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Geographic proximity and technological transfer in Italy

Davide Fantino, Alessandra Mori e Diego Scalise

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di Davide Fantino[1], Alessandra Mori[2] e Diego Scalise[3]

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Abstract

In the last decade R&D expenditure in Italy has been lagging at a bare one per cent of GDP. Its private share appears low in international comparison and, as a consequence, Italian firms take out a small number of patents. There are, however, external sources of innovation available to firms. The aim of this work is to measure the role of the latter using a completely new dataset developed at the Bank of Italy, focusing on research agreements between universities and firms. The results of the empirical analysis suggest that technological transfer is complementary to the presence of in house research centres and to the use of other external innovation sources (such as investments in machinery, software and patents). Using data on the quality and the relevance of university research we show that the distance from top research centres is one of the most important factors in determining the probability of knowledge transfer agreements with universities, controlling for possible endogeneity problems. Sector and scale effects also emerge from the analysis.

Key words: Technological transfer; R&D expenditure; innovation.

JEL codes: L24 O31 O32 R12

[1] Bank of Italy, Research Department. E-mail: davide.fantino@bancaditalia.it.
[2] Bank of Italy, Research Department. E-mail: alessandra.mori@bancaditalia.it.
[3] Bank of Italy, Research Department. E-mail: diego.scalise@bancaditalia.it.
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Summary

Applied research does not exist.
Only applications of research do exist.
A. EINSTEIN

1 Introduction and short literature review

Empirical evidence on research and innovation gives a peculiar and somehow worrying picture for Italy: R&D expenditure, already low in international comparison, has not been growing in the last ten years (in 2008 it represented 1.23 per cent of GDP as in 1998, against a UE27 average of around 2 per cent and values of more than 2.5 per cent for Northern European countries). Firms' share (usually the most dynamic component) is around fifty per cent, against values of more than 60 and sometimes 70 per cent registered by other European countries (Istat, Eurostat). As a consequence of that, public research and universities play a fundamental role for the Italian R&D system. In addition to this, Italian firms tend to take out a small number of patents, compared to international peers. The literature has proposed different explaining factors: the prevalent orientation toward traditional sectors, the relatively small dimension of Italian firms, which make financing of internal research difficult for them (see Rossi, 2006); some scholars defined this system, informal and non certified, "researchless innovation" (Bonaccorsi and Granelli, 2005 and Kleinknecht, 1987): a model, which has suffered from the introduction of new technologies and from the competition of emerging countries in international markets.

However, non-internal sources of innovation are available to firms, through contacts with universities and public research centres. Previous studies have found a positive relationship between academic basic research and local innovation outcomes thanks to the effects of knowledge spillovers (Arrow, 1962; Nelson, 1986; Jaffe, 1989) and of location of firms (Varga, 2000; Bade and Nerlinger, 2000; Abramovsky *et al.* 2007) on growth. Hence it is crucial, both in normative and positive terms, to understand the factors that facilitate knowledge transfer from universities to firms. "How much is geographical proximity important? What is the role of the quality of research supplied by universities?" (Mansfield and Lee, 1996) are among the questions that empirical research has tried to address.

The literature has suggested a number of variables to explain the probability of knowledge transfers from universities to firms.

A first strand has concentrated on firm's characteristics: in order to appreciate, acquire and make commercial use of the results of academic research, the firm needs to possess a set of specific skills (the concept of absorbtive capacity, in Cohen and Levinthal, 1990; see also Rothaermel and Thursby, 2005; Buganza *et al.*, 2007, Thune, 2006; or the idea of cognitive and social proximity, defined as a common ground of knowledge and relations, in Boschma, 2005) and to have a net of formal and informal relationships. According to this view, technological transfer is complementary to other forms of innovation developed within the firm or acquired from outside; the main drivers of research collaborations would then be firm's characteristics, such as dimension (larger firms are likely to have a more diversified set of skills within them), economic sector of activity, the presence of networks such as industrial districts: these could even be a substitute for academic research in the acquisition of innovative capacity (see for example Piergiovanni *et al.* ,1997).

More recently the literature has focused on the supply of scientific research: in this context the importance of geographic proximity of the firm to academic research centres is often stressed (see Thune, 2006). Knowledge transfers that lead to innovation are conceptualized as learning by doing, for which frequent and complex interactions (Polanyi, 1969) are necessary in order to develop what Lundvall (1992) defined tacit knowledge: geographical proximity would then make these contacts easier and more fruitful. Other studies, such as Keller (2002), show that R&D spillovers decrease with geographical distance. According to Gertler (2005) spatial proximity is a proxy for "communication distance", determined by technological, social and cultural factors. Piergiovanni *et al*. (1997), using data on patents in Italy, find that local spillovers from academic research are important in generating innovation for firms (less so for the larger ones, in which innovation is created mainly internally); Rodriguez-Pose and Refolo (2003), using a bibliometric indicator, show that the development of clusters of small firms is influenced by the presence of universities in the area and the quality of their research. Another important variable in the literature is the quality of research. Mansfield and Lee (1996) conduct a multivariate analysis to study the factors that influence the share of academic research financed by firms: the distance from the firm and the quality of research provided by universities emerge as the two main drivers in the decision of the i-th firm on how much research funding at the j-th university. Abramovsky and Simpson (2008), using data from the Community Innovation Survey on the transfers of knowledge from universities to innovative firms in the UK for four manufacturing industries, show that R&D offices tend to be concentrated in the vicinity of university departments of excellence relevant to the business sector of firms and that geographical proximity is one of the main factors pushing companies to seek knowledge transfer from universities located around them, though with some sectoral differences. This result is in line with the findings in Laursen *et al.* (2008) for the UK, in Rosa and Mohen (2008) for Canada and in Rasiah and Govindaraju (2009) for Malaysia.

Another possible driver for technology transfer from universities to firms, identified in the literature, is given by policies of commercial promotion of research carried out by research centres. In many countries universities have long been active in adopting policies to promote technology transfer and commercial exploitation of research results. Even in Italy this phenomenon is increasing, as well as initiatives to spread and monitor this practice (Pietrabissa and Conti, 2005; Piccaluga and Balderi, 2006; CRUI, 2007; Netval, 2008). The search for private financial support by universities is partly motivated by the need to integrate the funding by the State, which in Italy is mostly used to cover staff costs. However this is not the only reason: as well as to ease their budget constraint, universities promote partnerships with firms and technology transfer to improve their own efficiency. Empirical evidence (Breno *et al.* 2002, Bonaccorsi and Granelli, 2005) suggests that a greater proportion of private funding is correlated with higher productivity, both in teaching, in terms of number of students and graduates per professor, and in research, measured by the number of publications per faculty member. A growing number of universities[5] has also promoted the creation of specific structures for technology transfer (Technology Transfer Office), also activating business incubators and promoting the establishment of academic spin-offs, small business initiative often linked to the exploitation of a patent. The theory does not have a strong *a priori* on the correlation between the more commercially oriented universities and growth and innovation of firms located in the same territory: they can facilitate the production of

[5] See Appendix I

knowledge with a commercial value (Di Gregorio and Shane, 2003), but it is also possible that they inhibit the transfer of technology, in the interest of the sponsoring companies, to protect the results of patented research, in order to increase their market power (as in Colombo, D'Adda and Piva, 2009).

This work aims, first, at providing a direct measure of the importance of innovation sources for Italian firms, and in particular of the technology transfer from universities, using a completely new database based on the fifteenth round of the Bank of Italy Business Outlook Survey on Industrial and Service Firms (conducted in 2007 on a sample of about 3,000 industrial and 1,000 non-financial services enterprises with at least 20 employees). Secondly we will try to identify the relevant factors in determining the probability that firms have collaborations with research institutions, with particular regards to firms' characteristics, to the relations of complementarity or substitutability with intramural research or other sources of innovation, to distance from research supply, its quality and its relevance for the sector to which the company belongs. In order to measure the latter two factors we will make use of the Carnegie Mellon Survey (CMS Cohen *et al*., 2002), developed in 1994, which quantifies the importance of ten research fields for various manufacturing sectors, and of the results of the Triennial Evaluation Research Project (VTR) conducted by the Ministry of Education and Research in 2006 (MIUR, 2006), which ranks Italian universities and research centres according to a number of indicators.

The analysis thus contributes to the empirical literature on geographic spillovers, and, in particular, on the effects of the quality of academic research on knowledge transfer agreements between firms and universities in Italy, for different sectors and firm size.

The rest of the paper is structured as follows: Section 2 describes the sources of innovation used by Italian companies, Section 3 presents an econometric analysis of the probability of technology transfer and robustness checks; Section 4 concludes. In the Appendix we report some information on the universities' budgets.

2 Innovation sources and Italian firms: results from a survey

Innovation sources for firms can be internal or external, including technological transfers from the public research system (universities and research centres). The latter may take the form of sale of university research applications to third parties (i.e. private business) or of the promotion of new business ventures with research structures, often with universities directly involved in the strategic management of intellectual property. In Italy, however, this phenomenon of so-called academic spin-offs is not widespread (Appendix I). The channel of transmission of research results is represented by direct, formal and informal, contacts between firms and universities.

According to the fifteenth round of the Bank of Italy Business Outlook Survey on Industrial and Service Firms (the questionnaire is contained in Banca d'Italia, 2007 and is available on line), in the period 2005-07 the innovation source most frequently used by Italian firms has been the acquisition of innovative software or equipment from outside (52.9 per cent of companies). However, more than a few Italian firms develop innovation internally: 25.5 per cent of them has a research or design facility located within national boundaries; 3.9 per cent possesses one (sometimes additional) abroad. The use of all these forms of innovation is relatively more common among large companies, in higher value added sectors and in the northern regions (Table 1 and Fig. 1); the existence of a research centre abroad is more frequent where the presence of multinational companies is stronger.

