UNIVERSITÀ DELLA CALABRIA

**Dipartimento di Economia,
Statistica e Finanza
Ponte Pietro Bucci, Cubo 0/C
87036 Arcavacata di Rende (Cosenza) -
Italy**
http://www.unical.it/desf/

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ASSESSING THE IMPACT OF UNIVERSITY TECHNOLOGY TRANSFER ON FIRMS' INNOVATION

Paola Cardamone
Dipartimento di Economia,
Statistica e Finanza
Università della Calabria
Ponte Pietro Bucci, Cubo 0/C
Tel.: +39 0984 492442
Fax: +39 0984 492421
e-mail: p.cardamone@unical.it

Valeria Pupo
Dipartimento di Economia,
Statistica e Finanza
Università della Calabria
Ponte Pietro Bucci, Cubo 0/C
Tel.: +39 0984 492456
Fax: +39 0984 492421
e-mail: v.pupo@unical.it

Fernanda Ricotta
Dipartimento di Economia,
Statistica e Finanza
Università della Calabria
Ponte Pietro Bucci, Cubo 0/C
Tel.: +39 0984 492407
Fax: +39 0984 492421
e-mail: f.ricotta@unical.it

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Assessing the impact of university technology transfer on firms' innovation.

Cardamone P., Pupo V., Ricotta F.
Department of Economics, Statistics and Finance,
University of Calabria, Arcavacata di Rende (CS), Italy

Abstract. *This paper analyses the influence of universities on Italian firms' probability to innovate. Using firm-level data, we focus on institutionalised technology transfer (TT) activities in universities, namely spin-offs, patents and research contracts. Results show that TT activities play a significant role in the probability to innovate by Italian manufacturing firms located in the same province as the university. Nevertheless, the effect is not uniform: the contribution of university TT activities to the probability of firms' innovating is concentrated in certain territorial areas (North-East and Centre) and sectors (science based and scale intensive) and among firms that are large.*

Keywords: Universities, Technology transfer, Manufacturing firms, Innovation, Spillovers

JEL Classification codes: C25; O30

1. Introduction

In recent years, increasing attention has been given in economic studies and policy debates to the role that universities can play in the innovation process, but the literature does not provide a strong a priori assumption about the correlation between the more commercially orientated universities and innovation. On one hand, according to some supporters of Open Science, public research results should be accessible to everyone and openly shared. Greater commercial orientation of university research may inhibit knowledge transfer, e.g. as a result of patented research, since sponsoring companies attempt to protect their interests and increase their market power (Argyres and Liebeskind, 1998; Dasgupta and David, 1994; Stern, 2004; Colombo et al, 2010). This clearly hinders the generation of positive externalities from university research to other firms and, consequently, has negative effects on the potential innovation of local firms. On the other hand, some other scholars agree with the so called Triple Helix model, which regards the interactions between different institutional spheres, e.g. university, industry, and government, and states that "the university can play an enhanced role in innovation in increasingly knowledge-based societies"

(Etzkowitz and Leydesdorff, 2000, p.109). In this case, greater commercial orientation may facilitate the absorption by local firms of knowledge produced by universities. This, in turn, might encourage university production of knowledge with a commercial value (Di Gregorio and Shane, 2003) and involvement in more entrepreneurial activities, such as consultancy for industry, collaboration in new firms and participation in start-ups (Cohen et al 1998; Roberts and Malone, 1996).

The empirical literature on the relationships between university and industry has considered a great number of aspects (for a review, see Foray and Lissoni, 2010). Several analyses have examined the effects of university research on innovation (among others, see Acs et al 1992; Anselin et al, 1997; Audretsch et al, 2012; Autant-Bernard, 2001; Blind and Grupp, 1999; Del Barrio-Castro and García-Quevedo, 2005; Jaffe, 1989; Leten et al, 2011; Mansfield, 1991 and 1995; Piergiovanni et al, 1997). Generally, these studies document a strong positive relationship between university research and firms' innovative activity and show that knowledge spillovers from universities to the private sector tend to be geographically bounded to the area where the university is located.

Unlike previous studies, we wish to investigate whether the codified forms of technology transfer (TT) activities (research contracts, patents and spin-off activities) of universities would improve local firms' capacity for innovation, even those which have no formal relationship with a university.

While the individual channels of industry-university collaboration and their contribution to firm innovation performance have received considerable attention in the literature, little is known about spillovers that result from a formal relationship. In general, the process by which academic inventions are transferred or spilled over into external benefits is still an underdeveloped current of research in the literature (Marion et al, 2012). However, there is consensus in the literature that tacit transmission of knowledge may arise due, for example, to informal contacts between industry and university actors, and that firms could benefit from these knowledge flows and, as a result, they might improve their innovative output.

We believe that some differences could exist between generic knowledge spillovers and knowledge spillovers from formal TT activities. In more detail, formal TT activities arise in the context of a university which is favourable to the business exploitation of research, is familiar with the productive system and encourages researchers to cooperate with enterprises. All this may facilitate the industry-university relationship and ease the transfer of both codified and tacit knowledge. Certain studies carried out in Italy (IPI, 2005; Muscio, 2008) show that the difficulties in university-firms interaction are essentially due to the lack of a consolidated university procedure for collaboration with firms and, more generally, the existence of a cognitive distance between professors and entrepreneurs. Therefore, there is good reason to assume that the presence of institutionalised TT activities may contribute to the creation of a context which might promote more and better formal and informal relationships between universities and firms and that the resulting spillovers will be more easily absorbed by firms.

In a nutshell, even if the main channel of knowledge spillovers is the network of personal and informal interactions, in the case of formal TT, transfer to the firm is facilitated by the entrepreneurial motivation and the inclination to network of universities that care about the commercialisation of academic research.

For this reason, in this paper we focus on the role of the institutionalised TT activities (research contracts, patents and spin-off activities) in Italian manufacturing firms' probability to innovate. We use the UniCredit-Capitalia database (2008) for firm data, while we employ data from the Ministry of Education, University and Research (MIUR) to obtain the university indicator.

