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THE LINK BETWEEN CLUSTERS OF SMEs AND PUBLIC AND UNIVERSITY RESEARCH IN ITALY¹

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Abstract

Small and medium-sized firms (SMEs) are increasingly regarded as engines of innovative activity, especially in some of the most dynamic local production systems in Western Europe. However, most SMEs lack the adequate resources to conduct R&D, which is traditionally considered as the main source of innovation. This apparent contradiction has induced several researchers to try to answer the question of where do SMEs get their knowledge inputs from. This literature, which has tended to use patents as a proxy for public research, has found that SMEs are particularly sensitive to spillovers from university and public research. In this paper we readdress this question by using a bibliometric indicator of public research output, instead of patents, for 99 Italian provinces during the 1990s. The results highlight that there is a strong geographical connection between the territorial concentration of SMEs and public research and that this connection is affected by firm size.

Keywords: Clusters of SMEs, knowledge spillovers, universities, bibliometric analysis, Italy.

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1. Introduction.

The question of how small and medium-sized enterprises (SMEs) manage to innovate and remain competitive in a world in which technology plays an increasingly important role in determining economic dynamism has come under closer scrutiny in recent years. Most SMEs, and especially those outside high technology sectors, lack the capital and the human resources to invest heavily in R&D, and thus their capacity to generate innovation in-house tends to be limited. And yet, despite this apparent handicap, some networks and clusters of SMEs rank among the most dynamic spaces in the world. The innovative capacity and economic success of areas such as the Silicon Valley, Route 128 in the Boston Area, the German region of Baden-Württemberg, the Italian industrial districts, or the Danish region of Western Jutland have caught the eye of researchers who have delved into the causes of such economic dynamism.

The innovative capacity of these clusters of SMEs has been at the core of many analyses. If, in principle, SMEs are disadvantaged with respect to large companies in terms of their internal capacity to generate product and process innovation, how have clusters of SMEs managed to remain at the forefront of the innovative process? Where do SMEs derive their innovative capacity from? Most research on the topic has turned to the existence of knowledge spillovers from public research centres and universities as a possible explanation of the innovative capacity of SMEs (Acs, Audretsch and Feldman, 1994; Audretsch and Vivarelli, 1996; Piergiovanni, Santarelli and Vivarelli, 1997). The results of the studies which link innovative inputs to patents highlight that research conducted at universities and other public research centres generates knowledge spillovers reaped by firms in neighbouring areas (Acs, Audretsch and Feldman, 1994; Feldman, 1994), and fundamentally by local SMEs, since the spillovers of university research are considered to be more important for small-firm than for large-firm innovation (Audretsch and Vivarelli, 1996; Piergiovanni, Santarelli and Vivarelli, 1997).

The use of patents as a proxy for knowledge spillovers generated by universities and public research centres raises, however, questions about the robustness of the results of previous studies. Patents are a way -albeit a rather imperfect way (Harabi, 1995)- of trying to appropriate innovation and this attempt to appropriate innovation is likely to reduce, not to enhance, spillovers. Therefore, patents are, in our opinion, not the best way to measure the capacity of universities to generate spillovers.

In this paper we propose to use an alternative measure as a proxy of the capacity of universities and public research centres to generate tacit knowledge, which spills over to neighbouring firms. Recent research by Narin, Hamilton and Olivastro (1997) for the US has highlighted the increasing connection between basic science and applied technology and innovation, as well as the place-boundedness of this link. Innovators tend to cite research papers produced in their own country. If this trend holds at a local level, as claimed by Jaffe, Trajtenberg and Henderson (1993), it can be assumed that the quantity and quality of university and public research would impinge on innovation at the local level, and especially on the dynamism of SMEs.

The purpose of this paper is to try to test this hypothesis in Italy, probably the country in Europe where most attention has been paid to the dynamism of clusters of SMEs. Our aim is to identify if there is a relationship between the concentration of SMEs at a local level –in this case, the 99 Italian provinces- and public and university research output, measured by the number of articles published in internationally-recognised research journals, and whether this relationship is affected by firm size. The paper is divided in three further sections. The first section analyses the theoretical framework and presents the main underlying assumptions and a series of testable hypotheses. Section two deals with the research design and measurement of variables and reports the results of the econometric analysis. Some policy implications of the analysis are extracted in the conclusions.

