least one university).

[Figure 1 here]

[9] Further details on the criteria used in the data collection process are available from the authors upon request.

[10] See Appendix A2 for the list of Italian high quality universities according to the Scimago Institutions Ranging 2010.
[11] http://www.apsti.it.

Table 1 show some descriptive statistics on the number of patents, publications and graduates produced by universities in each Italian province and by universities located in neighboring provinces. Specifically, for each type of knowledge, the table shows the mean, the standard deviation, the minimum and the maximum at the local level (i.e. in the focal province) and the corresponding values relating to knowledge generated by all the universities located in other provinces, according to the different distance intervals (0-100km; 100-200km; 200-300km; 300-500km). From these figures, it is evident that ignoring the effect of the knowledge generated in neighboring provinces might underestimate the effect of university knowledge on new KIFs creation. For instance, let us compare the knowledge produced at the local level and the knowledge produced by universities located in the 0-100 km interval. An average Italian province exhibits 1.99 patents, 3.21 (thousands) publications and 2.84 (thousands) graduates. However, the corresponding values in the 0-100 km interval are 16.90, 25.96 and 22.42, respectively. Given these figures, it seems reasonable asking whether new KIFs creation in a province is influenced by university knowledge generated not only in the same province, but also in neighboring provinces, thus assessing the spatial range of university knowledge in shaping new KIFs creation.

[Table 1 here]

4 Econometric models

4.1 Model specification

Following the literature (e.g. Baptista and Mendonça, 2010), we estimate different models with the number of new KIFs as the dependent variable. Explanatory variables include a set of variables accounting for the different types of university knowledge and a set of control variables related to territorial characteristics. Since university variables are highly correlated,[12] we run separate regressions to avoid multicollinearity problems. We therefore estimate different models of type:

[12] The correlation matrix is in Table 3, section 4.2.

$$NKIFs_i = \alpha + \beta_1 x_i^{local} + \beta_2 x_i^{0-200} + \beta_3 x_i^{200-500} + \partial Z_i + \varepsilon_i \,; \qquad (1)$$

with i denoting the Italian province and ε_i the term for unobserved effects. The dependent variable, $NKIFs_i$, is the number of new KIFs established during 2010 in the province i. The variable x_i refer to the types of university knowledge ($Patents_i$, $Publications_i$ and $Graduates_i$) available at different distance intervals (for a similar approach see Bottazzi & Peri, 2003). Specifically, x_i^{local} refers to the knowledge produced by universities located in the province i, x_i^{0-200} refers to the knowledge produced by universities located within a range of 200 km from the province i (excluding knowledge produced by local universities) and $x_i^{200-500}$ refers to the knowledge produced by universities located in other Italian provinces, up to 500 km from the province i (excluding knowledge produced by local universities and universities in the interval 0-200 km). Distances have been calculated by considering the centroids of each province. As previously mentioned, the variable x_i refers to the different types of university knowledge. Let us first consider the two measures of codified knowledge. First, scientific knowledge is measured by the number of ISI publications, thus $Publications_i^{local}$ is the natural logarithm of number of ISI publications produced by universities located in the province i, $Publications_i^{0-200}$ is the natural logarithm of the number of ISI publications produced by universities in the interval 0-200 km and $Publications_i^{200-500}$ refers to the interval 200-500km. Second, technological knowledge is measured by the variables $Patents_i^{local}$, $Patents_i^{0-200}$ and $Patents_i^{200-500}$, calculated as the natural logarithm of number of patent applications by universities located in the province i, in the interval 0-200 km and in the interval 200-500 km, respectively. Finally, knowledge embodied in human capital is measured by the variables $Graduates_i^{local}$, $Graduates_i^{0-200}$ and $Graduates_i^{200-500}$, calculated as the natural logarithm of the number of graduates from universities located in the province i, in the interval 0-200 km and in the interval 200-500 km, respectively.