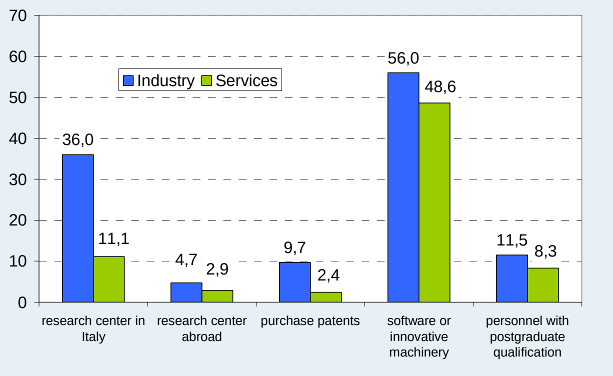
So widespread a presence of research centres is not incompatible with the picture that emerges from the traditional indicators of R&D expenditure and patents: over 50 per cent of these centres are small, with less than 5 people operating in them; only one-fifth of the companies have more than 15 researchers; big corporate research centres in Italy are just a few. This average dimension is also compatible with a type of incremental innovation which cannot be easily codified and usually does not result in patents.

Among the other non-internal channels for innovation acquisition, those used less frequently were the recruitment of highly educated staff (10.2 per cent), and the purchase of patents (6.6 per cent). Also in these cases, percentages are larger for industrial firms than for services (Fig. 1) and tend to grow with the business dimension. The purchase of patents, in particular, represents common practice for one quarter of large industrial enterprises, while it is a much less widespread (ten times less) in service enterprises. The recruitment of staff with a PhD is more common in the business service sector (16.6 per cent), followed by specialized industries sectors (machinery and chemistry); it is negligible in traditional or lower value added firms.

Figure 1

Innovation sources for Italian firms 2005-2007 (1)

(per cent; frequency of affirmative answers)

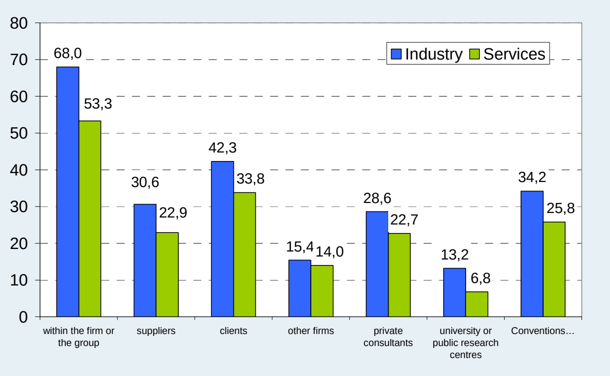


(1) Source: Bank of Italy, Business Outlook Survey of Industrial and Service Firms; Questions: 1. Does the firm, or the group to which it belongs, if any, have a research centre or a design facility? 2. Please indicate if in the period 2005-2007 the firm did any of the following: a) purchase patents b) Purchase software and/or innovative machinery c) Recruit personnel with postgraduate degree
Weighted by the population of firms and normalized with the number of valid answers

Figure 2

Importance of different innovation sources for Italian firms 2005-2007 (2)

(per cent)



(2) Source: Bank of Italy, Business Outlook Survey of Industrial and Service Firms; Question: In 2005-07, what importance did the following sources of information have for the firm's innovation activities? 0=not used; 1=of little importance; 2=fairly important; 3=very important; 9=don't know, not answering
Weighted by the population of firms and normalized with the number of valid answers

Table 2 shows the relative importance of different sources of innovation for firms in the period 2005-07. Sources internal to the company or the group were considered of high or medium importance by more than 60 per cent of the firms, followed by relationships with customers, suppliers and trade shows. Private consultancies and contacts with universities and public research centres have been judged important, respectively, by 26.1 and 10.5 per cent of firms, with higher frequencies registered for industrial firms (Fig. 2).

With regard to the particular instrument of co-operation with academia, in the period 2005-07 it was used by 22.3 per cent of the firms, a share almost twice as much as the previous three years (Figure 3 and Table 3). A quarter of the companies which co-operated with universities did so by taking part into specific research and funding entire projects, almost a half (42.3 per cent) bought consultancy services and 68.8 per cent of them just hosted internship students (Fig. 4). Larger firms registered more frequent contacts with universities, in all geographical areas; and industrial companies (especially in chemistry and machinery) had more contacts than service ones. In the majority of cases (86 per cent), relationships with institutions were carried out on an individual basis. The support from trade associations or business groups has been used most frequently by service firms (23.8 per cent), by those operating in traditional sectors (textiles and clothing trade) and in the southern regions. In the same areas and sectors, companies were less ready to take full advantage of tax benefits, or qualify for public funding, including EU's (respectively 12.7 and 24.8 per cent of the total).

Figure 3

Relationships between Italian firms and universities/public research centres over time (1)

(per cent; frequency of affirmative answers)

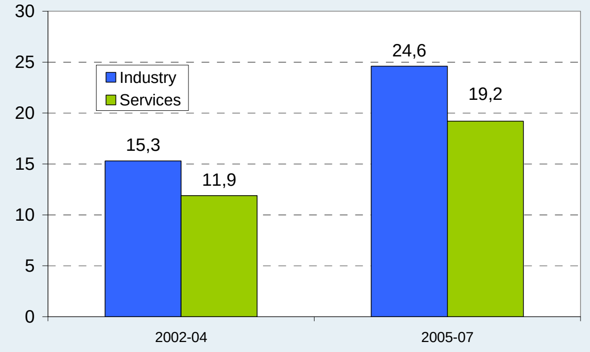
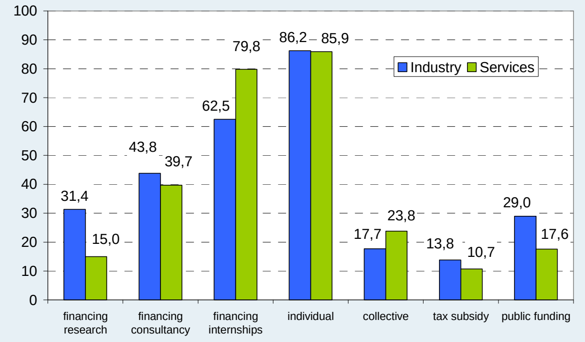


Figure 4

Firms with a relationship with universities: type of relationship(1)

(per cent; frequency of affirmative answers)



(1) Source: Bank of Italy, Business Outlook Survey of Industrial and Service Firms; Questions: 1. Has the firm entered into collaboration agreements with Italian universities (or public research centres) in the period 2002-2004? And in the period 2005-2007? 2. Only if the answer is yes, what was the type of agreement? Was it individual or collective? Has the firm received public funding or tax subsidies?
Weighted by the population of firms and normalized with the number of valid answers

These data do not allow for differentiating the type of internship hosted by companies; however, it is likely that internships often constitute the trial or training period for skilled labour, obtained at very low cost, and not a true instrument of technology transfer. Figure 5 thus depicts the collaborations with academia, in the years 2005-07, excluding cases in which the company limited itself to hosting interns: the average frequency decreases by about a half (13.1 per cent), is increasing in firm's size (up to 58.3 per cent for larger industrial companies) and higher in the North-West industrial sector (18.3 per cent); the most active sectors are chemicals (24.3 per cent), machinery (20.1) and business services (20.8).

Once established, the contact with academia is stable over time: 83.1 per cent of the companies that had collaboration agrrements with universities in the period 2002-04 has continued to do so in the next three years, in all geographical areas (a little more in the industrial sector, 87.0 per cent); the cooperation was not occasional for the whole of larger firms.

Although the phenomenon of academic collaborations is not negligible, the majority of Italian companies have no contacts with universities (Table 4); Fig. 6 reports the distribution of the reasons: the main obstacle does not seem to be either the low quality of research conducted in Italy, or the costs, or a preference to engage relationships with foreign research centres, or the burden of bureaucracy. The absence of collaborations is motivated mainly by a lack of interest by firms (54.3 per cent), but also by a widespread perception that academic research is not adequate for business use (33.3 per cent). Among the companies that have not renewed collaboration agreements, the motivation that academic research is distant from business logic loses importance, while the frequency of those who consider it too expensive increases.