2. On SMEs and innovation.

Individual SMEs normally face an innovative deficit. Time, finance and human resource constraints put SMEs at a disadvantage with respect to larger firms in terms of their capacity to generate and assimilate innovation. As a result of their size, the amount of resources SMEs devote to R&D is necessarily limited and their ability to generate both product and process innovation is influenced by this fact. However, and in contrast with the general view of SMEs as less innovative than large firms, recent research has identified clusters of SMEs as the engines of innovative activity in certain industries (Acs and Audretsch, 1993; Storper, 1997; Scott, 1998), and not just in high-tech sectors, but also in many sectors which require a low technological input. SMEs located in strong industrial clusters tend to be more innovative and dynamic than isolated SMEs (Baptista and Swann, 1998). The mismatch between the limited amount of resources individual SMEs invest in R&D and the innovative capacity of clusters of SMEs has raised the

question of where do small and medium-sized firms get their knowledge generating inputs. Researchers have looked for the answer to this question in the tacit and semi-public nature of technological knowledge. Technological knowledge generates spillovers which tend to be geographically concentrated, since its diffusion is often linked to informal interpersonal contact. Yet, if individual SMEs have a limited capacity to generate technological knowledge on their own, where is the source of this knowledge to be found? Researchers have turned to the research undertaken by public R&D laboratories and universities for an answer.

Jaffe (1989) was among the first to identify to what extent university and public research is able to effect innovative activity. The presence of universities and public research centres in a given locality is considered to have an impact that goes beyond the narrow economic indicators of employment and spending. According to Castells and Hall (1994), universities and public research centres may play three different roles in the genesis and the development of innovative milieux. The first role is to “generate new knowledge, both basic and applied. In this sense research-oriented universities are to the informational economy what coal mines were to the industrial economy” (p. 231). In contrast to private research labs or of research conducted in large firms, universities and public research centres have a greater incentive to diffuse their research findings and are able to spread the knowledge through the usual channels of dissemination of research, as well as through their graduates and interpersonal contacts within the community. The second role is to provide training and expertise to the local labour market, especially to local SMEs which may not have the strength and/or capacity to compete in the national labour market. And thirdly, the university itself may start up new business centres, as in the cases of Stanford or Cambridge (Castells and Hall 1994, p. 231), or generate spin-offs and establish links between employers and the university. In addition, universities may also play a significant role in the provision of free public lectures, supporting infrastructure, public access to university libraries and other facilities to entrepreneurs and workers (James and Clark, 1997). These factors contribute to enhance the links within the community and to develop the informal personal contacts on which the diffusion of tacit knowledge often relies, creating the cultural vitality and spontaneous networks which seem to have a significant effect on the genesis of public competitions goods and, consequently, on the prosperity of the region as a whole (Baptista and Swann, 1998; Rodríguez-Pose, 1999).

However the impact of university and public research in the community may also be limited by the nature of the research conducted in these centres. It has been argued that basic research conducted at universities rarely contributes directly and immediately to innovation (Martin, 1998, p. 682) and, from a more radical perspective, that this sort of research is largely irrelevant to technological progress (Kealey, 1998).

But if the impact of the research conducted at universities and public research centres spills over, to what extent is the diffusion of spillovers bounded by distance? Although technology and the ongoing globalisation process are reducing distances and allowing greater access to information, some researchers believe that personal interaction and knowledge spillovers still greatly benefit from proximity, especially in the case of SMEs (Scott, 1998). The basis for this argument lies on the idea that the transmission of knowledge, in general, and tacit knowledge, in particular, is more costly and affected by distance than the transmission of simple information. According to Audretsch and Feldman, “knowledge spillovers do not [...] transmit costlessly with respect to geographical distance” (1996a, p. 256). Empirical research has shown that the returns linked to the transmission of knowledge are geographically bounded (Jaffe, Trajtenberg and Henderson, 1993) and that this place-boundedness is also related to firm size. Firms with higher resources devoted to R&D -generally large firms- tend to rely on spillovers from distant institutions more often than firms with few or no resources in R&D -basically SMEs- which rely on local research institutions (Beise and Stahl, 1999). Proximity and location are thus important factors to be considered in the knowledge production function (Feldman, 1994; Audretsch and Feldman, 1996b); factors which ultimately lead to the spatial clustering of innovative activity, especially in industries which are R&D intensive (Audretsch and Feldman, 1996a).