The vector $Controls_i$ includes several control variables to account for factors affecting new KIFs creation at the local level other than those related to university knowledge. First, agglomeration effects may arise from the presence of other firms (e.g. Baptista and Swann, 1999; Acs and Plummer, 2005). Therefore, we include the number of incumbent KIFs in the province *i* on the total population of the province ($KIFsPop_i$,). We expect this variable to affect positively new KIFs creation in the province. Second, to account for demand effects, we consider the ratio between the value added and the population in the province i (VA_i) and the population density ($PopDensity_i$), as measured by the population per square meter in the province *i*. Third, unemployed individuals may be more likely to start their own firm as opportunity costs of self-employment are low (for a discussion on this issue see Carree et al. 2008). To control for this effect, we include the variable $Unemployment_i$, measured as the number of unemployed individuals out of the total workforce in the province *i*. We also include a dummy variable indicating if in the province *i* there is at least one business incubator centre (BIC_i). Indeed, business incubator centers assist nascent firms in developing their business and provide them support services (Colombo and Delmastro, 2002). Therefore, a positive effect on new KIFs creation is envisaged.

It is worth pointing out that the specification introduced with equation (1) does not allow to evaluate the effect of university quality on the spatial range of university knowledge. Therefore, we resort to equation (2):

$$\begin{aligned} NKIFs_i = \alpha + \gamma_1 x\_high_i^{local} + \gamma_2 x\_high_i^{0-200} + \gamma_3 x\_high_i^{200-500} + \\ + \gamma_4 x\_low_i^{local} + \gamma_5 x\_low_i^{0-200} + \gamma_6 x\_low_i^{200-500} + \partial Z_i + \varepsilon_i \end{aligned} \quad (2)$$

With respect to equation (1), equation (2) distinguishes between knowledge produced in high and low quality universities. Thus, for each type of knowledge (publications, patents and graduates), the variables $x\_high_i^{local}$, $x\_high_i^{0-200}$, $x\_high_i^{200-500}$ refer to knowledge produced by the top 40 Italian universities, according to the Scimago Institutions Ranking, at different distance intervals. Conversely, the variables $x\_low_i^{local}$, $x\_low_i^{0-200}$, $x\_low_i^{200-500}$ refer to knowledge produced by other Italian universities.

Table 3 reports the descriptive statistics of the variables used in the regressions and Table 4 the correlation matrix.

[Table 3 here]

[Table 4 here]

4.3 Methodology

We employ the negative binomial regression model as the econometric technique for estimating models of the type of equation (1) and equation (2). The underlying assumption is that the number of new KIFs in a province could be interpreted as count data (Audretsch and Lehmann, 2005; Abramovsky et al., 2007). Ordinary least squares regression is inappropriate for count dependent variables. The simplest form of a count data model is the one where the dependent variable follows a Poisson distribution, so its variance is set equal to the mean. Nevertheless, in cases where there is over-dispersion, i.e. where the variance is higher than the mean, the Poisson variance assumption does not hold (Cameron and Trivedi, 1986; 1990). The negative binomial model provides a useful generalization of the Poisson and it is well suited for data characterized by over-dispersion (Greene, 2003). To evaluate the appropriateness of negative binomial regression model, we performed a likelihood-ratio test, under the null hypothesis that the over-dispersion coefficient is zero.[13] Null hypothesis is always rejected at a confidence level of 99%, thus indicating that the negative binomial model must be preferred to the Poisson model.[14]

To avoid endogeneity concerns, both the university variables as well as the control variables are lagged with respect to $NKIFs_i$. As mentioned in section 3, data on university and on territorial characteristics of Italian provinces refer to 2008 while data on incumbent KIFs refer to 2009. Finally, we control for intra-regional correlation by adding dummy variables at NUTS 1 level and clustering data at NUTS 2 level (for a similar approach see Baptista and Mendonça, 2010).

[13] With respect to Poisson (P) model, the negative binomial (NB) model allows for mean-variance heterogeneity by means of the estimation of an additional over-dispersion coefficient (alpha). By calculating the Likelihood-ratio LR = 2*(Log Likelihood(NB) – Log Likelihood(P)), we test if alpha=0.

[14] Test results are available from the authors upon request.

5 Results

5.1 Main results

This section provides the results of the negative binomial regressions with the number of new KIFs as the dependent variable. Table 4 shows the results from the negative binomial estimates using equation (1), about the spatial range of the different types of university knowledge and their impact on new KIFs creation. Specifically, the first two columns show the results concerning codified knowledge (patents in column I and publications in column II). Column III reports results on the spatial range of knowledge embodied in human capital (i.e. university graduates).