Our work differs from other similar studies in three important ways. First, we evaluate the effect of TT activities on the innovation activities of nearby firms, regardless of formal university-firm relationships. To the best of our knowledge, this is the first contribution which addresses this issue. Moreover, in order to investigate the differences in firms' innovative output in depth, we analyse the effect of TT activities on the basis of firm territory, industrial sector, size, age and exporting status.

Second, a further element is that we consider a synthetic indicator which takes into account different forms of institutionalised TT, such as patents, spin-off firms and research contracts. To this end, we use, for the first time in Italy, an university technology transfer indicator computed by following the methodology of the first Triennial Research Evaluation exercise (MIUR, 2007), which was envisaged to evaluate the performance of universities.

Third, we provide an empirical contribution regarding the role of the local context and the industrial system in university-industry interactions. For policy-makers, this issue is particularly important, in Italy because of the high and persistent disparity between the South and the rest of the country, the fragmentation of the production system into many small firms which face difficulties innovating due to the high cost of R&D and the overspecialisation in mature industries which generally have few relationships with universities. Our results are also policy-relevant from the point of view of university policies. In the last 30 years, universities have experienced major changes that have affected their objectives, sources of funding and modes of operation. There have been significant modifications in university policy environments due to initiatives such as the 1980 Bayh–Dole Act in the USA, the abandoning of 'professor's privilege' in most European countries and its adoption in others such as Italy (Grimaldi et al, 2011). This paper may be useful in order to inform policy makers further of the appropriate balance between the fostering of universities' scientific eminence and the stimulating of science-industry interactions.

Results show that codified forms of TT activities play a significant role in the probability that Italian manufacturing firms located in the same province as the university have of innovating. This result is not uniform, but particularly applies to firms in the North-East and the Centre of Italy, medium-large firms and those belonging to the scale intensive and science based sectors of the Pavitt classification.

The paper is organised as follows. In the second section, we briefly describe the technology transfer process in Italy. In the third section, we present the TT indicator. The empirical setting and estimation results are discussed in the fourth section. The final section concludes.

2. Technology transfer in Italy

Interaction between the business sector and universities through the exchange of knowledge and technology is especially relevant for Italy since it has to catch up with other European countries in terms of the level of firms' innovation activity: Italy still lags behind the majority of European countries with regard the percentage of firms that innovate. The transfer of knowledge from universities to firms could be a key factor in the creation of innovation, especially given that Italian universities account for a large share of the country's total R&D expenditure (about 31% in 2008, Italian Trade Commission, 2011).

The Italian university system used to have a highly centralised governance structure, with a key role played by the State and low autonomy at the individual university level. However, since the late 1980s, universities' administrative autonomy has been increasing and universities are now allowed to use funds from the Ministry, attract external funding, and elaborate their own statutes and internal regulations, although the fundamental leverages of selection procedures and remuneration have remained under Government control through the Ministry of University and Education (Fini et al, 2011).

Since the late 1990s, the attention economists and policy makers give to University TT activities has increased. For example, many European countries have adopted the professor's privilege law which enforces intellectual property, albeit Germany, Austria, and Denmark have then abolished the law and Sweden is considering doing the same (Foray and Lissoni, 2010). In Italy, the "Legge Tremonti" of 2001 established that the researcher is the only patent holder.[1] Due to economic and political pressures, the university system has increased its focus on entrepreneurship and the transfer of scientific knowledge to the business sector (Pietrabissa and Conti, 2005; Piccalunga and Balderi, 2006; Netval, 2008). This process has involved several factors, such as the fact that, between 2000-2005, the majority of Italian universities set up Technology Transfer Offices (TTOs), specific structures devoted to technology transfer. The aim of TTOs is to encourage scientists to consider commercialisation and to support them through the process (Muscio, 2010; O'Gorman et al, 2008), although the majority of TTOs remain understaffed and do not offer specialised services (IPI, 2005). The main tasks of TTOs are: i) identification and protection of research results; ii) transfer of research results through the stipulation of licenses; iii) support in spin-off creation; iv) the carrying out of complimentary activities, such as the "scouting" of patent development within R&D projects and intellectual property management in collaborative research programmes (Balderi et al, 2010). With the support of TTOs, technology transfers from universities to firms may occur through licensing, spin-off companies and research contracts. Licensing principally consists of transferring the intellectual property rights (IPRs) of patents to firms. Technology transfer through spin-off companies may occur when the know-how and the results obtained through university research activities are commercialised by new, ad hoc created companies. Finally, knowledge may also be transferred through collaborative research with an existing firm and/or industrial group into specific topics (Balderi et al, 2010).

In addition, two other aspects help us explain universities' increased interest in developing collaboration with industry. Firstly, there are many national and regional programmes which aim to provide tools to promote cooperation between public research institutes and the private sector. Therefore, the reduction in government structural funds creates incentives for public universities to pursue research that is of interest to firms: if the primary source of funding for university departments in 2006 was provided by MIUR (more than 20% of the entire research budget), in 2009 the primary sources of funding were research contracts and consultancies (31.45%) (Muscio et al, 2013).

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[1] This law allows an inventor the possibility to take advantage of economic benefits from a discovery. However, it also states that the researcher should take the economic and administrative burden. Hence, one potential result might be the transfer of patent rights from researchers to firms and this would mean a loss for universities in terms of exploitation and development of the discovery, as well as sunk costs (Poma and Ramaciotti, 2008).

3. TECHNOLOGY TRANSFER INDICATOR

The relationship between universities and firms is mediated by a complex set of interaction.

We are interested in exploring the effect of universities technology transfer activities on a firm's likelihood to innovate. Before presenting the indicator used in this paper, it is necessary to clarify two empirical questions. First, which type of technology transfer activities we consider, and second, how these activities could exert a positive influence on the innovative output of firms located in the same province as the university.

Regarding the first aspect, we do not use a broad definition of knowledge and technology transfer activities, but we only consider those forms of knowledge transfer that are formalised and have been institutionalised in universities, namely patents, spin-offs and research contracts (Geuna and Muscio, 2009).