Researchers have, however, run into difficulties when trying to operationalise the link between university and public research and clusters of SMEs. How does the knowledge generated by research centres spill over to the local community and local SMEs? How can these spillovers be measured? The most common measure used in dealing with these questions has been patents as a “proxy for economically useful knowledge” (Jaffe, 1989 p.958). Numerous studies have resorted to patents in different geographical contexts (Audretsch and Vivarelli, 1996; Piergiovanni, Santarelli and Vivarelli, 1997). The use of patent counts as a proxy for knowledge has been widespread mainly because of the availability of geographical patent data. It has, nevertheless, also come under criticism. Some have argued that the number of patents is not a valid measure for the

innovative activity of firms (Mansfield, 1984; Griliches, 1990). Alternative proxies have been also used. Acs and Audretsch and Feldman (1992) resorted to patents ‘introduced in the market’. The results of these approaches have generally sanctioned Jaffe’s findings and further supported the view that university and public research generates spillovers which are the main source of the innovative capacity of clusters of SMEs and that the size of the firm is important in the spillover effect (Acs, Audretsch and Feldman, 1994).

The use of patents or even of patents ‘introduced in the market’ clashes however with the idea of the diffusion of research spillovers to clusters of SMEs for several reasons. First and foremost, the main aim of patenting is to allow the developers of inventions to appropriate the economic returns of transforming the invention into innovation. Trying to prevent others from using the incremental knowledge protected by the patent, does not necessarily imply that this knowledge does not spill over. However, this aim of appropriating innovation is at odds with the claim stated by most literature on dynamic local production systems that if clusters of SMEs have been capable of successfully competing in a more global and open market, it is basically due to their capacity to generate local collective competition goods (Streeck, 1992; Storper, 1997; Le Galès and Voelzkow, 2000). Innovation spillovers fall within this category. Yet any attempt to appropriate innovation via patents is likely to enhance the private economic returns to the detriment of the social returns of innovation and thus to limit research spillovers. Second, not all new inventions tend to be patented, with some sectors and industries, such as pharmaceuticals and chemicals –sectors where SMEs tend to be conspicuously absent-, patenting much more than others (Scherer, 1983) and the economic impact of individual patents varies enormously. Third, patent propensity rates increase with firm size and “are higher among firms that find patent to be an important method for preventing competitors from copying both product and process innovations” (Arundel and Kabla, 1998, p. 127). Also a higher percentage of product innovations compared with process innovations are patented (Arundel and Kabla, 1998, p. 132), yet process innovations, often linked to collective learning, are considered to be fundamental in the dynamism of clusters of SMEs (Capello, 1999). And fourth, most university and public research centre R&D, in contrast to private R&D, produces primarily non-appropriable knowledge. In sum, patents are perhaps a better indicator of the innovation of large firms than of the possible relationship between public research and clusters of SMEs.

Other studies have resorted to alternative indicators as a way to measure the diffusion of knowledge in the community. Some studies have used expenditure or employment in R&D in order to try to capture the relationship between knowledge

spillovers and the clustering of firms (Acs, Audretsch and Feldman, 1992; Feldman, 1994). Large surveys or innovation panels have been used by authors such as Audretsch and Feldman (1996a and 1996b) and Beise and Stahl (1999). However, the problem of using measures of R&D input or innovation citations is that the transformation of such input into R&D output depends on a wide range of factors such as the quality of the researchers and the nature or the type of the research conducted. Since applied research tends to be more directly linked to innovation than basic research and product innovations are more frequently cited in surveys than process innovations, such indicators may also underestimate the capacity of universities and public research centres to generate spillovers.