Figure 5

Research agreements aimed to technology transfer 2005-07 (1)

(per cent; frequency of affirmative answers)

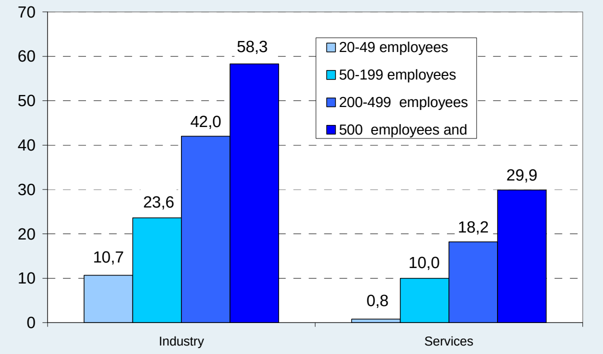
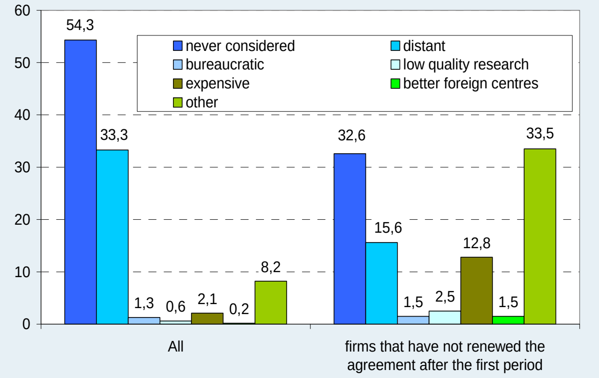


Figure 6

Reasons behind the absence of collaborations (2)

(per cent; frequency of affirmative answers)



Source: Bank of Italy, Business Outlook Survey of Industrial and Service Firms;
(1) Questions: 1. Has the firm entered into collaboration agreements with Italian universities (or public research centres) in the period 2005-2007?
(2) 2. Only if the answer is no, why not? a) the idea has never been considered b) academic research is unrelated to the firm's requirements c) universities involve too much bureaucracy d) the quality of research is unsatisfactory e) the cost is too high f) the firm prefers to work with foreign universities g) other
Weighted by the population of firms and normalized with the number of valid answers

3 The determinants of technology transfer: econometric analysis

Multivariate analysis

In this section we present the results of a multivariate probit analysis on the determinants of the probability that the firm had technology transfer collaborations with a university in 2005-07 (excluding the cases in which the firm has only hosted internships)[6].

This analysis aims to answer some of the questions emerging from the literature review:

- Is technology transfer a complement to or a substitute for intra-mural research?
- Is the phenomenon influenced by the availability, in the area in which the firm is located, of high quality academic research?

[6] Hosting internships *per se* is not a good proxy to measure collaboration with academia. However, it is, surprising that the willingness to host skilled labour for such training experiences never has explanatory power in any regression (results available upon request).

The maximum likelihood function for the probit model (Greene, 1993) has the following shape:

$$Ln\ L = \sum_{i \in S} w_i \ln \Phi(x_i b) + \sum_{i \notin S} w_i \ln[1 - \Phi(x_i b)] \qquad (1)$$

Where Φ is the normal distribution; S is the set of observations *transf* $_i$ different from zero, where *transf* $_i$ represents the technology transfer collaboration for the i-th firm; w_i are sample weights (given by the inverse of the probability that the i-th observation is included in the sample design); x_i is a vector of individual firm characteristics, territorial and sector controls. We employ the robust Huber/White/Sandwich estimator for the variances.

Data

In equation (1) explanatory firm's characteristics variables x_i are taken from the fifteenth round of the Bank of Italy Business Oulook Survey on Industrial and Service Firms (2007) and include: dimension (measured as the log average workforce in 2006); dummy variables to check for the presence of an in-house research centre in Italy or abroad, for the acquisition of a patent, software or innovative machinery in 2005-07; the degree of importance attributed to different innovation sources: suppliers, private consultancies, universities, public research centres; the incidence of software expenditure over fixed investments in 2006; a dummy to check if the firm is part of an industrial district (according to Sforzi-Istat definition, not necessarily with the same productive specialization[7]); sector, region and macro area controls.

To evaluate the importance of different scientific research fields for firms, we used (as in Abramovsky and Simpson, 2008) the Carnegie Mellon Survey (1994) which details the importance of ten subject areas (biology, chemistry, physics, computer science, materials science, medicine, mechanical engineering, electronics, chemistry and mathematics) for the various manufacturing industries[8].

In order to measure the quality of the research produced by universities, we used the results of the first exercise of the National Triennial Research Evaluation in 2001-03 (VTR, 2006), published in MIUR (2006, currently the only one available). The VTR (2006) is used to distribute state funds to individual structures (universities and research centres). It involved the 102 participating centres directly: they had to select, independently, a predetermined number of research products (books and their chapters, including conference proceedings, journal articles, patents and designs etc. ...) completed in the analyzed period, and to submit them electronically to one of the 20 established evaluation panels, depending on their research field. The number of products required from each structure has been normalized on the number of full-time equivalent researchers (FTE). Research products were evaluated by the area panel; the number of panelists spanned between 5 and 17, depending on the complexity of the subject and on the number of products submitted. Panels made use of 6.661 experts, chosen independently by panels themselves, who had the task of expressing a judgement on

[7] We have also included a dummy equal to 1 if the firm is part of a science park. Results (available upon request) never change.

[8] The CMS is based on interviews with managers of the R&D departments of manufacturing companies located in the United States. They were asked to evaluate the importance of research in any field, for their innovation activities. See Cohen *et al.* (2002) for a complete description.

the submitted material. Each product was evaluated by at least two experts, who took into account its quality, relevance, originality/innovation and internationalization and/or its international competitive potential (for patents and applied results, the socio-economic impacts, even potential ones, were assessed). The following criteria for the allocation of funds to individual structures were envisaged, based on six parameters, each of them with a specific weight:

- Indicator A – quality of the selected products (weight 4/9)
- Indicator B – property rights on the selected products (weight 2/9)
- Indicator C – International mobility propensity (weight 1/9)
- Indicator D – advanced training propensity (weight 0,5/9)
- Indicator E – ability to attract financial resources (weight 1/9)
- Indicator F – ability in using available funds to finance research projects (weight 0,5/9)

For the various subjects, thus, both a ranking of quality of scientific research, based only on the Indicator A, and a composite index (the weighted average of the six sub-indicators presented), suitable to be used for the allocation of state funds, were produced. In the multivariate analysis presented here we will always refer to the first one, since the main object of interest are the spillovers of academic research on innovation and not the quality of teaching.

We then created a dummy variable to catch the localization of high quality university research: it takes the value of 1 if one of the two best performing departments[9] in the fields considered most relevant for the firm is located within a range of 10 Km from the firm itself. Relevant research fields are definied as the three most important, according to the managers interviewed in the CMS, provided that they have been judged as "important" or "very important" by at least 50 per cent of the sample[10]. To reconcile the data from CMS to those from VTR, computer science has been merged with mathematics; the branches of engineering (chemical, mechanical and electronic) have been put together in the discipline "Industrial Engineering and Information"; materials science was not included in VTR and therefore was not used in the empirical analysis. The Table below shows the two most important fields of research, for the entire sample of manufacturing firms and for the different sub-sectors:

[9] Best performers are defined as the first two research structures in the ranking, among "mega-centres", "normal centres" and "small centres".

[10] In the pooled regressions we also included chemistry, third in the CMS ranking, but with a score of 33,7 per cent, in order to evaluate the effects of scientific research in a wider sense on the whole sample, considering also that this includes service companies, not covered by CMS. In addition to this, chemistry, even if it does not reach a score of 50 per cent on the whole sample, reports judgments of relevance for more than 60 per cent in many sub-sectors. Anyway, results are robust both including and excluding chemistry from the relevant subjects.

	Most relevant research fields
whole sample	engineering, mathematics/computer science, chemistry
textiles	engineering, mathematics/computer science
chemicals, rubber and plastics	engineering, chemistry
mechanics	engineering, mathematics/computer science
other manufacturing	engineering, mathematics/computer science
energy and extraction	engineering, mathematics/computer science
transports and communications	engineering, mathematics/computer science

We also created a dummy variable which takes the value of 1 if a generic university, without distinctions of quality or field, is located within 10 Km from the firm: this is to check for the effect of a more widespread supply of scientific research, regardless of its quality.

The commercial orientation of a university is measured by the presence of an operational dedicated Technology Transfer Office (TTO), detected from the web sites of universities and double-checked by telephone. The variable "intensity of TTO in the region" takes the value of 1 if the office is operational and 0 otherwise. The variable is normalized on the number of firms with more than twenty employees in the area (Census source).

For a complete definition of the covariates included see Table 5.

Results

Table 6 shows the results of the probit estimation of the probability that a firm had technology transfer agreements with a university in the period 2005-07; controls include firm's characteristics, academic research supply variables and sector (column [1]), with region dummies (column [2]) or macro-area dummies (column [3]). The sample was then partitioned by size (Table 7) and sector (Tables 8 and 9).

Results are robust to different specifications (Table 6). The probability of technology transfer is positively correlated with the average size of the company, with investments in ICT and with the presence of an intra-mural research centre (while the existence of a research centre abroad does not seem to have any effect); the purchase of software or innovative equipment and of patents, and the fact of considering university as a valuable source of innovation, all show positive and significant coefficients (while the importance attributed to private consultants does not show any relevant effect). On the contrary, the reliance on suppliers as innovation source tends to decrease the probability of research agreements with universities.

The proximity to major quality scientific research increases the probability of technology transfer collaborations: the coefficient is significantly different from zero always above the 5% level of confidence. It doubles in value and becomes significant at the 1% level when regional dummies are inserted, i.e. when controlling for regional fixed effects. It is interesting to note that proximity to a university not characterized by high quality research in relevant subjects does not exert any significant impact on the probability of collaborations. What matters therefore is not the widespread supply of research but the supply of relevant high quality research.

In all specifications, the pseudo-R^2 is equal to about 0.4. The χ^2 Wald[11] test rejects the hypothesis of joint no significance of explanatory variables. The Link test[12] of dependent variable specification rejects the hypothesis of misspecification.

Therefore, it seems to emerge a picture in which technology transfer is complementary to intra-mural research, and where companies exploit the different sources of innovation developed by others, protected by patents, or embedded in machines and software synergistically. The hypothesis that public research can simply replace the (lack of) research (not) conducted by firms[13] seems rejected. The importance of the size variable seems to support the view that the firm must possess a set of specific skills to be able to capture, understand and commercially exploit the results of academic research (the concept of absorptive capacity, Cohen and Levinthal, 1990, or the cognitive proximity, as in Boschma, 2005): in this sense size is an important factor. Hence, policies aiming at encouraging firms' growth can be interpreted as spurring research and innovation (Rossi, 2006).