We recognise that knowledge is exchanged with business actors in various ways including traditional channels of TT, such as attendance at conferences, consultancy, personnel exchanges and publishing. However, in many cases, informal contacts underlie the establishment of formal collaborations as the complementarity between publishing and patenting highlights (e.g., Breschi et al, 2007 for Italy). Furthermore, the TT activities of Italian universities regard research contracts, intellectual property rights (IPR) and spin-offs, and data on these activities are collected by TTOs. This makes data on these types of output more easily available.

To consider the role of geographical proximity, we decide to focus on provinces (NUTS 3 level) as territorial units in order to take account of the impact of TT activities on innovation. This decision is supported by empirical evidence suggesting that, despite the ready availability of modern telecommunications systems, the intensity of university–industry interaction varies inversely with the distance that separates academics from firms (Anselin et al,1997).

As for how TT activities could exert an influence on the innovative output of firms, we refer to what literature evidence relatively to the components of our TT indicator.

With respect to patents, on one hand Henderson et al (1998) have provided empirical evidence that academic institutions produce substantial spillovers, since university patents are generally cited more often and in a broader range of fields than other patents. On the other hand, Jaffe et al (1993) have shown that, although patents are considered as codified knowledge, spillovers are geographically localised.

With regard to spin-off firms, this phenomenon has received considerable attention over recent decades, often in terms of their contributions to regional development but also as technology transfer agents serving a role in the dissemination of research into application (see Rasmussen et al, 2012, for a review). It is to this last strand of literature that we refer as background. The most important economic impact delivered by new, technology-based firms may be a catalysing one delivered through technology interactions between firms and their operating environment (Autio, 1997). Spin-off entrepreneurs act as intermediaries between research organisations' knowledge and its potential users. The new firm enables existing companies to access knowledge that might otherwise have remained unintelligible to the companies' competence base (Perez and Sanchez, 2003; Fontes, 2005). Generally, the economic benefits of a spin-off accrue locally since spin-offs shows a preference for locations near the parent institution (Egeln et al, 2004; Perez and Sanchez, 2003; Fontes, 2005).

One of the main mechanisms through which proximity can help the diffusion of universities' technological and scientific development is personal contacts between the firm's human resources and university staff (Thursby and Thursby, 2003) as well as through links that a firm may build up with other local firms and, thus, contribute to spreading new knowledge into the local economy. Such a mechanism of knowledge transmission may also apply in the case of research contracts, albeit most empirical studies consider the influence of academic knowledge that firms acquire through formal cooperation with universities (among others Becker, 2003; Belderbos et al, 2004; Eom and Lee, 2010; Fritsch and Franke 2004; Lööf and Broström, 2008; Monjon and Waelbroeck 2003; Robin and Schubert, 2013).

In order to obtain the university technology transfer indicator, we use the results of the first National Triennial Research Evaluation exercise for the years 2001-2003 (VTR 2001-03, in MIUR, 2007). The Exercise was entrusted to the Italian National Committee for Research Evaluation (CIVR) to evaluate the scientific performance of universities (both State and private) and research institutions.[2]

In this evaluation process, the CIVR developed an indicator of upgrading research and transfer activities for each university that takes account of the patenting, spin-offs activated and the number of partnerships, and weighted these elements on the basis of their relevance. We refer to the methodology, data and weights used by the CIVR to calculate this indicator, but we aggregate the data on a provincial basis. In addition, unlike the indicator CIVR, we only consider universities, that

[2] For the various structures (universities and research centres), a composite index, suitable for the allocation of state funds, was produced. This index relates to product quality, property rights on the products, international mobility propensity, advanced training propensity, ability to attract financial resources, and ability in using available funds to finance research. For more information, see the website: http://vtr2006.cineca.it/index_EN.html.

is we do not take into account other research centres and affiliated institutions. Overall, 76 universities are considered.

The provincial level TT indicator is equal to zero if there is no university in the province, while for the j-th province with $u=1,..,U_p$ universities, where U_p varies from one to eight (see Figure 1), is computed as:

$$TT\_Uni_j = \frac{1}{10}\left\{ \frac{\sum_{u=1}^{U_p} PAT_{uj}}{\sum_{u=1}^{76} PAT_u} + \frac{\sum_{u=1}^{U_p} PATact_{uj}}{\sum_{u=1}^{76} PATact_u} + 2\frac{\sum_{u=1}^{U_p} REV_{uj}}{\sum_{u=1}^{76} REV_u} + 4\frac{\sum_{u=1}^{U_p} SPIN_{uj}}{\sum_{u=1}^{76} SPIN_u} + 2\frac{\sum_{u=1}^{U_p} PART_{uj}}{\sum_{u=1}^{76} PART_u} \right\} \times 100 \qquad [1]$$

where $PAT_u = PAT_u^{NAT} + 1{,}5\ PAT_u^{INT}$, with PAT_u^{NAT} indicating the number of national patents of the u-th university registered during the 2001-2003 and PAT_u^{INT} expressing the number of international patents of the u-th university during the 2001-2003 period. Similarly, $PATact_u$ is based on the sum of national ($PATact_u^{NAT}$) and international ($PATact_u^{INT}$) patents active on 31/12/2003 for the u-th university, that is $PATact_u = PATact_u^{NAT} + 1{,}5\ PATact_u^{INT}$. Moreover, REV_u is the revenues from patent selling and licensing during 2001-2003, $SPIN_u$ indicates the number of spin-offs activated for 2001-2003 and $PART_u$ is the number of partnerships (with receipts of above 500,000 Euros for the Structure) active for 2001-2003 for the u-th university.