If patents and different indicators of R&D input can be considered as imperfect proxies for measuring R&D spillovers, which is the best way to capture the relationship between public and university research and clusters of SMEs? In this paper we propose the use of research output, measured by the number of scientific papers published by local universities and public research centres in the areas of science and technology, as a proxy for the transmission of research spillovers to industry, and especially to SMEs. Publication is the main transfer channel of research conducted at universities (Beise and Stahl, 1999, p. 400), which, in contrast to firms, publish more than they patent (Meyer, 2000, p. 410). Hence the use of bibliometric indicators, following the methodology adopted by Matthiessen and Schwarz (1999), has the advantage of resorting to an indicator which shifts the weight from companies to the quantity and the quality of the research conducted at universities and public research centres as the main source of tacit knowledge in the community. The aim of diffusion inherent to any publication may imply that researchers whose ultimate intention is publishing their work may be more prone to share their knowledge in the community than researchers whose main aim is to appropriate the returns of the knowledge they generate. In addition, bibliometric indicators are increasingly being used as measures of the scientific wealth of a territory. In this type of research, nations are usually taken as the unit of analysis. The reasons for this are the compilation of many statistical indicators and the existence of large bibliometric banks at the national scale (Matthiessen and Schwarz, 1999). However, in a world where the importance of regions and cities is growing and where the diffusion of knowledge is costly, the scientific strength at the local level may be a more adequate indicator of the existence and of the dimension of knowledge spillovers.

In this paper, we will thus try to test the link between the presence of clusters of SMEs and the local scientific wealth, measured by the number of scientific articles published in internationally-recognised journals, in the 99 Italian provinces. The article data source is the Institute for Scientific Information's (ISI) *Science Citation Index (SCI)*. The reason for choosing Italian provinces -rather than regions, as in previous studies on the topic- for this analysis is related to the fact many recent studies which have focused on the dynamism of clusters of SMEs have taken Italian industrial districts as one of the main examples. The crisis of traditional manufacturing regions across Europe during the 1970s and 1980s brought to the fore the dynamism of a large number of clusters of SMEs in Italy, which achieved considerable levels of growth at a time when large industries in the north west of the country –the traditional industrial hub- were undergoing a serious decline (Trigilia, 1992). This shift in market conditions brought many social scientists to the analysis of clusters of SMEs in Italy, a country which in 1996 had 60% of its industrial workforce employed in firms of less than 50 employees. In addition, Italy has also been the focus of several of the studies which have used patent data to analyse the link between public research and SMEs innovation (Audretsch and Vivarelli, 1996; Piergiovanni, Santarelli and Vivarelli, 1997). This will allow for comparisons between results.

2.1. The hypotheses of the analysis.

The aim of the empirical analysis is to test the link between the geographic concentration of SME activity and the existence of knowledge externalities, as well as a series alternative hypotheses which try to control for other factors which may have an influence on the agglomeration of SMEs in Italy. Several hypotheses are established for this purpose. The first hypothesis focuses on the theory that research undertaken by local universities and public research centres plays an important role in fostering entrepreneurship and the clustering of SMEs¹.

Hypothesis 1: Local scientific strength, measured by the research output of universities and public research centres, is at the origin of knowledge spillovers, which, in turn,

¹ Ideally we would have liked to include an indicator of the rate of creation of SMEs as the dependent variable. Lack of available data on the topic forced us to resort to the total number of SMEs in a province instead.

promote the clustering of SMEs: Although many factors may influence the geographical concentration of SMEs, this first hypothesis tries to indicate some degree of relationship between the research level of a locality and the existence of small firms. The logic behind this hypothesis is that while larger firms may have their own R&D laboratories and generate innovation in-house, university and public research output may serve as a key input of new knowledge for generating innovative activity in SMEs (Acs, Audretsch and Feldman, 1994; Audretsch and Vivarelli, 1996). If, as stated in the hypothesis, SMEs rather than large firms are the main beneficiaries from local university and public research spillovers, we can extract the following hypothesis:

Hypothesis 2: There is little or no geographical coincidence between the research output of universities and public research centres and the clustering of larger firms: If larger firms conduct R&D activities in-house and benefit from spillovers generated mainly by clients, competitors or other large firms belonging to the same networks, geographical proximity to the sources of knowledge will be less relevant for larger firms. SMEs are likely to be more sensitive to public and university research, whereas larger firms will primarily benefit from private R&D (Acs, Audretsch and Feldman, 1994; Beise and Stahl, 1999).

The next three hypotheses consider alternative factors (economic output, population and location in a specific socio-economic context) which may also influence the clustering of SMEs.

Hypothesis 3: The probability of SMEs clustering within a certain province increases with the level of local economic output: This hypothesis takes into account the effects of local output per capita, following the logic that richer areas may have more resources available for the promotion of firms and for channelling entrepreneurial activity.

Hypothesis 4: The probability of SMEs clustering within a certain province increases with the size of the local population: The introduction of population variables in the analysis controls for the probability of greater agglomeration of SMEs in heavily populated areas.