As discussed above, if the firm considers the relationship with suppliers an important source of innovation, the probability of academic collaborations decreases. This result seems to suggest that, where networks of firms exist, they can represent a substitute for agreements with universities. The coefficient on the district variable, instead, is never significantly different from zero, probably due to the structure of the sample, which contains only firms with more than 20 employees, and hence less oriented to take advantage of district networks.

Finally, the probability of contacts with universities is higher for firms operating in the relatively higher technology sectors (textiles and clothing is the base one): mostly so in manufacturing and in business services, which include research and professional activities.

We then portioned the sample by size: small enterprises (20-49 employees), medium ones (50-199 employees), large ones (between 200 and 499 employees) and very large ones (more than 500 employees). We also included the presence of Technology Transfer Offices (TTO), normalized on the number of firms with more than 20 employees in the region, as an explanatory variable. The hypothesis that we want to test is whether the location of the firm in a region with a relatively rich supply of a strongly commercially oriented university research[14] has influence on the probability of cooperation with universities.

For small firms, the results are very similar to those obtained for the entire sample: in particular the effect of proximity to high quality university research is highly significant and

[11] The χ^2 Wald test is an asymptotic test on the null hypothesis that all the coefficients of explanatory variables are jointly equal to zero.
[12] The Link test (Pregibon, 1979 and 1980) is a test on the specification of the dependent variable, based on the detection of a link error; the model is re-estimated, including estimates of y and its square among regressors. It is plausible that the latter is significant if there is a specification error: the null hypothesis is that this coefficient is not significant.
[13] Piergiovanni *et al.* (1997), using data on Italian provinces, find that complementarity arises only for smaller firms. For a literature review on this topic see Rodriguez and Refolo (2000).
[14] For the whole sample and in the sectoral regressions this variable (for a full description see Appendix I) is never significant and has not been inserted in the Tables to allow presenting results robust for regional dummies.

larger in magnitude than for the pooled regression: this seems to confirm the theory that distance is a more important cost for small companies, that are less able to absorb it on a wider customer base than larger ones. Investments in software and relationships with suppliers do not seem to exert any significant effect[15].

Also for medium-sized companies the effect of proximity to high quality academic research is significant and external innovation sources acquire significance and magnitude, confirming the hypothesis of complementarity. The presence of a generic university does not show any effect.

Only for large and very large companies the distance from high quality research does not seem to have any significant effect on the probability of research agreements with universities: this confirms the line of thought that, for large enterprises, the cost determined by the distance from the target university is not a decisive factor in the choice of establishing relations with it. On the contrary, it appears that for very large firms the commercial orientation of universities is a key feature in determining the probability of collaboration. It is interesting to note that the presence of a research centre abroad turns out to be complementary to the acquisition of innovation from universities (while the purchase of patents does not show any significant effect) and that belonging to a district of the same sector negatively affects the probability of transfer. Larger firms seem to choose universities that are better able to sell the results of their research and appear able to exploit their size to capture district synergies in the most fruitful way.

In Tables 8 and 9 the results of sector regressions are reported for textiles, chemicals, engineering, other manufacturing, and transport and communications; for each sector only the subjects considered relevant for it were taken into account in defining variables[16]. Proximity to relevant departments of excellence is significant and important for the textile, other manufacturing and transportation industries. On the contrary, it does not seem to be crucial for chemicals and engineering, sectors in which the complementarity to other sources of innovation exerts a stronger influence.

Robustness checks

The definition of the variable measuring the distance of the firm from qualified research centres is the first area in which we performed robustness checks: by definition dummy variables have a more limited explanatory content than continuous ones. Moreover, checking for robustness of results with respect to a complete range of different definitions of the dummy turns out to be a difficult task, given the arbitrariness in the definition of the threshold of kilometres within which the university should be placed so that the variable assumes a value of 1: some controls of this type have been made[17], they are not shown in the tables and

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[15] For smaller firms, proximity to a generic university decreases the probability of collaborations. This result is in line with the findings in Laursen *et al.* (2008), who highlight that what matters is the distance-quality ratio and that being in the proximity of a low quality university can harm academic collaborations.

[16] We have not reported results for Energy sector, given the small number of observations (72).

[17] Results are robust to different definitions of the variable. For example, in substitution for the described dummy, we inserted a regressor that counts the number of high quality, relevant scientific departments in the 10km range; in another exercise the dummy has been replaced by a discrete variable taking value of zero if there

they do not alter the conclusions. Table 10 shows the results of regressions on the entire sample where the explanatory variable is either the average or the minimum distance from relevant high quality research (this second case to capture the idea that it's the quality of the nearest research centre that could be more relevant, as the number of collaborations is limited). Results are confirmed: the distance from the supply of relevant top quality research has a significantly negative impact on the probability of technology transfer.

The inclusion of other firm's characteristics (such as the share of exported sales)[18] among covariates does not change the results of the analysis in any case: note that the international openness of the company does not seem to exert any significant effect on the probability of academic collaborations. The use of more precise sectoral dummies[19] shows that, within the chemical industry, pharmaceutical companies and manufacturers of plastics are more prone to academic partnerships aimed at technology transfer; oil companies appear to be les willing to engage in such agreements.

Given the possible (probable) endogeneity of the geographical proximity measure (as shown by Abramovsky and Simpson, 2008, more innovative companies tend to be located near excellent scientific research centres), the results shown above need to be considered more as an evidence of "co-movement", rather than of causality in a strict sense. Although a complete analysis of the issue of endogeneity lies beyond the scope of this work, in Table 11 we report estimates obtained using an instrumental variables probit approach, in order to address the problem more systematically. The characteristics that an instrument needs to have are: being relevant, i.e. correlated with the explanatory variable to be instrumented, and exogenous, i.e. not affected by the same problem as the original regressor. The distance of the firm from research centres of excellence in "Ancient History, Philological-Literary and Historical Arts" (as defined in the VTR, 2006) seems to meet these requirements as the location of the best humanities departments is typically related to the that of the best scientific research centres (the correlation between the average distance of firms from top tired scientific research centres and from top humanities departments is 0.80), but it does not affect the decision of firms on where to locate, not presenting *ex ante* advantages for them. Results of the regression in which the average distance from top scientific research centres is instrumented by the distance from the best humanities departments are reported in Table 11. Wald test[20] of exogeneity indicates that there is not enough information to reject the null hypothesis of exogeneity of the original regressor. Therefore probit estimation produces consistent and efficient coefficients. In any case, the instrumental variables estimation, although less precise, seems to confirm that the location of the best scientific research centres determines the probability of collaborations.

4 Conclusions

In this paper we have analyzed the sources of innovation used by Italian firms, using data from the fifteenth round of the Bank of Italy Outlook Survey of Industrial and Service

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is no qualified research within 10 Km, 1 if there is one department, 2 if there are two departments dealing with different fields (to assess the effect of a more diversified scientific research). Results never change.

[18] Results avilable upon request.

[19] Results avilable upon request.

[20] If the Wald statistics is not significant (as in our case), there is not enough information in the sample to reject the null hypothesis of non endogeneity. See Hakkala *et al*. (2008).

Firms, based on a sample of about 4.000 industrial and non-financial service enterprises with at least 20 employees. We have then conducted an econometric analysis to identify the factors that influence the probability that a firm enters into cooperation agreements with universities aimed at knowledge transfer. We have focused on various research questions: which firm characteristics facilitate such relationships? What is the role of local supply of relevant academic research? How do the distance from and the quality of this supply shape firm-university agreements?

The econometric analysis indicates that the probability of technology transfer is positively correlated with the average size of the firm and with its willingness to invest in immaterial assets: this supports the commonly accepted idea that a company should be big enough to support the fixed costs of investment in knowledge. The different channels of innovation, external and internal, appear complementary: firms with an internal research centre, which buy innovation from outside, in the form of patents or innovative machinery, are more likely to enter agreements with universities. In order to commercially exploit applications of research developed extra-moenia, therefore, companies need specific skills and must be able to create synergies, more likely found in those, often large ones, already innovating in other ways; the hypothesis that public research can completely compensate for the lack of internal research is rejected.

Using data from the Carnegy Mellon Survey and from the 2006 Triennal Research Evaluation (VTR) in the econometric analysis we have shown that the proximity to relevant top quality research centres is one of the main determinants of the probability of technology transfer agreements; the presence of low quality research departments does not seem to have any effect. Results are robust to various specifications. The partition of the sample by firm size highlights that distance is crucial for small and medium-sized enterprises, and is not relevant for the larger ones: this seems to confirm that distance represents a cost, which large firms are able to bear through their size and their partly different pattern of innovation, in which the commercial orientation of universities plays an important role.

These results are also relevant from a policy point of view: in Italy, after the Ministerial Decree 509/1999 which introduced three-year degrees, a marked increase in the number of universities has occurred: in 2008 there were 95 of them, almost one for each province (including web universities, not counting the numerous satellite locations); there were around half as many in the early eighties. Such a widespread supply can encourage technology transfer only if it is accompanied by an increase in the quality of the research produced: on the other hand, an excessive number of universities may prevent them from reaching the critical mass needed to produce relevant research, transforming them into teaching dedicated centres.