The university indicator, aggregated on a provincial basis, is added to each company's dataset on the basis of its location so as to pool the university indicator with the company dataset.[3]

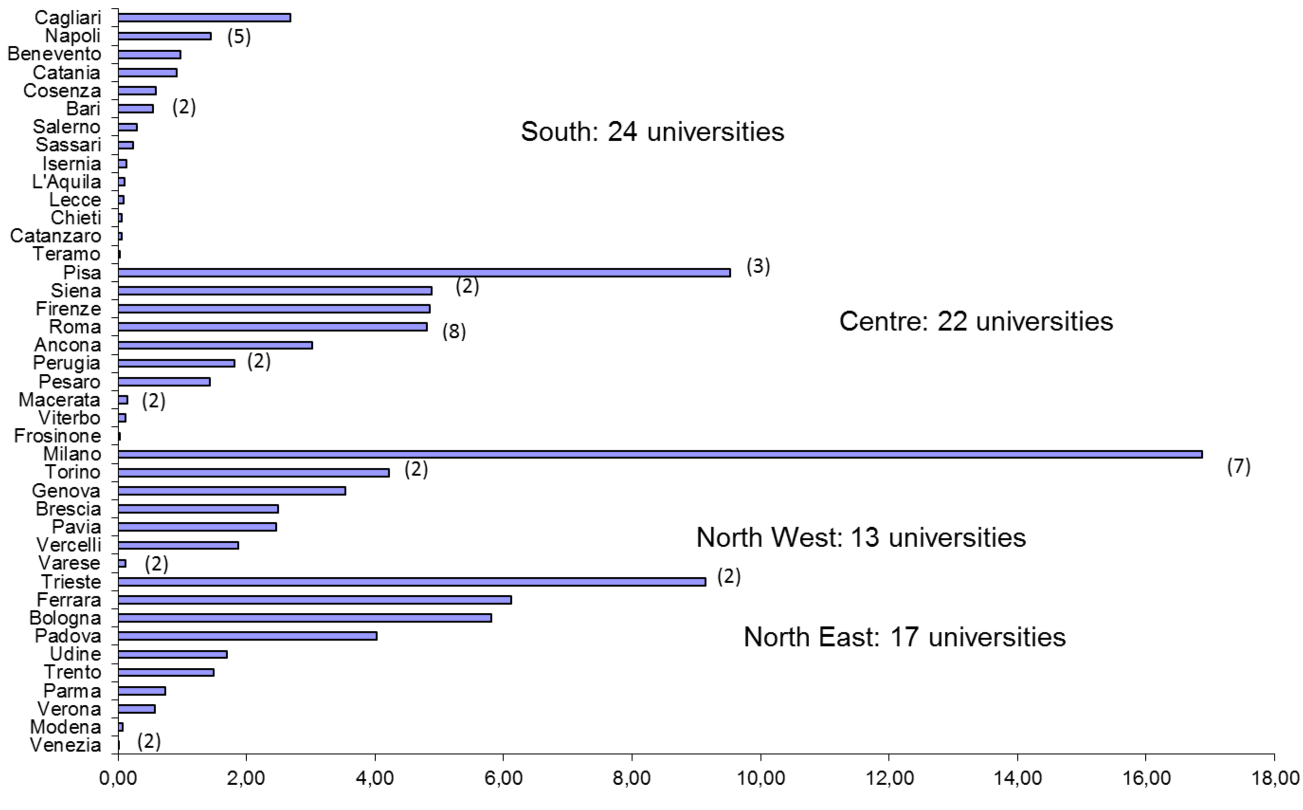
Figure 1 shows the geographical distribution of Italian universities (in parentheses) and presents the value of the TT indicator. The 76 universities considered are located in 49 out of the 107 Italian provinces. In particular, 37 provinces have just one university, 8 provinces have 2 universities and 1 province (Pisa) has 3 universities. A marked concentration of universities exists in the provinces of Naples (5 universities), Milan (7) and Rome (8). Italian universities are generally located in the North (39%) and in the South (32%).

The indicator on research upgrading and transfer activities shows high variability: among the 49 Italian provinces in which at least one university is located, 28 have a value of less than 1 (8

[3] The location of company headquarters is used to link provincial indicators to firms. It is worth noting that the unit of analysis in the Capitalia-Unicredit survey is the firm and no information is reported on the number of each firm's establishments. Thus, results have to be interpreted cautiously, although it is also important to bear in mind that 69% of our dataset is formed by small-sized firms which are probably single-plant firms (see table 1).

of these register a value of zero)[4], 11 a value between 1 and 4.03, and 10 a superior value. The highest value of the transfer activity indicator is found for the North-West in the province of Milan (16.87). Four out of the ten provinces with a value above 4.03 are located in the North-East (Trieste, Ferrara, Bologna and Padua) and the Centre (Pisa, Siena, Florence and Rome), two in the North-West (Milan and Turin) and none in the South. The concentration of university researchers is higher in these ten provinces than in other Italian provinces and two (Milan and Turin) out of four polytechnics in Italy are located there. More generally, what emerges from the data is a low level of TT activity in the South and a high concentration in a few Italian provinces.

Figure 1 Indicator on research upgrading and transfer activities



Note: in parentheses the number of university for each province are reported. The provinces for which the indicator assumes zero value are not reported.

Source: elaborations on data from MIUR (2007)

[4] Bergamo, Bolzano, Messina, Palermo, Potenza, Reggio Calabria and Verona.

4. EMPIRICAL ANALYSIS

4.1 Firm Level Data

This paragraph will present the firm level data used in the empirical analysis. Our firm-level data come from the Xth UniCredit-Capitalia survey (2008), which covers the period 2004-2006 and is compiled on the basis of information collected by means of a questionnaire sent to a sample of Italian manufacturing firms.[5] The survey is complemented with balance sheet data for the period 1998-2006.

Table 1 reports the distribution of our sample broken down into innovative and non innovative firms. We consider any firm that claimed, in the Xth wave of the UniCredit-Capitalia survey, to have carried out at least one innovation (product, process or organisational innovation) in the period 2004-2006 to be innovative. The values are reported on the basis of some firm characteristics, such as Pavitt sector, territorial distribution and size. The firms considered operate predominantly in traditional sectors and are mainly located in Northern Italy (around 72%). Innovative firms make up 63% of the sample (3,077 out of 4,899 firms), they are concentrated in the specialised suppliers and science based Pavitt sectors (68% and 71% respectively) and in the Centre-North of the country. Moreover, a higher share is observed for medium-large firms (72% of innovative firms and 28% for others).