Hypothesis 5: The probability of SMEs clustering within a certain provinces varies according to the geographical location of the province: This hypothesis considers the

heterogeneity of the Italian territory and the social and economic influences this may have on entrepreneurial activity. Although diversity of output within a national boundary is a frequent phenomenon in most countries, the Italian territory represents a special case due to the marked division between a richer and more dynamic North and a less prosperous South, with several intermediate cases (Bagnasco, 1977).

To further evaluate the link between university and public research output within the province and the existence of clusters of SMEs one final hypothesis is investigated.

Hypothesis 6: Small and medium-sized firm clustering is greater in those provinces with at least a university, than in those without one: The logic behind this assumption is the belief that the presence of a university has a notable impact on the development of the area (Castells and Hall, 1994). This hypothesis will allow us to determine whether the mere location of a research centre, regardless of the quantity and quality of the research conducted there, suffices to trigger the clustering of firms.

3. Data and empirical analysis

3.1. A cautionary note regarding the use of bibliometric indicators

Researchers, research institutions and councils, publishers, universities and society as a whole increasingly rely on bibliometric indicators in order to assess a wide range of issues regarding the quantity and quality of the research output. Although bibliometric and citations methods are often considered biased in terms of their coverage, their scope and versatility have made them a practical tool as quality indicators for journal publishers, research funding institutions and policy makers, among others. However, there are risks involved in the extensive use of bibliometric and citation analyses. Some, despite recognising the utility of these approaches, believe that bibliometric analyses, in general, and the *Science Citation Index* (SCI), in particular, should only be used for their original purpose of serving scientists in the process of research and development. Researchers which have used the SCI for other purposes, such as Matthiessen and Schwarz (1999), acknowledge some degree of inaccuracy of the data set. However, they consider international bibliometric databases as useful tools for the analysis of international, national and local research systems, and conclude that analyses based on bibliographic data can give indications of a quantitative nature. Our analysis must be

placed within this context. Any results and interpretations must be valued in light of the inherent limitations of the use of bibliometric methods as the source of our research output indicators.

3.2. Data and unit of analysis

The paper studies science and technology research output by universities and public research centres over a period of seven years (1989-95) in 99 Italian provinces. The choice of the province rather than the region –as was the case in most previous studies– has been made in order to narrow the analysis down to the specific locality since the province is the administrative division which is territorially closer to the industrial district. The small size of most Italian provinces makes this country an ideal case for this kind of analysis.

The dependent variable considered is the number of small firms in any given province. Small firms are defined in this paper using one of the Italian Statistical Institute's (ISTAT) definition: those firms with more than 20 and less than 50 employees (FIRMS20-49). Three alternative dependent variables –the number of medium-sized firms, those with between 100 and 199 (FIRMS100-199), larger firms, those with between 250 and 499 employees (FIRMS250-499), and the total number of firms (ALLFIRMS)– are used in order to check whether the impact of local research output is related to firm size. The use of separate regressions reflecting firm size follows the methodology used by Audretsch and Vivarelli (1996) for Italian regions and will allow us to compare our results to theirs. The size linked to the second and third variables reflects different ISTAT's definition of medium and larger enterprises. The dependent variables include firms which span across all sectors of production and reflect the situation in 1996. The source of the data is ISTAT.

The dependent variables are regressed on a series of independent variables which reflect the hypotheses presented above in order to establish the link between clusters of SMEs and local research output.

The independent variables include the research output by university and public research institutions over a cumulative period of 7 years (1989–1995) (RESEARCH). The logic behind the choice of a lagged variable lies in the belief that the visible effects of research may only be observed after a certain lapse of time. The data set was elaborated using the ISI's *Science Citation Index* (SCI) by placing the province in the address for

author of a given publication. The name of the province had to be entered both in English and Italian in order not to leave out any publications that were lacking a full translation for the address. The selection of the registered papers was made in the ‘articles’ mode exclusively. The SCI is able to record both university and public research centres output within a locality and it is hereby used as a proxy measure for the scientific strength of a province. A dummy depicting the presence of a university or universities in the province (UNIV) is used in some regressions as a substitute for RESEARCH.

The second and third independent variables are the gross domestic product per capita (GDPCAP) and the population (POP) of each Italian province in 1995. The source of these variables is the ‘Istituto Tagliacarne’, an economic research institute based in Rome, Italy. They are included in the regression analysis as control variables.