5 Statistical tables

Table 1

Innovation sources for Italian firms 2005-2007 (1)

(per cent; frequency of affirmative answers)

	Research centre, 2007		Purchase of patents	Purchase of software and/or innovative machinery	Recruit personnel with postgraduate degree
	in Italy	abroad			
			Industry excl. construction		
Geographical areas					
North West	40.6	8.1	11.9	59.0	12.3
North East	36.2	2.8	9.3	57.3	13.0
Center	32.9	2.1	8.6	52.1	9.6
South	28.4	3.5	5.6	48.7	7.6
Islands	23.4	0.2	8.8	53.7	11.8
Number of employees					
20-49	28.5	3.5	7.3	53.4	9.2
50-199	49.7	5.2	13.6	60.3	13.8
200-499	61.4	12.4	18.7	65.9	24.8
500 and more	71.8	26.1	25.9	72.7	44.1
Sector					
Textile, clothing, leather, shoes	35.8	1.2	5.2	50.2	8.7
Chemicals rubber and plastics	41.0	8.4	16.1	63.1	13.7
Engineering	42.1	6.5	13.2	57.7	14.5
Other manifacturing	26.5	2.7	5.2	54.9	8.2
Energy and extraction	10.7	3.8	1.9	49.5	6.9
Total industry excl. construction	**36.0**	**4.7**	**9.7**	**56.0**	**11.5**
			Services		
Geographical areas					
North West	11.5	4.6	1.9	45.8	6.7
North East	7.6	2.2	1.7	52.4	7.2
Center	14.6	2.7	2.6	51.3	10.1
South	12.0	1.5	5.4	48.9	10.7
Islands	9.5	..	0.4	39.4	9.9
Number of employees					
20-49	8.9	1.7	2.0	47.8	6.9
50-199	15.8	6.0	3.4	48.7	9.8
200-499	12.1	2.9	1.8	52.1	14.5
500 and more	26.4	5.6	4.7	67.8	27.4
Sector					
Wholesale and retail trade	3.1	4.6	2.1	46.7	5.4
Hotels and restaurants	1.4	0.1	..	46.0	2.7
Transport and communication	5.9	1.6	1.3	53.7	5.0
Other business and household services	28.7	2.7	4.4	49.0	16.4
Totale services	**11.1**	**2.9**	**2.4**	**48.6**	**8.3**
Total	**25.5**	**3.9**	**6.6**	**52.9**	**10.2**

Source: Bank of Italy, Business Outlook Survey of Industrial and Service Firms.
(1) The questions were: :
1. Does the firm, or the group to which it belongs, if any, have a research centre or a design facility?
2. Please indicate if in the period 2005-2007 the firm did any of the following: a) pucrhase patents b) Purchase software and/or innovative machinery c) Recruit personnel with postgraduate degree
Reported frequencies are adjusted for sampling weights and reported net of missing

Table 2

Importance of different innovation sources for Italian firms 2005-2007 (2)

(per cent)

	Inside the firm or the group	Suppliers	Clients	Other firms	Private consultants	Universities and public research centres	Fairs, conventions, trade associations
			Industry excl. construction				
Geographical areas							
North West	69.2	29.3	36.9	16.4	28.8	14.7	28.9
North East	71.4	37.3	52.0	16.7	28.5	11.0	38.0
Center	63.6	25.8	40.6	13.5	31.9	13.9	36.5
South	62.5	24.2	39.0	12.8	25.0	13.7	37.0
Islands	61.4	26.5	26.5	10.6	22.8	12.2	33.2
Number of employees							
20-49	65.9	30.5	40.7	15.4	26.7	9.5	34.3
50-199	70.2	30.9	44.9	14.3	32.7	19.1	33.7
200-499	80.3	28.7	51.0	19.2	31.6	30.1	37.4
500 and more	88.6	34.3	47.6	21.6	34.3	33.7	30.3
Sector							
Textile, clothing, leather, shoes	56.7	28.8	46.2	15.3	24.1	6.6	39.8
Chemicals rubber and plastics	68.6	37.6	46.9	16.7	25.9	19.0	27.1
Engineering	73.3	30.5	45.0	15.7	31.1	16.0	31.9
Other manifacturing	67.0	30.7	36.0	14.7	27.6	10.8	37.7
Energy and extraction	54.0	13.4	15.9	11.9	36.7	8.8	24.6
Total industry excl. construction	**68.0**	**30.6**	**42.3**	**15.4**	**28.6**	**13.2**	**34.2**
			Services				
Geographical areas							
North West	52.2	18.6	32.3	13.9	28.2	6.1	20.5
North East	54.5	27.2	38.2	14.0	15.8	6.7	26.2
Center	57.3	25.4	35.3	13.4	23.6	6.7	34.9
South	53.0	23.3	35.4	14.7	21.7	9.3	24.6
Islands	40.6	18.5	14.6	13.9	22.9	6.0	22.7
Number of employees							
20-49	50.9	23.4	33.6	13.5	21.3	6.0	25.8
50-199	57.6	21.8	34.8	14.7	23.5	6.5	27.1
200-499	56.3	18.0	30.3	16.0	32.0	14.8	18.3
500 and more	70.3	30.6	38.5	17.9	42.7	20.5	26.3
Sector							
Wholesale and retail trade	51.3	29.1	31.7	11.7	17.9	2.9	22.9
Hotels and restaurants	45.2	3.8	31.9	10.6	14.4	1.8	40.1
Transport and communication	51.2	25.0	30.1	13.7	23.7	3.0	20.4
Other business and household services	60.3	21.5	39.7	18.4	31.9	16.6	27.1
Totale services	**53.3**	**22.9**	**33.8**	**14.0**	**22.7**	**6.8**	**25.8**
Total	**61.8**	**27.4**	**38.8**	**14.8**	**26.1**	**10.5**	**30.7**

Source: Bank of Italy, Business Outlook Survey of Industrial and Service Firms

(1) The question was:

In 2005-07, what importance did the following sources of information have for the firm's innovation activities? 0=not used; 1=of little importance; 2=fairly important; 3=very important; 9=don't know, not answering. In the Tables frequencies of 2) and 3) are reported, net of missing. Reported frequencies are adjusted for sampling weights.

Table 3

Relationships bewteen Italian firms and universities and type of collaborations

(per cent; frequency of affirmative answers)

	Relationships with universities		only for firms that have had collaborations with universities in the period 2005-07						
	2002-2004	2005-2007	type			collaboration		use of	
			financing of research	Purchase of consulting services	offered student internships	individual	collective	tax subsidies	public funding
				Industry excl. construction					
Geographical areas									
North West	17.2	26.5	30.9	48.8	60.5	86.3	18.0	15.9	22.5
North East	14.4	22.5	30.5	44.6	67.1	91.6	11.9	13.0	32.4
Center	13.7	23.3	35.1	39.8	53.0	81.9	19.5	16.2	34.9
South	12.6	24.2	32.8	35.1	70.2	82.3	24.7	8.6	38.3
Islands	18.3	32.8	23.7	30.6	66.8	76.4	27.5	5.1	19.2
Number of employees									
20-49	11.1	18.4	26.6	38.2	62.6	86.0	15.9	12.0	29.4
50-199	19.8	33.7	35.4	44.9	60.3	85.0	19.1	13.6	27.7
200-499	40.7	54.2	34.4	63.2	63.3	91.1	19.2	19.3	27.2
500 and more	59.5	73.4	45.1	62.2	77.1	89.6	23.9	27.7	39.0
Sector									
Textile, clothing, leather, shoes	8.4	13.3	22.2	17.1	61.2	77.2	23.5	16.2	27.9
Chemicals rubber and plastics	19.7	32.8	37.5	56.4	57.6	89.7	20.3	25.4	38.9
Engineering	17.5	27.9	34.5	49.6	59.6	87.9	15.7	12.4	32.6
Other manifacturing	14.1	23.6	25.6	37.2	69.2	84.1	18.1	10.9	19.2
Energy and extraction	20.0	26.1	37.0	38.8	79.7	93.2	19.2	4.5	9.9
Total industry excl. construction	**15.3**	**24.6**	**31.4**	**43.8**	**62.5**	**86.2**	**17.7**	**13.8**	**29.0**
				Services					
Geographical areas									
North West	7.7	18.3	10.4	49.4	75.3	87.4	21.3	15.4	10.9
North East	13.6	16.2	15.0	35.7	72.0	81.0	29.5	11.5	26.7
Center	14.6	22.9	17.7	32.2	87.3	88.1	19.4	6.3	11.0
South	12.9	18.3	27.9	47.9	88.5	82.6	31.8	8.9	26.4
Islands	17.6	25.9	4.5	18.8	78.7	91.3	19.0	6.7	24.1
Number of employees									
20-49	10.0	16.1	10.0	42.8	78.2	84.4	18.5	11.5	13.4
50-199	13.9	24.3	18.3	28.4	85.0	87.1	33.6	8.2	20.5
200-499	19.9	28.2	29.2	52.0	71.0	88.4	20.9	8.6	20.3
500 and more	34.5	42.2	38.1	60.8	74.6	93.5	32.0	21.0	52.0
Sector									
Wholesale and retail trade	5.2	11.6	12.9	28.4	77.8	69.5	31.9	13.3	12.3
Hotels and restaurants	12.9	13.5	3.8	4.9	98.3	90.9	19.7	1.7	..
Transport and communication	9.5	15.0	16.9	24.5	84.9	93.6	20.6	5.0	15.1
Other business and household services	21.6	33.9	17.3	54.3	76.1	90.3	21.7	12.6	23.3
Totale services	**11.9**	**19.2**	**15.0**	**39.7**	**79.8**	**85.9**	**23.8**	**10.7**	**17.6**
Total	**13.8**	**22.3**	**25.4**	**42.3**	**68.8**	**86.1**	**20.0**	**12.7**	**24.8**