[5] The survey design includes all firms with a minimum of 500 employees. A sample of firms with between 11 and 500 employees is selected according to three stratifications: geographical area, Pavitt sector and firm size. Although the survey covers the period 2004-2006, some parts of the questionnaire refer to 2006 only.

Table 1. Distribution of sample by sector, geographic area, size and export status (2006)

	Innovators	Non innovators	All firms[1]
Sectors			
Supplier dominated	1439	991	2430
	59%	*41%*	50%
Scale intensive	577	346	923
	63%	*37%*	19%
Specialised suppliers	906	423	1329
	68%	*32%*	27%
Science based	155	62	217
	71%	*29%*	4%
Geographical area			
North West	1326	794	2120
	63%	*37%*	43%
North East	886	532	1418
	62%	*38%*	29%
Centre	537	257	794
	68%	*32%*	16%
South	328	239	567
	58%	*42%*	12%
Size			
Small (11-50 employees)	1978	1396	3374
	59%	*41%*	69%
Medium-large (>50)	1099	426	1525
	72%	*28%*	31%
N.firms	3077	1822	4899
	63%	37%	100%

Source: elaborations on data from UniCredit-Capitalia (2008)

[1] Shares of firms with respect to the total in the column.

4.2 Econometric specification

The aim of the empirical analysis is to explore the effect of universities' TT activities on a firm's likelihood to innovate. In order to address this objective, we consider the province where firms operate as the territorial unit for the university indicators.

Our dependent variable *Inno* is a 0/1 variable that takes a value of 1 when a firm reports introducing at least one innovation (product, process or organisational innovation) during the 2004-2006 period.

Given the nature of our dependent variable, the base empirical specification is a probit model. We estimate the following model:

$$P(Inno = 1/x_{ij}) = \Phi(\beta_0 + \beta_1 \ln EMP_{ij} + \beta_2 \ln K_{ij} + \beta_3 RD_{ij} + \beta_4 \ln CL_{ij} + \beta_5 Age_{ij} + \beta_6 Pav_{ij} + \beta_7 North_{ij} + \beta_9 Aggl_j + \beta_{10} TT\_Uni_j) \quad [2]$$

where $i=1,\dots,N$ indicates firms and $j=1,2,\dots, P$ stands for provinces. Moreover, *EMP* indicates firm size as measured by its number of employees in 2005, *K* stock of physical capital at firm level (proxied by 2005 tangible fixed assets), *RD* is the average 2004-2006 R&D intensity (R&D expenditures as a share of sales) of firms, *CL* represents the 2005 cost of labour per employee as a proxy of labour quality[6], *Age* represents the number of years the firm has operated, *Pav* and *North* are two dummies which are equal to one if a firm is in the specialised or science based sector according to the Pavitt taxonomy and if a firm is located in the North of Italy, respectively, and zero otherwise.[7] The variable *Aggl (Agglomeration)* measures a province's industry density (number of firms per 100 inhabitants) in 2004.[8] *TT_Uni* identifies the indicator on research upgrading and transfer activities.[9] Nominal values have been deflated.[10]

Firm size in general is a very important factor in companies' innovation behaviour (see Schumpeter 1942). However, there is no strong *a priori* expectation about the sign for the size variable since there are arguments which support the idea of an innovative superiority in large firms and others in favour of an innovative superiority of small firms (Acs and Audretsch, 1987). Capital at firm level allows consideration of innovative strategies based on the acquisition of innovation which is embodied in capital goods developed by external suppliers. Investments in R&D and the

[6] Cost of labour per employee should be correlated with skill intensity if more skilled workers receive higher wages.

[7] We have also considered whether the firm belongs to a group since firms that form a unit in a larger entity may have access to more resources that affect their ability to innovate (Beugelsdijk, 2007), but the coefficient was not significant. Furthermore, we have taken account of the possibility that the probability to innovate differs between family-owned firms and non-family firms (for a recent review, see De Massis et al 2013). Our data do not support such a hypothesis.

[8] At the provincial level, two additional variables have been considered in the model: an index of infrastructure endowment that summarises the availability of different kinds of infrastructure relevant for production (source: Istituto Guglielmo Tagliacarne, 2001) and the patent intensity indicator calculated on the basis of the total number of national patents registered at the European Patent Office (EPO) per 1000 inhabitants in 2003 (source: ISTAT http://www.istat.it/it/archivio/16777). The first, has been included to test whether firms located in provinces with an adequate provision of infrastructure innovate more than firms operating in under-endowed provinces. We use the second to account for the innovativeness of provincial economies, since the ability of firms to absorb and exploit knowledge may depend on the degree of innovativeness of an economic context. Since neither indicator showed significant coefficients, they have both been excluded from the model.

[9] In the appendix, a list with a brief description of variables used in the empirical analysis (table A.1), descriptive statistics (table A.2) and correlation matrix (table A.3) are reported.

[10] For the tangible fixed assets, values have been deflated by using the average production price indices of the following sectors: machines and mechanical appliances, electrical machines and electrical equipment, electronics and optics and means of transport. The source of the sectoral indices is ISTAT. As regards the cost of labour, data have been deflated by using the consumer prices index for families of workers and office workers provided by ISTAT.

quality of the labour force provide a firm with the capability not only to develop new products and processes, but also to absorb knowledge developed outside the firm (Cohen and Levinthal, 1990). Therefore, we expect the level of R&D intensity and human capital to influence positively the likelihood to innovate. Age is introduced as a measure of firm experience. In fact, although it has received limited attention in the context of innovation, some studies show a link between firm age and innovation (Balasubramanian and Lee, 2008; Huergo and Jaumandreu, 2004).[11] In addition, the model controls for sectoral and territorial effects. Territorial aspects are particularly relevant in the Italian context since the country is characterised by pronounced geographical disparities with a persistent backwardness in southern regions (for more details see Iuzzolino et al, 2011). Finally, since there are many indications from the empirical literature that innovative activities tend to benefit from agglomeration (see Feldman 1999 for a survey), we control for the impact of agglomeration by including a province's industry density, *Agglomeration*.