[Table 4 here]

Let us first analyze control variables. In all estimates, $KIFsPop_i$, VA_i, $Unemployment_i$ and BIC_i are highly significant (at 99% confidence level in most cases). Hence, we find evidence that agglomeration effects from the presence of incumbent KIFs, demand effects, unemployment and the presence of business incubator centers do matter. Moreover, in line with the literature, the coefficient of $PopDensity_i$ is positive, but with generally lower statistic significance.

We now turn attention on university variables. Column I shows that technological knowledge, measured by patents, positively affects new KIF creation at the local level. Indeed, the coefficient of $Patents_i^{local}$ is positive and significant at 95% confidence level. Moreover, we find that $Patents_i^{0-200}$ is positive and significant as well. Conversely, $Patents_i^{200-500}$ is not significant. These results highlight that technological knowledge, codified in documents produced by universities, exerts a positive effect on new KIFs creation not only at the local level, but also in neighboring provinces, up to a distance of about 200 km. Conversely, when looking at scientific knowledge (publications, in column II) and at knowledge embodied in human capital (graduates, in column III), a different picture comes out. Indeed, while both $Publications_i^{local}$ and $Graduates_i^{local}$ are positive and significant at 95% confidence level, $Publications_i^{0-200}$, $Publications_i^{200-500}$, $Graduates_i^{0-200}$ and $Graduates_i^{200-500}$ are not significant. These latter results highlight that the effect of scientific knowledge and of knowledge embodied in human capital on new KIFs creation is limited to the province in which the university is located. In other words, the spatial range of these types of knowledge is more limited than that of technological knowledge.

We now go in dept by analyzing how the spatial range of university knowledge as regards to new KIFs creation differs when considering knowledge produced by high and low quality universities. Table 5 reports the results from the negative binomial estimates using equation (2). Therefore, with respect to results shown in Table 4, here we evaluate whether university quality affects the spatial range of the different types of university knowledge. Again, the first two columns show the results concerning codified knowledge (patents in column I and publications in column II), while column III reports results on the spatial range of knowledge embodied in human capital (i.e. university graduates).

[Table 6 here]

As to the coefficients of the control variables, their magnitude and statistical significance remain substantially unchanged with respect to Table 4. As to the university variables, results reported in Table 5 highlight a very clear pattern. First, when looking at the local values of the different types of knowledge, we find that only high quality knowledge exerts a positive and significant impact on new KIFs creation. Indeed, $Patents\_high_i^{local}$, $Publications\_high_i^{local}$ and $Graduates\_high_i^{local}$ are positive and significant at 95% confidence level. Conversely, $Patents\_low_i^{local}$, $Publications\_low_i^{local}$ and $Graduates\_low_i^{local}$ are not significant. Moreover, $Patents\_high_i^{0-200}$ is positive and significant at 95% confidence level, while other university variables are not significant. These results confirm again that the spatial range of technological knowledge is wider than the spatial range of scientific knowledge and knowledge embodied in human capital. Moreover, with respect to results shown in Table 4, these results highlight that only high quality knowledge matter for new KIFs creation at the local level, and that the spatial range of high quality technological knowledge is about 200 km.

5.2 Robustness checks

In order to further validate our conclusions, we run two robustness checks. First, we checked if results obtained thorough the estimation of equation (1) are driven by the specification of the distance intervals. Therefore, in unreported estimates, we considered a finer classification of the distance intervals, namely 0-100 km, 100-200 km, 200-300 km, 300-500 km. Results confirm that university knowledge affect new KIFs creation at the local level. Moreover, the spatial range of technological knowledge is wider than that of scientific knowledge and knowledge embodied in human capital, since only $Patents_i^{0-100}$ and $Patents_i^{100-200}$ are positive and statistically significant, thus confirming results reported in Table 4.

Second, we checked whether other factors might explain the spatial range of technological knowledge. Accordingly, in the estimation of equation (2) we added two further controls, namely the distance from the administrative centre at NUTS 2 level (out of 40 high quality universities, 21 are located in a administrative centre) and the number of incumbent KIFs in the neighboring provinces, up to a distance of 200km from province *i*, out of the total population of these neighboring provinces. These two further controls are not significant and results substantially confirm the findings reported in Table 5.[15]

6 Discussion and conclusion

In this work, we have offered empirical evidence on the spatial range of university knowledge as regards to new KIFs creation. Specifically, results show that the spatial range of university knowledge on new KIFs creation depends on two prominent aspects, namely the *nature* of

[15] Results on these robustness checks are available from the authors upon requests.

university knowledge and the *quality* of the university where knowledge is produced, that mirrors the quality of the knowledge.