Source: Bank of Italy, Business Outlook Survey of Industrial and Service Firms
(1) The question was:
1. Has the firm entered into collaboration agreements with Italian universities (or public research centres) in the period 2002-2004? And in the period 2005-2007?
2. Only if the answer is yes, what was the type of agreement? Was it individual or collective? Ha the firm received public funding or tax subsidies?
Reported frequencies are adjusted for sampling weights and reported net of missing

Table 4

Reasons behind the absence of collaborations

(per cent; frequency only for firms which have not had research agreements with universities)

	never considered	academic research unrelated to business requirements	universities involve too much bureaucracy	unsatisfactory quality of research	the cost is too high	better to work with foreign universities	other
				Industry excl. construction			
Geographical areas							
North West	54.9	33.6	2.2	0.9	1.9	0.2	6.3
North East	53.2	31.6	1.6	0.6	1.1	0.8	11.1
Center	57.1	31.6	1.2	0.5	0.6	..	9.0
South	65.0	19.7	3.3	0.4	4.6	..	7.1
Islands	58.9	26.2	5.8	0.9	2.5	..	5.8
Number of employees							
20-49	56.4	30.8	2.3	0.6	1.6	..	8.4
50-199	54.9	30.7	1.5	1.1	2.2	1.5	8.2
200-499	51.4	33.6	0.2	2.0	0.9	0.7	11.3
500 and more	57.0	25.1	4.0	..	1.6	..	12.3
Sector							
Textile, clothing, leather, shoes	58.2	30.4	1.5	0.1	0.7	0.4	8.8
Chemicals rubber and plastics	46.9	38.4	0.5	1.5	3.3	..	9.4
Engineering	54.4	31.3	2.8	0.7	1.7	0.6	8.7
Other manifacturing	58.3	29.4	1.8	0.9	2.0	0.1	7.6
Energy and extraction	73.1	14.0	1.7	1.7	2.1	0.8	6.7
Total industry excl. construction	**56.0**	**30.8**	**2.0**	**0.7**	**1.7**	**0.4**	**8.4**
				Services			
Geographical areas							
North West	50.7	37.1	..	..	5.0	..	7.2
North East	44.4	40.8	0.2	1.3	1.7	..	11.6
Center	53.8	34.2	1.4	0.4	0.9	..	9.3
South	68.5	27.3	..	..	1.4	..	2.8
Islands	51.4	42.7	2.1	..	..	..	3.8
Number of employees							
20-49	51.4	36.4	0.5	0.5	2.9	..	8.3
50-199	54.1	36.8	0.2	0.3	1.7	..	7.0
200-499	57.7	33.6	1.1	0.5	2.7	..	4.4
500 and more	48.9	36.2	..	..	1.9	..	13.0
Sector							
Wholesale and retail trade	48.2	40.5	0.5	0.9	1.5	..	8.5
Hotels and restaurants	67.0	24.4	..	..	0.5	..	8.1
Transport and communication	51.4	38.7	1.1	..	2.8	..	6.0
Other business and household services	51.6	34.2	0.2	0.2	5.4	..	8.4
Totale services	**52.2**	**36.4**	**0.4**	**0.4**	**2.6**	**..**	**7.9**
Total	**54.3**	**33.3**	**1.3**	**0.6**	**2.1**	**0.2**	**8.2**

Source: Bank of Italy, Business Outlook Survey of Industrial and Service Firms
(1) The question was:
Only if the answer is no, why not? a) the idea has never been considered b) academic research is unrelated to the firm's requirements c) universities involve too much bureaucracy d) the quality of research is unsatisfactory e) the cost is too high f) the firm prefers to work with foreign universities g) other
Reported frequencies are adjusted for sampling weights and reported net of missing

Table 5

Explanatory variables used in the regressions

Interest variables	Definition
University<10Km	Dummy equal to 1 if a university is located within 10 Km range from the firm
Top engineering……<10Km	Dummy equal to 1 if one of the best two departments that deal with the most relevant subjects for the firm is located within 10 Km range from the firm
Number of universities within 10 Km	Number of top universities within 10km range from the firm
Average workforce	Log average workforce in 2006
Research centre in Italy	Dummy equal to 1 if a university has a research facility in Italy
Research centre abroad	Dummy equal to 1 if a university has a research facility abroad
Suppliers	Importance of suppliers as innovation source (0 to 3)
Private consultants	Importance of private consultants as innovation source (0 to 3)
University	Importance of universities as innovation source (0 to 3)
Purchase of patents (2005-2007)	Dummy equal to 1 if the firm has purchased a patent in the period 2005-2007
Purchase of software and/or innovative machinery	Dummy equal to 1 if the firm has purchased software or innovative machinery in the period 2005-2007
Investment in software/investments	Investments in software/investments
Control variables	**Definition**
District	Dummy equal to 1 if the firm belongs to an economic district
Same sector district	Dummy equal to 1 if the firm belongs to an economic district of the same economic sector
Different sector district	Dummy equal to 1 if the firm belongs to an economic district of a different economic sector
TTO density in the region	Number of TTOs in the region
Density of firms in the region	Number of firms with more than 20 employees in the region
Average distance from top	Average distance from the best two departments that deal with the most relevant subjects for the firm
Minimum distance from top	Minimum distance from the best two departments that deal with the most relevant subjects for the firm
Average distance from humanities	Average distance from the best two departments that deal with humanities
Exports over sale	Exports over total sales
Investiments in machinery in 2006	Investiments in machinery in 2006
Science park	Dummy equal to 1 if the firm is located in a province where a science park is active (source: APSTI)

Table 6

Probability of academic collaborations for technology transfer (2005-07)

Dependent variable: probability of collaboration (2005-07), excluding intenships; model: Max Likelihood Probit

INDEPENDENT VARIABLE (1)	[1] base			[2] with regional dummies			[3] with macroarea dummies		
	Coefficient	Rob. S. E.	Signif. (2)	Coefficient	Rob. S. E.	Signif. (2)	Coefficient	Rob. S. E.	Signif. (2)
University<10Km	-0.160	0.123		-0.234	0.145		-0.162	0.123	
Top engineering, math chem.<10Km	0.293	0.134	**	0.548	0.166	***	0.308	0.137	**
Average workforce 2006 (log)	0.271	0.040	***	0.294	0.041	***	0.275	0.043	***
Research centre in Italy	0.378	0.106	***	0.367	0.110	***	0.379	0.106	***
Research centre abroad	0.242	0.215		0.230	0.226		0.248	0.221	
Suppliers	-0.107	0.051	**	-0.102	0.051	**	-0.098	0.050	**
Private consultants	-0.058	0.047		-0.068	0.048		-0.060	0.047	
University	0.772	0.056	***	0.777	0.056	***	0.772	0.055	***
Purchase of patents (2005-2007)	0.347	0.136	**	0.368	0.137	***	0.344	0.137	**
Purchase of software and/or innovative machinery	0.355	0.116	***	0.372	0.112	***	0.359	0.116	***
Investment in software	0.036	0.010	***	0.033	0.010	***	0.062	0.010	***
District	0.046	0.112		0.094	0.138		0.060	0.124	
Chemicals rubber and plastics	0.741	0.217	***	0.747	0.210	***	0.749	0.217	***
Engineering	0.683	0.204	***	0.651	0.193	***	0.696	0.203	***
Other manifacturing	0.742	0.215	***	0.731	0.202	***	0.761	0.211	***
Energy and extraction	0.519	0.292	*	0.561	0.288	*	0.503	0.290	*
Wholesale and retail trade	0.059	0.252		0.027	0.240		0.060	0.246	
Hotels and restaurants	-0.603	0.285	**	-0.646	0.279	**	-0.601	0.279	**
Transport and communication	0.410	0.276		0.355	0.265		0.405	0.274	
Other business and household services	0.879	0.272	***	0.868	0.265	***	0.888	0.280	***
Macroarea dummies	no			no			yes		
Regional dummies	no			yes			no		
Costant	-3.481	0.320	***	-3.298	0.443	***	-3.485	0.388	***
Number of obs	3102			3102			3102		
Pseudo R2	0.394			0.410			0.396		
Wald chi2(2) Testparm	573.30		***	653.07		***	580.22		***
Linktest (hatsq) (2)	-0.020	0.037		-0.038	0.039		-0.016	0.037	

(1) For sector dummies the base is textiles; for macroarea dummies North West; for regional dummies Piedmont; regressions are weighted for sampling weights– (2) Stars indicate levels of significance: 1% (***); 5% (**); 10% (*). Standard errors are calculated using the Huber/White/sandwich robust estimator.