As regards the estimation method, since firms from the same province are likely to be more similar than firms from different provinces (because of socio-economic factors, for example), the assumption that errors are independent might be violated. For this reason, we control for a potential downward bias in the estimated errors by clustering firms at provincial level.[12]

4.3 Results

The econometric evidence is reported in table 2. We have estimated equation [2] by considering the probability of the firm's introducing at least one innovation. Results, reported in the first column show that the variables at firm level have a positive effect on the probability to innovate. With respect to firm size, the result is in line with the Schumpeterian assumption (Schumpeter, 1942) that large firms play a fundamental role in the field of innovation. The positive effect of physical capital could be due to the fact that the carrying out of innovation requires the

[11] Balasubramanian and Lee (2008) examine how firm age relates to a specific aspect of innovation, technical quality, as measured by the number of citations made to a patent, and find that it decreases with firm age. Furthermore, since entry is envisaged as the way in which firms explore the value of new ideas, the highest innovators in a given industry are expected to be found among the entrant firms. By looking at the probability manufacturing firms at different stages of their lives have of introducing innovations, Huergo and Jaumandreu (2004) show that firms of the youngest cohorts in Spain are prone to innovate more while the oldest ones tend to innovate less than entrants. However, some firms above an intermediate age (20 to 36 years) appear to be almost as active as entering firms, especially in product innovations.

[12] By relaxing the independence assumption, multilevel modelling provides a tool for the analysis of clustered data. A multilevel model emerges if one lets the intercept become random, allowing, in our case, each province to have a different average outcome (random-intercept model). We tested whether the multilevel approach might be more appropriate for our data. We performed a likelihood-ratio (LR) test comparing the nested model with random effects at the province level and the same model without these random effects. The LR test is insignificant and, therefore, does not support the random-effect model. An application of a multilevel approach to the likelihood to innovate is provided by Srholec (2010).

use of machinery and fixed equipment. The age of the firm, quality of employees and firm R&D investment also enhance the likelihood of introducing an innovation. This last result is in line with Conte (2009), according to whom R&D investment increases both the likelihood of product innovation and a firm's innovation intensity. In addition, firms in the specialised or science based sectors of the Pavitt classification have a higher probability of introducing an innovation, while firms in the North of Italy have, *ceteris paribus,* a lower probability to innovate. Finally, industry density has a positive and significant effect confirming that agglomeration economies drive innovation (Feldman, 1999).

As regards the aim of our paper, university technology transfer activities seem to foster the likelihood of surrounding firms' innovating, even those which are not directly involved in TT activities. Indeed, the TT indicator has a positive and significant effect on the innovative output of firms in the province where the university is located. This result adds new empirical evidence to the literature which, instead, has mainly looked at the direct effect and has used R&D cooperation as a measure of TT activities (see Becker 2003, Fritsch and Franke 2004 for Germany; Monjon and Waelbroeck 2003 for France; Lööf and Broström 2008 for Sweden; Robin and Schubert, 2013 for France and Germany; Eom and Lee, 2010 for Korea; Belderbos et al 2004 for the Netherlands). These studies found a positive effect of TT activities on different measures of innovative performance such as the propensity to register an innovation for patenting, the number of patent applications, R&D intensity, and the introduction of product and/or process innovations as well as the sales share of innovative products. Similar results are found in Arvanitis et al. (2008), who evaluated the effect of Swiss firms' involvement with universities in any kind of TT activity (general information, educational activities, research activities, activities related with technical infrastructure and consulting) on the firm' innovative output. It was found that TT activities with research institution and/or institutions of higher education seem to improve the innovation performance of firms considerably in terms of R&D intensity and sales of new product.

Our results are also in line with the prevailing literature which has examined the effect of university research on innovative output and, found a spillover effect of university research (Acs et al, 2002; Anselin et al, 1997; Jaffe, 1989 for the USA; Blind and Group, 1999 for Germany; Autant-Bernard, 2001 for France; Del Barrio-Castro and García-Quevedo, 2005 for Spain). Similar results were found for Italy by Piergiovanni et al (1997), who, by using patented innovations at the regional level over the period 1978–86 and product innovations at the provincial level for the year 1989, found that local spillovers from academic research are an important source of innovation in small firms. Along similar lines, Leten et al (2011) estimated regional knowledge production functions for 101 Italian provinces over the 1995-2001 period and found a strong positive relationship between industrial technological performance and the presence of nearby universities

A relevant question is whether university TT effects hold uniformly across regions or whether regions with different levels of economic development respond differently. We have split the sample on the basis of where firms are located. Results, reported in table 2 (columns 2 – 5), suggest that, while R&D investment significantly affects innovative output of north-western and southern firms, university efforts only play a significant and positive role in innovation by firms in the North-East and the Centre of Italy. The TT indicator has no effect on innovative output for north-western firms. A possible explanation for this result may be that universities might be more commercially orientated in this area of the country, where, not by chance, the two most important polytechnics are to be found. As pointed out by Colombo et al (2010), the greater commercial orientation of university research may inhibit university-based knowledge spillovers. Large companies often sponsor academic research to obtain privileged access to research findings and technology since it may generate competitive advantage and market power for sponsoring firms. As a consequence, sponsoring firms are particularly motivated to protect intellectual property and secure exploitation rights for research results. This hinders the generation of positive externalities to firms from university research. In the South, university does not seem to affect firms' probability to innovate. This result might be explained by the fact that Southern regions differ from other Italian regions in terms of their level of income, private R&D investment and industrial structure. Many studies have documented that universities can only benefit from the commercialisation of advanced knowledge when their local context is 'fertile' enough to leverage academic resources. The key argument is that communities near universities must have the capabilities to absorb and exploit the science and knowledge that those universities generate. Even though new knowledge is generated in many places, only those regions that can absorb and apply ideas are able to turn it into economic wealth. As a consequence, universities are a necessary but not sufficient condition for the improvement of Italian firms' innovative output (Fini et al, 2011).