The social and economic disparities within Italy are represented by a set of dummy variables. Five of the six dummy variables reflect the territorial subdivision of Italy used by the ISTAT. Although scientific literature usually divides Italy in North, Centre and South (Bagnasco, 1977), the extended subdivision used by the ISTAT allows for broader and more specific analysis. We have included an extra zone to indicate those areas of Italy, such as Turin, Milan or Rome which are considered to be international nodes and therefore benefit from greater external economies. The dummy variables represent the following zones: Northwest Italy (ZONE1), Northeast Italy (ZONE2), Central Italy (ZONE3), Southern Italy (ZONE4), Insular Italy (ZONE5), and Milan, Rome and Turin (ZONE6). 5 dummies are included in the regression analysis, and the first dummy (ZONE1) is left out as reference.

3.3. Model and results

A simple OLS estimate is carried out on a model derived from the hypotheses presented previously. The basic model adopts the following form:

$$\text{FIRMS}_i = \alpha + \beta_1 \text{RESEARCH}_i + \beta_2 \text{POP}_i + \beta_3 \text{GDPCAP}_i + \sum_{j=2}^6 \gamma_j \text{ZONE}_i + \epsilon \quad (1)$$

where FIRMS denotes the number of firms in 1996 in any given Italian province; RESEARCH is the research output, measured by the number of science papers published in internationally-recongnised journals between 1989 and 1995, in any given province;

POP is the population of the province in 1996; GDPCAP its GDP per capita in the same year; and ZONE represents the geographical location of the province. All regressions are run twice: first without the territorial variable (Regression 1) and then including the geographical location of the province (Regression 2). The dependent variable is changed in different regressions of the model to allow for firm size. FIRMS20-49 represent the number of small firms, FIRMS100-199 depicts the number of medium-sized firms, and FIRMS250-499, larger firms. ALLFIRMS is the number of firms in a province, regardless of their size.

In subsequent models RESEARCH is replaced by UNIV which denotes the presence of a university or several universities in a province. The reason for substituting research output by the presence of a university is to analyse whether the clustering of SMEs in Italy is linked just to the presence of a large research centre in the province, or whether the quantity and quality of research output by local research centres also plays a part in this concentration.

Tables 1 and 2 report the results of regressing the concentration of firms by size on the independent variables. Table 1 includes the results using RESEARCH as an independent variable, whereas in Table 2 RESEARCH is substituted by UNIV. The results of the empirical analysis confirm most of the hypotheses presented earlier. First of all, the results highlight the existence of a positive and significant association between the clustering of firms in a province and the research output of the universities and public research centres located in that province (Hypothesis 1). They also indicate that size matters in this relationship (Hypotheses 1 and 2). The standardized β coefficients and the t-statistics indicate that in the Italian case the relationship is stronger and more significant in the case of small firms than in that of medium-sized firms, and that the research output of universities and public research centres bears almost no connection with the concentration of larger firms (Table 1). These findings are consistent with the claims stated by previous research conducted using patent data that the knowledge base of a locality is an important element in the generation of knowledge spillovers and the development of small and medium-sized enterprises, whereas larger companies rely either on in-house innovation or research spillovers which are less constrained by geographical factors (Audretsch and Vivarelli, 1996; Piergiovanni, Santarelli and Vivarelli, 1997). As Beise and Stahl put it, smaller firms “often compensate the lack of basic knowledge and research abilities with partners of the public research infrastructure than companies with

large R&D laboratories, which more often outsource auxiliary R&D functions” (1999, p. 406).

Table 1

Regression results using research output as independent variable.