Table 7

Probability of academic collaborations for technology transfer (2005-07), by dimension

Dependent variable: probability of collaboration (2005-07), excluding intenships; model: Max Likelihood Probit

Independent variable (1)	[4] Small (20-49 employees)			[5] medium (50-199 employees)			[6] Large (200-499 employees)			[7] Very large (oltre 500 employees)		
	Coefficient	Rob. S. E.	Signif. (2)	Coefficient	Rob. S. E.	Signif. (2)	Coefficient	Rob. S. E.	Signif. (2)	Coefficient	Rob. S. E.	Signif. (2)
University<10Km	-0.525	0.242	**	-0.160	0.123		0.084	0.222		0.143	0.258	
Top engineering, math chem.<10Km	0.812	0.334	**	0.293	0.134	**	0.150	0.280		0.079	0.253	
Average workforce 2006 (log)	1.109	0.412	***	0.271	0.040		1.415	0.357	***	0.221	0.119	*
Research centre in Italy	0.315	0.174	*	0.378	0.106	***	0.549	0.205	***	0.733	0.234	***
Research centre abroad	0.120	0.376		0.242	0.215		-0.386	0.378		0.638	0.284	**
Suppliers	-0.103	0.083		-0.107	0.052	**	-0.001	0.102		-0.055	0.100	
Private consultants	-0.099	0.081		-0.058	0.047		-0.233	0.099	**	0.023	0.102	
University	0.784	0.094	***	0.772	0.056	***	1.092	0.123	***	0.775	0.115	***
Purchase of patents (2005-2007)	0.437	0.245	*	0.347	0.136	**	0.588	0.282	**	0.170	0.266	
Purchase of software and/or innovative machinery	0.430	0.161	***	0.355	0.116	***	0.145	0.211		0.310	0.202	
Investment in software	0.077	0.114		0.036	0.010	***	0.023	0.044		-0.058	0.055	
District	-0.034	0.246		0.046	0.112							
District of the same sector							0.810	0.643		-0.648	0.379	*
District of a different sector							0.325	0.239		-0.0007	0.284	
Chemicals rubber and plastics	0.506	0.363		0.741	0.217	***	2.429	0.766	***	0.351	0.536	
Engineering	0.464	0.324		0.683	0.200	***	2.346	0.717	***	0.446	0.367	
Other manifacturing	0.649	0.323	**	0.742	0.215	***	2.281	0.721	***	0.221	0.432	
Energy and extraction	0.233	0.476		0.519	0.292	*				0.402	0.548	
Wholesale and retail trade	-0.364	0.388		0.059	0.252		0.456	1.089		-0.259	0.552	
Hotels and restaurants				-0.603	0.285	**	2.488	0.957	***	0.258	0.565	
Transport and communication	0.297	0.415		0.410	0.276		2.029	0.791	***	0.119	0.515	
Other business and household services	0.832	0.401	**	0.879	0.272	***	2.695	0.796	***	0.233	0.463	
Macroarea dummies	no			no			yes			yes		
Regional dummies	yes			yes			no			no		
TTO density in the region							0.057	0.061		0.281	0.117	**
Firms density in the region							-0.001	0.002		-0.0001	0.0001	
Costant	-5.859	1.372	***	-2.837	0.755	***	-12.241	2.394	***	-3.875	0.954	***
Number of obs	1040			1260			413			330		
Pseudo R2	0.417			0.390			0.496			0.410		
Wald chi2(2) Testparm	196.1		***	324.2		***	137.87		***	142.04		***
Linktest (hatsq) (2)	0.026	0.072		-0.069	0.052		-0.0001	0.094		-0.093	0.064	

(1) For sector dummies the base is textiles; for macroarea dummies North West; for regional dummies Piedmont; regressions are weighted for sampling weights– (2) Stars indicate levels of significance: 1% (***); 5% (**); 10% (*). Standard errors are calculated using the Huber/White/sandwich robust estimator

Table 8

Probability of academic collaborations for technology transfer (2005-07), by sector

Dependent variable: probability of collaboration (2005-07), excluding intenships; model: Max Likelihood Probit

INDEPENDENT VARIABLE (1)	[7] Textiles			[8] Chemicals, rubber, plastics			[9] Engineering		
	Coefficient	Rob. S. E.	Signif. (2)	Coefficient	Rob. S. E.	Signif. (2)	Coefficient	Rob. S. E.	Signif. (2)
Top engineering/math/computer science<10Km	2.191	0.690	***				0.048	0.221	
Top engineering/chemistry <10Km				0.025	0.474				
Average workforce 2006 (log)	0.181	0.186		0.468	0.151	***	0.387	0.088	***
Research centre in Italy	0.762	0.353	**	0.653	0.286	**	0.407	0.166	**
Research centre abroad	-0.611	0.656		-0.099	0.459		-0.526	0.301	*
Suppliers	0.522	0.231	**	-0.205	0.179		-0.075	0.090	
Private consultants	-0.153	0.151		-0.051	0.152		-0.036	0.074	
University	1.344	0.211	***	1.147	0.159	***	0.859	0.086	***
Purchase of patents (2005-2007)	1.469	0.472	***	0.659	0.383	*	0.116	0.234	
Purchase of software and/or innovative machinery	0.267	0.379		0.808	0.334	**	0.564	0.160	***
Investment in software	0.077	0.114		0.812	0.547		0.286	0.229	
District	0.169	0.249		-0.296	0.371		0.149	0.195	
Macroarea dummies	no			no			no		
Regional dummies	yes			yes			yes		
Costant	-4.703	1.014	***	-4.846	0.821	***	-3.337	0.568	***
Number of obs	241			183			904		
Pseudo R2	0.772			0.587			0.439		
Wald chi2(2) Testparm	100.52		***	125.58		***	302.89		***
Linktest (hatsq) (2)	-0.047	0.097		-0.131	0.055	**	-0.063	0.259	

(1) For sector dummies the base is textiles; for macroarea dummies North West; for regional dummies Piedmont; regressions are weighted for sampling weights– (2) Stars indicate levels of significance: 1% (***); 5% (**); 10% (*). Standard errors are calculated using the Huber/White/sandwich robust estimator

Table 9

Probability of academic collaborations for technology transfer (2005-07), by sector

Dependent variable: probability of collaboration (2005-07), excluding intenships; model: Max Likelihood Probit

INDEPENDENT VARIABLE (1)	[8] Other manufacturing			[9] Transport and communication		
	Coefficient	Rob. S. E.	Signif. (2)	Coefficient	Rob. S. E.	Signif. (2)
Top engineering/math/computer science<10Km	0.613	0.336	*	0.900	0.537	*
Top engineering/chemistry <10Km						
Average workforce 2006 (log)	0.249	0.080	***	0.120	0.108	
Research centre in Italy	0.228	0.174		1.320	0.422	**
Research centre abroad	-0.334	0.351		-0.380	0.774	
Suppliers	0.031	0.094		-0.232	0.186	
Private consultants	0.111	0.083		-0.134	0.184	
University	0.566	0.086	***	1.165	0.231	***
Purchase of patents (2005-2007)	0.145	0.329		-0.110	0.453	
Purchase of software and/or innovative machinery	0.244	0.163		0.739	0.450	*
Investment in software	-0.007	0.068		0.056	0.038	
District	0.065	0.199		-0.895	0.543	*
Macroarea dummies	no			yes		
Regional dummies	yes			no		
Costant	-2.886	0.508	***	-3.215	0.61	***
Number of obs	792			209		
Pseudo R2	0.266			0.496		
Wald chi2(2) Testparm	145.09		***	199.26		***
Linktest (hatsq) (2)	-0.027	0.094		-0.118	0.095	

(1) For sector dummies the base is textiles; for macroarea dummies North West; for regional dummies Piedmont; regressions are weighted for sampling weights–
(2) Stars indicate levels of significance: 1% (***); 5% (**); 10% (*). Standard errors are calculated using the Huber/White/sandwich robust estimator

Table 10

Probability of academic collaborations for technology transfer (2005-07), robustness checks

Dependent variable: probability of collaboration (2005-07), excluding intenships; model: Max Likelihood Probit

INDEPENDENT VARIABLE (1)	[1] Average distance			[2] Minimum distance		
	Coefficient	Rob. S. E.	Signif. (2)	Coefficient	Rob. S. E.	Signif. (2)
University<10Km	-0.072	0.134		-0.099	0.145	
Minimum distance from top				-0.003	0.001	*
Average distance from top	-0.004	0.001	***			
Average workforce 2006 (log)	0.299	0.040	***	0.299	0.041	***
Research centre in Italy	0.377	0.110	***	0.373	0.110	***
Research centre abroad	0.232	0.222		0.229	0.223	
Suppliers	-0.095	0.051	*	-0.096	0.051	*
Private consultants	-0.070	0.048		-0.069	0.048	
University	0.787	0.055	***	0.785	0.056	***
Purchase of patents (2005-2007)	0.401	0.139	***	0.375	0.138	***
Purchase of software and/or innovative machinery	0.368	0.110	***	0.361	0.112	***
Investment in software	0.033	0.010	***	0.033	0.010	***
District	0.072	0.140		0.094	0.139	
Chemicals rubber and plastics	0.731	0.211	***	0.747	0.214	***
Engineering	0.650	0.196	***	0.677	0.199	***
Other manifacturing	0.718	0.205	***	0.746	0.209	***
Energy and extraction	0.510	0.295	*	0.548	0.295	*
Wholesale and retail trade	0.011	0.242		0.033	0.245	
Hotels and restaurants	-0.570	0.288	**	-0.565	0.277	**
Transport and communication	0.375	0.268		0.388	0.270	
Other business and household services	0.888	0.264	***	0.901	0.268	***
Macroarea dummies	no			no		
Regional dummies	yes			yes		
Costant	-1.88	0.764	**	-3.08	0.499	***
Number of obs	3102			3102		
Pseudo R2	0.407			0.405		
Wald chi2(2) Testparm	645.27		***	648.48		***
Linktest (hatsq) (2)	-0.041	0.037		-0.038	0.040	

(1) For sector dummies the base is textiles; for macroarea dummies North West; for regional dummies Piedmont; regressions are weighted for sampling weights–
(2) Stars indicate levels of significance: 1% (***); 5% (**); 10% (*). Standard errors are calculated using the Huber/White/sandwich robust estimator

Table 11

Probability of academic collaborations for technology transfer (2005-07), endogeneity checks

Dependent variable: probability of collaboration (2005-07), excluding intenships; model: Instrumental variable probit