Other interesting results are found when we split the sample according to Pavitt sectors and size (small and medium-large firms). Results are reported in columns 6 - 9 of the table 2, respectively. The business sector to which firms belong seems to have an important role. Findings are coherent with the Pavitt taxonomy of innovating firms (Pavitt, 1984) and correspond broadly to previous results in the field (Cohen et al, 2002; Klevorick et al, 1995; Laursen and Salter, 2004). Research upgrading and transfer activities have a positive effect on the probability of introducing an innovation for enterprises operating in scale intensive and in science based sectors. For the supplier dominated sector, the general indicator of university TT is not significant while firm capital intensity, size and quality of labour have a positive and significant effect on the likelihood to innovate. Our results confirm that such firms rely more on innovative strategies based on the acquisition of innovation which is embodied in capital goods developed by external suppliers. University TT indicators show a negative effect on the probability of specialised suppliers to innovate. On the other hand, industry density coefficient is positive and significant which suggests that Italian specialised suppliers benefit more from informal process of learning-by-interacting with customers than from university TT activities.[13]

As regards size, our results show that TT activities play an important role exclusively for medium-large firms (table 2, columns 10-11). This evidence is consistent with survey data for the USA used by Cohen et al (2002)[14] and Laursen and Salter's econometric results (2004). The latter study finds that the capability of firms to draw upon university research increases with firm size since larger firms are more likely to have the competency to exploit external knowledge sources and to manage interactions with universities, maybe because they tend to be better organised, more specialised in their activities and routines, and to have greater access to financial markets (Carboni, 2013).

Further evidence can be found when considering the age and exporting status of the firm. New technology orientated young firms are potentially more dependent on technological innovations and scientific advancement and, thus, more inclined to use knowledge generated by universities. However, older firms may have established a set of links to universities over the years and, therefore, have more experience of interacting with universities. The effect of TT activities on the probability to innovate is not known *a priori* on the basis of firm's age. Our results, reported in Appendix (table A.4), show that the effect of university TT activities do not differ significantly between young and old firms.

With respect to the exporting status,[15] TT activities significantly affect the probability to innovate of exporting firms only (table A.4). It is worth mentioning that Fantino et al (2012) present a somewhat different result in that they find no significant effect of a company's international openness on its probability of being involved in technology transfer collaborations with universities.

[13] On the contrary, Laursen and Salter (2004) found for the UK that machinery (specialised suppliers) and the chemical industry are the sectors that most use universities as a source for their innovative activities.

[14] Using the Carnegie Mellon Survey, Cohen et al (2002) show that the influence of public research, i.e. university and government R&D labs, on industrial R&D is greater for larger firms.

[15] The status of 'exporting' is assigned on the basis of the answer to the question "Did you export in 2006?" in the Xth wave of the UniCredit-Capitalia survey.

Table 2. Estimation results, 2004-2006

	All firms (1)	North West (2)	North East (3)	Centre (4)	South (5)	Supplier dominated (6)	Scale intensive (7)	Specialised suppliers (8)	Science based (9)	Small (11-50 employees) (10)	Medium-large (>50) (11)
lnEMP	0.0655***	0.0631***	0.0652***	0.0622**	0.0558***	0.0539***	0.0568**	0.0894***	0.0501	0.1119***	0.0785***
	(0.0089)	(0.0093)	(0.0230)	(0.0253)	(0.0207)	(0.0152)	(0.0230)	(0.0173)	(0.0385)	(0.0161)	(0.0249)
lnK	0.0183***	0.0201***	0.0280	0.0076	0.0234	0.0225**	0.0092	0.0157	0.0367**	0.0208**	0.0216
	(0.0070)	(0.0077)	(0.0219)	(0.0122)	(0.0159)	(0.0102)	(0.0155)	(0.0118)	(0.0172)	(0.0082)	(0.0138)
RD	0.0053*	0.0235***	0.0032	0.0010	0.0243**	0.0041	0.0155*	0.0062	0.0096	0.0042*	0.0287**
	(0.0027)	(0.0058)	(0.0026)	(0.0022)	(0.0116)	(0.0031)	(0.0080)	(0.0038)	(0.0073)	(0.0025)	(0.0125)
lnCL	0.0339***	0.0268	0.0400	0.0240	0.0270	0.0280*	0.0280	0.0531*	0.0195	0.0609***	-0.0499*
	(0.0125)	(0.0171)	(0.0326)	(0.0233)	(0.0301)	(0.0149)	(0.0405)	(0.0293)	(0.0379)	(0.0142)	(0.0260)
Age	0.0007**	0.0006	0.0001	0.0012	0.0012	0.0011*	0.0005	0.0001	-0.0006	0.0003	0.0011**
	(0.0003)	(0.0004)	(0.0007)	(0.0014)	(0.0016)	(0.0006)	(0.0006)	(0.0007)	(0.0015)	(0.0004)	(0.0005)
TT_Uni	0.0027*	0.0015	0.0120**	0.0154**	-0.0022	0.0039	0.0057***	-0.0026*	0.0120***	0.0033	0.0024*
	(0.0015)	(0.0011)	(0.0053)	(0.0069)	(0.0190)	(0.0029)	(0.0021)	(0.0015)	(0.0030)	(0.0020)	(0.0014)
Aggl	0.0784**	0.0631	0.0297	0.0426	0.2130**	0.0778*	0.0694	0.1237**	0.1298	0.0852**	0.0559
	(0.0325)	(0.0704)	(0.0344)	(0.0446)	(0.0894)	(0.0430)	(0.0627)	(0.0498)	(0.1230)	(0.0387)	(0.0416)
North	-0.0480**					-0.0560*	-0.0406	-0.0103	-0.2277***	-0.0693***	-0.0071
	(0.0203)					(0.0296)	(0.0405)	(0.0361)	(0.0437)	(0.0264)	(0.0293)
Pav	0.0718***	0.0400**	0.1260***	0.0713*	0.0572					0.0568***	0.1090***
	(0.0171)	(0.0183)	(0.0322)	(0.0388)	(0.0634)					(0.0202)	(0.0221)
Observations	3,732	1,575	1,098	621	438	1,829	706	1,029	168	2,568	1,164
Wald-Chi2	191.61	151.41	71.98	41.84	38.59	104.75	31.11	89.16	40.19	133.11	72.41
Pseudo R2	0.0467	0.0523	0.0634	0.0398	0.0612	0.0353	0.0364	0.0698	0.1608	0.0417	0.0657