	FIRMS20-49		FIRMS100-199		FIRMS250-499		ALLFIRMS	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
RESEARCH	0.296** (3.946)	0.227** (2.987)	0.213** (3.067)	0.154* (2.113)	0.115 (0.835)	-0.064 (-0.444)	0.260** (3.038)	0.139 1.594
POP	0.483** (6.943)	0.614** (5.947)	0.385** (5.942)	0.580** (5.795)	0.006 (0.044)	0.453* (2.320)	0.375** (4.692)	0.685** (5.728)
GDPCAP	0.305** (5.008)	0.376** (3.043)	0.548** (9.745)	0.546** (4.606)	0.124 (1.108)	0.370 (1.598)	0.411** (5.909)	0.534** (3.802)
ZONE2		0.226** (3.331)		0.024 (0.368)		0.110 (0.856)		0.147 (1.864)
ZONE3		0.217** (3.208)		-0.069 (-1.045)		0.032 (0.247)		0.073 (0.934)
ZONE4		0.157 (1.421)		-0.053 (-0.507)		0.181 (0.876)		0.111 (0.888)
ZONE5		0.180 (1.900)		-0.027 (-0.294)		0.149 (0.839)		0.120 (1.099)
ZONE6		-0.065 (-0.738)		-0.219** (-2.559)		-0.488** (-2.922)		-0.310** (-3.015)
Df	3,95	8,90	3,94	8,89	3,93	8,88	3,93	8,88
R ²	0.708	0.756	0.749	0.772	0.041	0.154	0.627	0.684
Adj R ²	0.699	0.734	0.741	0.752	0.010	0.078	0.614	0.655

β standardized coefficients reported

t-statistics in parenthesis

Statistical significance at the 0.01/0.05 level is denoted by **/*

The results of the regression also indicate that the concentration of small and medium-sized firms is also connected to factors such as the wealth and economic output of a locality and the size of the population (Hypotheses 3 and 4). The concentration in a province of economic activity, population and dynamic research centres create the sort of agglomeration economies which encourage the development of clusters of SMEs and Marshallian industrial districts and trigger self-reinforcing innovation mechanisms. The fact that these three independent variables alone explain between two-thirds and three-fourths of the variance in the number of small and medium-sized firms is a clear indicator

of the importance of these three factors in determining the clustering of SMEs in Italy (Table 1). In contrast, the geographical concentration of larger firms seems to be completely unrelated not only to the research output of universities and public research centres, but also to the relative wealth and to the population of the province. In the case of larger firms, the adjusted R^2 drops from levels of around 70 per cent to one per cent and none of the independent variables included in this model is significant. The decline in significance of the model using larger firms as the dependent variable is in stark contrast with Audrestch and Vivarelli's (1996) and Piergiovanni, Santarelli and Vivarelli's (1997) results. Their models –which use patents or R&D expenditure instead of bibliometric indicators- explain a larger share of the variance in innovation when larger rather than smaller firms are considered. Our results thus reinforce the fact that patents and R&D expenditure indicators are probably biased towards large firms and perhaps less able than bibliometric indicators to measure the capacity of universities to generate spillovers reaped by SMEs.

The inclusion of the geographical variables only marginally increases the significance of the models. The main exception is the model which includes small firms as the dependent variable. The dummies which represent the North East and the Centre of Italy, precisely the areas of Italy where most industrial districts have been identified, are positively and significantly associated to the clustering of small firms. The comparative advantage of these regions in sectors such as textiles and clothing, food, drinks and tobacco and mechanical equipment has contributed to the concentration of small firms there (Iammarino and Santangelo, 2000). There is no such relationship in the cases of medium-sized and larger firms (Table 1). These results lead towards the partial rejection of hypothesis 5. With the exception of small firms, the clustering of firms at the local level in Italy seems to be unrelated to geographical location when factors such as the research output, the GDP per capita and the population of a province are accounted for. Indeed, it can be assumed that research output, GDP per capita and population capture many of the disparities which have traditionally been attributed to the three tier geographical division of Italy. The introduction of the geographical variables also implies a slight decline in the strength and the significance of the association between research output and the clustering of firms. In the case of larger firms, a slight and non-significant positive relationship is even transformed into a slight and equally non-significant negative association.

Table 2**Regression results using the presence of universities as independent variable.**