INDEPENDENT VARIABLE (1)	[1] Instrumental variable		
	Coefficient	Rob. S. E.	Signif. (2)
University<10Km	-0.062	0.134	
Average distance from top university (=Average distance from top humanities department)	-0.005	0.002	**
Average workforce 2006 (log)	0.299	0.041	***
Research centre in Italy	0.377	0.110	***
Research centre abroad	0.231	0.222	
Suppliers	-0.095	0.051	*
Private consultants	-0.069	0.047	
University	0.787	0.055	***
Purchase of patents (2005-2007)	0.400	0.139	***
Purchase of software and/or innovative machinery	0.365	0.111	***
Investment in software	0.031	0.010	***
District	0.071	0.140	
Sector dummies	yes		
Macroarea dummies	no		
regional dummies	yes		
Costant	-1.96	0.802	**
Number of obs	3102		
Wald chi2(2) Testparm	649.94		***
Wald test of exogeneity chi2 (1)=0,18 Prob>chi2=0,67			

(1) For sector dummies the base is textiles; for macroarea dummies North West; for regional dummies Piedmont; regressions are weighted for sampling weights–
(2) Stars indicate levels of significance: 1% (***); 5% (**); 10% (*). Standard errors are calculated using the Huber/White/sandwich robust estimator

6 Appendix I: Balance sheet indicators for Italian universities

The financial statements of Italian universities are compiled according to harmonized criteria and made available by the Ministry of Education, University and Research. Main revenue items include transfers from the Government, local authorities, the European Union or other administrations and own revenues such as students' fees, income from contracts, sale of goods and services, rents and interests. On the expenditure side, staff and current expenses, interventions for students, purchases of durables and financial charges are usually very relevant.

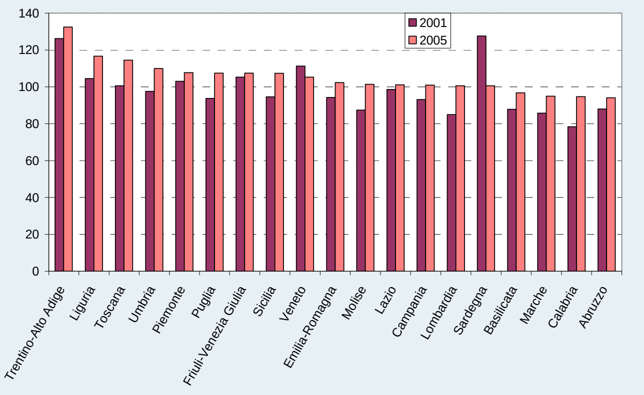
State universities are funded by the central government through the Ordinary Financing Fund (Ffo): the Fund was established in 1993 and is used to finance universities mainly on the base of past spending, re-balanced according to quantitative parameters linked to their research output and teaching load (using the model devised by the National Agency for University Evaluation, ANVUR[21]). In the period 2007-09, on average, the fund reached about 7 billion euros; between 2011 and 2013 it will decrease by more than 5 per cent: with this amount of money universities cover almost only staff costs[22], and increasingly so. The ratio of total expenditure on human resources and the Ffo[23] can be interpreted as the inverse of universities' productivity, which seems to have decreased. The indicator, together with its increase over the period, has modest regional variability (Fig. 7); larger and more economically advanced regions, though, do not appear to be also the most efficient ones.

Figure 7 **Figure 8**

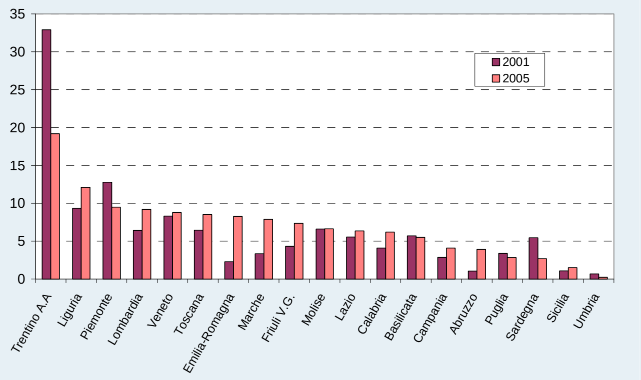
Balance sheet indicators of regional university systems in Italy: (1)

(per cent)

Human resources/Ffo



Third parties/Ffo



Source: Ministry of Education, University and Research.

(1) Balance sheet items used for indicators are at current euro prices. Human resources are total staff costs; Third parties include own revenues from contracts with companies and from sale of goods and services; they exclude other own revenues. The denominator is the Ordinary Financing Fund (Ffo).

With almost all of the state funds employed to cover staff costs, the incentive for universities to seek private funding has increased. An indicator of universities entrepreneurial spirit is the incidence of revenues from contracts with private companies (hereinafter, "Third parties")[24] on Ffo. Between 2001 and 2005, the Third parties account has increased on average from 5.0 to 5.8 per cent

[21] Research is evaluated looking at the number of researchers that successfully applied for Italian or European funds and at the quality of results after peer review. Teaching quality is assessed on the base of the number of students, the share of employed graduates, the number of full professors and the presence of an internal quality monitoring system.

[22] According to the 1998 Budget Law universities can use at most 90 per cent of Ffo to cover staff costs.

[23] Note that the indicator presented includes all staff costs and is then slightly different from that used for legal purposes.

[24] An alternative indicator is the incidence of private funding on expenditure on human resources. The two measures are highly correlated (0.98).

of Ffo; the growth of median values has been stronger (from 3.9 to 5.2 per cent)[25].The variability among universities translates into marked differences among the various regional systems (Fig. 8): in 2005 Trentino-Alto Adige and the North Western regions registered a share of private funding on Ffo around or over 10 per cent, while the South and the Islands reached a value close to half the Italian average. The most dynamic universities have also adopted internal policies based on incentives to the professors involved, mainly in the form of profit sharing or, less frequently, of increases of funds for research or of promotion of career advancement (Netval 2006[26]): between 2001 and 2005, the incidence of the Third parties account on Ffo has increased significantly in Emilia-Romagna, Marche, Friuli-Venezia Giulia, Abruzzo, Lombardy and Liguria; it has decreased in Trentino and Piedmont, though remaining high. It has also fallen in Sardinia, Apulia, Basilicata and Umbria.

As an additional tool to attract resources from companies, Italian universities have intensified their active policies for the exploitation of research results, with the creation of dedicated structures. This represents a rather new phenomenon for Italy: before 1985 there were no universities active in this field (Netval, 2008); later some universities implemented this task with some internal offices; the first TTO (Technology Transfer Office) was established in 1997, twenty years later than in the most advanced European countries; it is only from the 2000s that this phenomenon has started to be more widespread. In 2007, 42 out of the 63 universities analyzed had a TTO[27], actively engaged in the commercial exploitation of intellectual property and in the management of consultancy contracts with companies.

From around 2000, finally, as a result of institutional changes, the phenomenon of spin-offs, entrepreneurial initiatives of academic nature often linked to the exploitation of a patented invention, has accelerated; up to the early eighties these constituted sporadic episodes, looked at with indifference by universities[28]. The Parliament has regulated the subject with the l. 297/1999 and subsequent DM 593/2000, which has made order in the whole system of incentives for research and innovation by providing, among other things, a free grant for high-tech spin-offs. Also, the l. 88/2000 has established a scheme of public co-financing for start-ups (not necessarily academic), albeit with modest results (Finlombarda 2006). Finally, measures regarding property rights of academics (law 383/2001), who recognized the individual ownership of any patents developed within the university, although criticized by most of the Italian universities, have offered incentives to foster a culture of commercially oriented research.

According to the RITA database (2005), developed by the Department of Management Economics and Industrial Engineering at Politecnico di Milano on nearly 2,000 new high-tech

[25] This indicators differs from other measures suggested by previous studies: Colombo, D'Adda and Piva (2009) use the share of privately funded research on total research funds, on average 2.7 per cent in 2003-04; Bonaccorsi and Granelli (2005) use the share of funds provided by industry (around 3-5 per cent in the period 1995-99); OECD (2006) estimates that the share of funds from firms and foundations on total private funds amounted to 9 per cent in 2003.

[26] More than 85 per cent of the 37 universities analyzed in Netval (2006) adopted profit sharing mechanisms for professors; about 10 per cent of them recognized technology transfer as a criterion to distribute research funds; 9 per cent of the sample used it for career advancement purposes.

[27] See also Mori (2008). Netval (2008) finds 54 TTOs out of 65 interviewed universities; this number, however, includes private and web based universities and therefore is not comparable to ours.

[28] Spin-offs from public research - sometimes called academic start-ups - are defined as a newly established company operating in high-tech industries, whose founders group includes professors, researchers and students at public research institution, who may leave or stay bound to the institution of origin to start the company (RITA, 2005). This definition, more common in the literature, explicitly excludes companies founded by students. Netval (2008), instead, uses the broad definition proposed in Piccaluga and Balderi (2006) which includes students among founders, provided they have carried out many years of research on a specific issue, usually at the centre of the firm's activity.

companies, there are 123 academic start-ups in Italy, in the narrow sense that excludes students enterprises; nearly half of them were established after 2000. According to the survey developed by the Scuola Superiore Sant'Anna of Pisa (Balderi and Piccaluga, 2006), spin-offs, defined in a broad sense (including those of students) are 710 (Netval 2008), in four out of five cases localized in the Northern-Central regions. They constitute, however, a phenomenon of modest relevance, much less widespread than in other European countries, Canada or the United States (Finlombarda, 2006). Definitely spin-offs are not the key instrument for technology transfer in Italy.

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