Specifically, in accordance with the literature (e.g. Woodwart et al., 2006; Kirchhoff et al., 2007 Baptista and Mendonça, 2010; Acosta et al. 2011), our results show that new KIFs creation at the local level is influenced by university knowledge. We find indeed strong evidence that technological knowledge, scientific knowledge and knowledge embodied in human capital (i.e. patents, publications and graduates) positively affect the number of new KIFs in each province. Moreover, we find that the spatial range of scientific knowledge and knowledge embodied in human capital is more limited than that of technological knowledge. The effect of academic patents on new KIFs creation is indeed relevant up to a distance of 200 km from the university producing that knowledge. Finally, when we consider the quality of the university in which knowledge is produced, our results highlight that only high quality knowledge matters for new KIFs creation at the local level, and that, again, the spatial range of technological knowledge is about 200 km, but only if this knowledge is produced by a high quality university.

The paper contributes to the extant literature along several dimensions. First, we assess the spatial range of university knowledge as regards new KIFs creation by looking at the nature of university knowledge. Only Woodward et al. (2006) consider this issue as regard to new firm creation, but their work is limited to the impact of university R&D on new firm creation in high-tech industries, while the present study uses different university variables. Moreover, to our knowledge this is the first study that examines the role of quality in shaping the assimilation of knowledge for new KIFs creation. A closely related work in this respect is that of Laursen et al. (2011). However, the study of Laursen et al. (2011) focuses on incumbent firms and considers the effect of the three closest universities. Here, we consider instead the whole population of Italian KIFs and universities, thus extending the generalizability of previous findings.

We are aware that the work has some limitations, which leave room for further inquiry. First, one may argue that some results are driven by unobserved heterogeneity. The inclusion of further controls in the regressions may contribute to further validate our results. More specifically, it would be important to consider some peculiar characteristics of the Italian productive and innovation system, such as the role of industrial districts (Becattini et al. 2003). Second, this is a cross-sectional study, with data on new KIFs creation as in 2010. The availability of panel data would allow us to investigate whether time-varying effects are at work and to better control for unobserved fixed effects. In this respect, it is also worth observing that new KIFs creation in 2010 is likely to be negative affected by the adverse macroeconomic conditions forged by the current global crisis. This might limit the generalizability of our results over time. Finally, the present chapter is limited to the Italian case. Extending the analysis to other relevant countries might again help us to understand if results are driven by peculiarities of the Italian context.

Despite the aforementioned limitations, our results have important policy implications. This work advances our knowledge on the spatial range of university knowledge, thus contributing to the design of policies to support regional development. New KIFs play indeed a central role in spawning economic advances, generating positive effects on regional development (e.g. Audretsch and Keilbach, 2004; 2005; for a study on the Italian context see also Piergiovanni et al., 2011). Hence, by investigating whether and how the spatial range of university knowledge depends on the nature and the quality of university knowledge, we contribute to the policy debate on the design of the national university systems. Specifically, our results support the view that increasing the quality of the technological output of universities (patens) might overcome the problem of distance in the assimilation of knowledge by new KIFs. Nevertheless, distance is an issue when considering scientific knowledge and knowledge embodied in human capital. Therefore, our results highlight the need to facilitate informal knowledge flows, through improvements in information and communication technologies and other channels (Agrawal and Goldfarb, 2008) and the importance of labor mobility and policies that influence it.