	FIRMS20-49		FIRMS100-199		FIRMS250-499		ALLFIRMS	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
UNIV	0.240** (3.327)	0.127* (2.026)	0.127* (2.459)	0.117* (1.993)	0.222* (2.045)	0.129 (1.129)	0.235** (3.468)	0.158* 2.284
POP	0.562** (9.097)	0.716** (7.702)	0.442** (7.765)	0.627** (7.143)	-0.021 (-0.189)	0.324 (1.902)	0.419** (6.138)	0.695** (6.712)
GDPCAP	0.396** (6.953)	0.456** (3.729)	0.616** (11.742)	0.592** (5.173)	0.164 (1.164)	0.311 (1.398)	0.490** (7.784)	0.562** (4.209)
ZONE2		0.222** (3.193)		0.015 (0.231)		0.072 (0.567)		0.125 (1.607)
ZONE3		0.201** (2.833)		-0.087 (-1.308)		-0.007 (-0.054)		0.042 (0.532)
ZONE4		0.153 (1.335)		-0.067 (-0.631)		0.119 (0.574)		0.078 (0.624)
ZONE5		0.183 (1.828)		-0.041 (-0.434)		0.094 (0.518)		0.093 (0.835)
ZONE6		-0.110 (-1.265)		-0.241** (-2.919)		-0.434** (-2.709)		-0.316** (-3.237)
Df	3,96	8,91	3,95	8,90	3,94	8,89	3,94	8,89
R ²	0.698	0.745	0.745	0.775	0.081	0.170	0.642	0.698
Adj R ²	0.688	0.722	0.737	0.755	0.051	0.095	0.630	0.670

ß standardized coefficients reported

t-statistics in parenthesis

Statistical significance at the 0.01/0.05 level is denoted by **/*

The substitution of the research output by the presence of a university as an independent variable (Table 2) results in a drop of the explanatory capacity of the models. In the case of small and medium-sized firms the positive association and the statistical significance of the relationship between the presence of a university and the clustering of firms is below that observed when the research output was included as an independent variable (Table 2). Still the results of the analysis confirm hypothesis 6: the clustering of small and medium-sized firms is greater in the provinces with a university or universities than in those without. In the case of larger firms, the inclusion of UNIV instead of RESEARCH has an opposite effect: the existence of a university in the province is positively associated and significant at the five per cent level. However, the explanatory capacity of the model is still well below that of the models where small and medium-sized firms are

included as dependent variables. These results suggest that although the presence of universities and public research centres is important for the clustering of SMEs in any geographical location, the quality and quantity of the research conducted in those centres is more important. Provinces which seem to have dynamic clusters of SMEs also have universities and research centres which perform more or higher quality research than those with a lower concentration of SMEs. This excellence in research generates greater knowledge spillovers which are reaped by local firms and contribute to raise the competitive edge of the area. Finally, the inclusion of the geographical variables produces results which are similar to those described for Table 1.

4. Conclusions and policy implications

The results of the analysis come to reinforce the claim that the spatial clustering of SMEs is related to the presence of universities. Research conducted by universities and public research centres promotes the concentration of small and, to a lesser extent, medium-sized firms, not just in high-tech sectors as suggested by Audretsch and Feldman (1994 and 1996b), but in all sectors, as the evidence from Italy shows. The clustering of larger firms is, in contrast, largely unrelated to the research performance of public research institutions. And although the mere presence of public research institutions generates knowledge spillovers which favour the clustering of SMEs, the results of the analysis highlight that the amount and quality of research produced by those research institutions is a more important factor. Other than research output, factors such as the relative wealth, the population and, to a much lesser extent, the geographical location of the province also play an important part in the spatial clustering of SMEs.

The economic contribution of research conducted by universities or public research institutions is thus crucial for local economic development, since it generates knowledge spillovers, synergies and agglomeration economies which contribute not only to the formation, but also to the survival and development of clusters of SMEs. But if a locality is to fully maximise such dynamic synergies, improving the quality of the research conducted in public research institutions and developing the links between the sources of knowledge and local firms become key elements for the successful generation, diffusion and assimilation of locally generated spillovers. The clear cut evidence of the analysis is that the effects of local knowledge for the development of SMEs are positive. And if the clustering of SMEs is particularly influenced by knowledge spillovers, policies which

facilitate the genesis of spillovers and the spread of such knowledge in the local milieu are likely to result in greater local economic dynamism. Consequently, governments should encourage partnerships between universities and public research centres, and private businesses.

This approach to the question raises, however, almost as many questions as it provides answers. Our method of analysis does not allow us to deal with the factors which explain how the transmission between locally generated knowledge and local innovation by clusters of SMEs takes place or with which areas of research may be more prone to generate spillovers which may be later reaped by SMEs. Further research is therefore needed in order to deal with these and other questions. Case studies and time series analyses may complement this type of research and provide suitable answers to these questions. Only in this way we will be able to further enhance our understanding about how the knowledge spillovers generated by public research affect the creation and development of dynamic clusters of SMEs.

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