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Tables and figures

Figure 1. Geographical distribution of new KIFs per million inhabitants and of universities in Italy

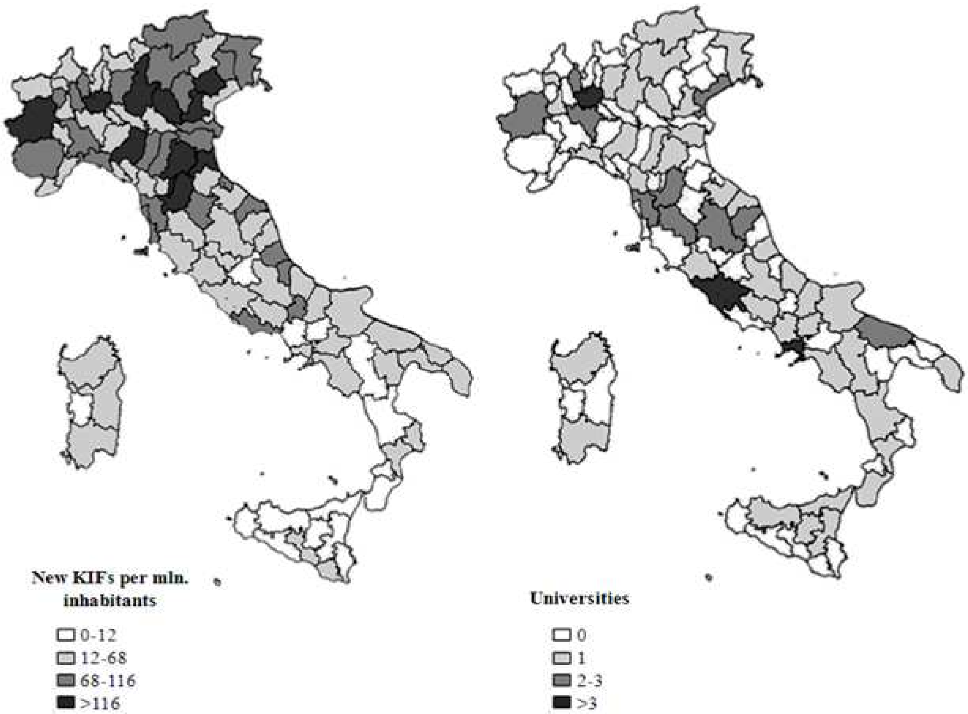

Table 1. Type of university knowledge and distance intervals

University Knowledge type	*Mean*	*Std. Dev.*	*Min*	*Max*
Number of patents				
Local (0 km)	1.99	7.41	0.00	59.00
0-100km	16.90	20.69	0.00	67.00
100-200 km	32.63	28.18	0.00	86.00
200-300 km	32.10	32.92	0.00	129.00
300-500 km	60.18	30.17	6.00	148.00
Number of publications (thousands)				
Local (0 km)	3.21	6.62	0.00	38.15
0-100 km	25.96	21.09	0.00	76.10
100-200 km	52.70	34.61	0.00	135.45
200-300 km	53.17	34.57	0.00	132.14
300-500 km	86.29	37.04	30.89	192.70
Number of graduates (thousands)				
Local (0 km)	2.84	5.91	0.00	37.87
0-100 km	22.42	17.70	0.00	64.61
100-200 km	43.85	27.20	0.00	105.48
200-300 km	44.22	28.06	0.00	117.61
300-500 km	77.82	28.57	27.89	161.33

Note. For each knowledge type (patents, publications and graduates), the table shows the mean values, the standards deviations, the minimum and the maximum in each province and in neighboring provinces according to different distance intervals (0-100 km;100-200 km;200-300 km;300-500 km).

Table 2. Summary statistics on regression variables

Variable	*Obs*	*Mean*	*Std Dev*	*Min*	*Max*
$NKIFs_i$	103	46.22	105.86	1	1008
$KIFsPop_i$	103	2.18	1.00	0.67	7.69
VA_i	103	22.14	5.32	13.06	35.35
$PopDensity_i$	103	0.25	0.34	0.04	2.63
$Unemployment_i$	103	7.86	3.71	2.13	17.94
BIC_i	103	0.39	0.49	0.00	1.00
$Patents_i^{local}$	103	0.45	0.83	0.00	4.09
$Patents\_high_i^{local}$	103	0.38	0.82	0.00	4.09
$Patents\_low_i^{local}$	103	0.08	0.26	0.00	1.10
$Publications_i^{local}$	103	0.79	1.02	0.00	3.67
$Publications\_high_i^{local}$	103	0.67	1.04	0.00	3.63
$Publications\_low_i^{local}$	103	0.16	0.36	0.00	1.54
$Graduates_i^{local}$	103	0.62	0.96	0.00	3.49
$Graduates\_high_i^{local}$	103	0.62	0.96	0.00	3.49
$Graduates\_low_i^{local}$	103	0.22	0.48	0.00	1.96

Table 3. Correlation matrix

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
(1) $NKIFs_i$	1.00														
(2) $KIFsPop_i$	0.75	1.00													
(3) VA_i	0.43	0.81	1.00												
(4) $PopDensity_i$	0.60	0.48	0.19	1.00											
(5) $Unemployment_i$	-0.16	-0.55	-0.83	0.02	1.00										
(6) BIC_i	0.23	0.26	0.16	0.24	-0.08	1.00									
(7) $Patents_i^{local}$	0.60	0.53	0.30	0.34	-0.07	0.39	1.00								
(8) $Patents\_high_i^{local}$	0.62	0.56	0.32	0.36	-0.08	0.36	0.95	1.00							
(9) $Patents\_low_i^{local}$	-0.03	-0.04	-0.04	-0.07	0.03	0.16	0.21	-0.10	1.00						
(10) $Publications_i^{local}$	0.49	0.47	0.22	0.43	0.03	0.43	0.79	0.79	0.06	1.00					
(11) $Publications\_high_i^{local}$	0.49	0.50	0.26	0.45	-0.02	0.44	0.75	0.81	-0.14	0.96	1.00				
(12) $Publications\_low_i^{local}$	0.34	0.17	0.01	0.27	0.11	0.13	0.40	0.23	0.61	0.35	0.12	1.00			
(13) $Graduates_i^{local}$	0.50	0.42	0.16	0.43	0.08	0.44	0.79	0.76	0.15	0.96	0.90	0.39	1.00		
(14) $Graduates\_high_i^{local}$	0.50	0.46	0.20	0.44	0.03	0.43	0.75	0.82	-0.15	0.94	0.98	0.11	0.92	1.00	
(15) $Graduates\_low_i^{local}$	0.39	0.17	-0.01	0.45	0.14	0.17	0.38	0.20	0.56	0.34	0.14	0.78	0.46	0.14	1.00

Table 4. The spatial range of university knowledge depending on the nature of knowledge (eq. 1)

	Patents		Publications		Graduates	
$KIFsPop_i$	0.335	**	0.381	***	0.375	***
	(0.144)		(0.130)		(0.126)	
VA_i	0.109	***	0.106	***	0.104	***
	(0.030)		(0.029)		(0.030)	
$PopDensity_i$	0.468	**	0.337	*	0.318	
	(0.215)		(0.198)		(0.196)	
$Unemployment_i$	0.079	***	0.072	***	0.070	***
	(0.026)		(0.027)		(0.026)	
BIC_i	0.337	***	0.334	***	0.301	**
	(0.122)		(0.119)		(0.130)	
x_i^{local}	0.239	**	0.176	**	0.222	**
	(0.108)		(0.081)		(0.091)	
x_i^{0-200}	0.177	**	0.109		0.111	
	(0.086)		(0.148)		(0.133)	
$x_i^{200-500}$	0.004		-0.078		-0.138	
	(0.121)		(0.186)		(0.249)	
Constant	-1.402	**	-1.179		-0.885	
	(0.683)		(1.210)		(1.422)	
NUTS 1 dummies	Yes		Yes		Yes	
N	103		103		103	

The endogenous variable is the number of new KIFs in the province *i*. Standard errors are in brackets. The asterisks, *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

Table 5. The spatial range of university knowledge depending on the nature and the quality of knowledge (eq. 2)

	Patents		Publications		Graduates	
$KIFsPop_i$	0.338	**	0.389	***	0.380	***
	(0.148)		(0.122)		(0.133)	
VA_i	0.106	***	0.112	***	0.104	***
	(0.031)		(0.030)		(0.031)	
$PopDensity_i$	0.483	**	0.347	*	0.237	
	(0.188)		(0.181)		(0.242)	
$Unemployment_i$	0.082	***	0.078	***	0.071	***
	(0.028)		(0.023)		(0.023)	
BIC_i	0.330	***	0.329	***	0.305	**
	(0.127)		(0.105)		(0.129)	
$x\_high_i^{local}$	0.255	**	0.145	**	0.193	**
	(0.111)		(0.072)		(0.080)	
$x\_high_i^{0-200}$	0.237	*	-0.055		0.029	
	(0.122)		(0.164)		(0.131)	
$x\_high_i^{200-500}$	0.064		-0.221		-0.139	
	(0.143)		(0.346)		(0.287)	
$x\_low_i^{local}$	0.265		-0.028		0.195	
	(0.196)		(0.207)		(0.156)	
$x\_low_i^{0-200}$	-0.123		0.163		0.107	
	(0.147)		(0.165)		(0.130)	
$x\_low_i^{200-500}$	-0.226		0.325		-0.048	
	(0.251)		(0.589)		(0.372)	
Constant	-1.242	*	-1.141		-0.620	
	(0.741)		(1.027)		(1.314)	
NUTS 1 dummies	Yes		Yes		Yes	
N	103		103		103	

The endogenous variable is the number of new KIFs in the province *i*. Standard errors are in brackets. The asterisks, *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

Appendix

A1 Industry classification

Table A1. Knowledge intensive industries

NACE code	*Industry Description*	*Number of new KIFs*	*Percentage out of the total*
C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	3	0.06
C26	Manufacture of computer, electronic and optical products	112	2.35
J62	Computer programming, consultancy and related activities	750	15.75
J63	Information service activities	492	10.33
M69	Legal and accounting activities	114	2.39
M70	Activities of head offices; management consultancy activities	1,263	26.53
M71	Architectural and engineering activities; technical testing and analysis	522	10.96
M72	Scientific research and development	92	1.93
M73	Advertising and market research	393	8.25
M74	Other professional, scientific and technical activities	889	18.67
R90	Creative, arts and entertainment activities	127	2.67
R91	Libraries, archives, museums and other cultural activities	4	0.08
	TOTAL	4,761	100.00

A2 Scimago Institutions Ranking and Italian Universities

Table A2. Top 40 Italian universities according to the Scimago Institutions Ranging 2010

Italian ranking	*Scimago Institutions Ranking 2010*	*University*	*Province (NUTS3)*
1	56	Università degli Studi di Roma La Sapienza	Roma
2	89	Università degli Studi di Bologna	Bologna
3	96	Università degli Studi di Milano	Milano
4	107	Università degli Studi di Padova	Padova
5	144	Università degli Studi di Napoli Federico II	Napoli
6	188	Università degli Studi di Pisa	Pisa
7	190	Università degli Studi di Firenze	Firenze
8	230	Università degli Studi di Torino	Torino
9	294	Università degli Studi di Roma Tor Vergata	Roma
10	301	Università degli Studi di Genova	Genova
11	325	Politecnico di Milano	Milano
12	364	Università degli Studi di Bari	Bari
13	375	Università degli Studi di Pavia	Pavia
14	417	Università Cattolica del Sacro Cuore	Milano
15	437	Università degli Studi di Catania	Catania
16	440	Università degli Studi di Palermo	Palermo
17	458	Università degli Studi di Siena	Siena
18	460	Università degli Studi di Perugia	Perugia
19	463	Politecnico di Torino	Torino
20	505	Università degli Studi di Parma	Parma
21	511	Università degli Studi di Milano-Bicocca	Milano
22	517	Università degli Studi di Modena e Reggio Emilia	Modena
23	530	Università degli Studi di Ferrara	Ferrara
24	549	Università degli Studi di Trieste	Trieste
25	592	Seconda Università degli Studi di Napoli	Napoli
26	630	Università degli Studi di Verona	Verona
27	633	Università degli Studi di Messina	Messina
28	669	Università degli Studi di Cagliari	Cagliari
29	684	Università degli Studi di Trento	Treno
30	695	Università degli Studi di Salerno	Salerno
31	711	Università degli Studi dell Aquila	L'Aquila
32	733	Università degli Studi di Brescia	Brescia
33	743	Università Politecnica delle Marche	Marche
34	747	Università della Calabria	Cosenza
35	781	Università degli Studi di Udine	Udine
36	821	Università degli Studi Roma Tre	Roma
37	849	Università degli Studi Gabriele d'Annunzio	Chieti
38	899	Università degli Studi dell Insubria	Varese
39	906	Università del Salento	Lecce
40	1082	Università degli Studi del Piemonte Orientale Amedeo Avogadro	Vercelli