Note: average partial effects are reported. Standard errors clustered at provincial level in parentheses; *** p<0.01, ** p<0.05, * p<0.1

4.4 Robustness checks

In order to test the robustness of our results, we have also taken other TT indicators into account. In more detail, we have estimated eq. [4] by using, one-by-one, the number of patents that were active up to the end of 2003 (*Patents*) and the number of spin-offs activated over the 2001-2003 period (*Spin-off*) (Source: MIUR, 2007). In addition, we have considered the proportion of professors and assistant professors in science and technology fields (S&T) in 2004 (*share_ResST*), the S&T graduates as a share of the graduates in all fields in 2004 (*share_gradST*), and the total 2004 spending on research by the university in the same province as the one the firm was located (*R&D_UNI*). These indicators are described in Cardamone et al (2012) and are built by using individual university level data provided by National Agency for Evaluation of Universities and Research Institutes (ANVUR) and Ministry of Higher Education and Research (MIUR).

Results are reported in table 3 and confirm the evidence obtained with the CIVR indicator. In fact, we find that both university patents and spin-off firms enhance the probability of Italian manufacturing firms to innovate. On the other hand, indicators that have a less direct relationship with firms, such as University R&D and the share of researcher and graduates in S & T, do not seem to affect the firms' probability to innovate. Hence, while in the previous section we have found that spillovers coming from TT activities significantly affect the firm's likelihood to innovate, here we have obtained that knowledge flows coming from university research and educational activities play no significant role in firm innovative performance. This confirms the underlying assumption of this work, that is the fact that TT activities which require efforts by university to move themselves closer to the business sector, may facilitate firms in benefiting from knowledge flows coming from university activities.

Table 3. Estimation results on the probability to introduce an innovation – other knowledge transfer indicators, 2004-2006

	(1)	(2)	(3)	(4)	(5)
lnEMP	0.0654***	0.0656***	0.0654***	0.0660***	0.0660***
	(0.0089)	(0.0089)	(0.0089)	(0.0089)	(0.0089)
lnK	0.0183***	0.0182**	0.0178***	0.0170**	0.0168**
	(0.0070)	(0.0071)	(0.0068)	(0.0068)	(0.0068)
RD	0.0053**	0.0053**	0.0053*	0.0053**	0.0053**
	(0.0027)	(0.0027)	(0.0027)	(0.0027)	(0.0027)
lnCL	0.0339***	0.0343***	0.0354***	0.0362***	0.0365***
	(0.0125)	(0.0126)	(0.0122)	(0.0122)	(0.0121)
Age	0.0007**	0.0007**	0.0007**	0.0007**	0.0007**
	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Patents	0.0004*				
	(0.0002)				
Spinoff		0.0034*			
		(0.0019)			
R&D_UNI			6.4536		
			(4.4071)		
share_ResST				0.0129	
				(0.0251)	
share_gradST					0.0115
					(0.0418)
Aggl	0.0811**	0.0769**	0.0793**	0.0729**	0.0714**
	(0.0329)	(0.0327)	(0.0314)	(0.0311)	(0.0310)
North	-0.0485**	-0.0491**	-0.0333*	-0.0431**	-0.0433**
	(0.0205)	(0.0208)	(0.0192)	(0.0204)	(0.0206)
Pav	0.0717***	0.0721***	0.0732***	0.0734***	0.0735***
	(0.0172)	(0.0172)	(0.0169)	(0.0170)	(0.0169)
Observations	3,732	3,732	3,732	3,732	3,732
Wald-Chi2	191.97	191.55	196.19	188.48	188.19
Pseudo R2	0.0467	0.0466	0.0469	0.0461	0.0461

Note: average partial effects are reported. Standard errors clustered at provincial level in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Although this article focuses on the effect of universities' TT activities on the firm's probability to introduce at least one innovation, we also separately consider the different types of innovation, such as product, process and organisational innovation (table 4.1). The University knowledge transfer indicator has a positive and significant effect on the probability a firm has of introducing a product and an organisational innovation, while it seems to play no role for process innovation. These results confirm the evidence from other studies (among others, Eom and Lee, 2010 for Korea; Robin and Schubert, 2013 for France and Germany; Rouvinen, 2002 for Finnish manufacturing firms) according to which industry-university cooperation increases product innovation, but has no effect on process innovation.[16]

This result is confirmed when the likely correlation between disturbances of the last three equations is taken into account. In fact, firms can engage simultaneously in different types of innovation and, thus, correlation between choices for the different types of innovations could exist. In this case, the estimates of separate equations for product, process or organisational innovation are inefficient. For this reason, we have estimated a multivariate probit model (Greene, 2003)[17] and results, reported in the table 4.2, do not substantially change in terms of sign and significance with respect to those regarding the three separate probits.

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[16] Even when we consider the variables at the firm level, the results change. To be more precise, while the number of employees positively affects all kinds of innovation, R&D investment and physical capital have a significant effect on the probability to introduce a process or product innovation only. Moreover, the quality of employees only affect the product innovations and age only influences process innovations . Moreover, being in the specialised or science based sector significantly increases the probability of introducing a product or process innovation while Northern firms are less likely to innovate whatever the specific type of innovation considered. The presence of other firms located in the same province seems to spur product and organisational innovation.

[17] To this end, we have used the mvprobit Stata command which carries out simulated maximum likelihood estimations by using the Geweke–Hajivassiliou–Keane (GHK) simulator (Cappellari and Jenkins, 2003).

Table 4.1. Estimation results on the probability to introduce an innovation, 2004-2006

	Product innovation	Process innovation	Organizational innovation
lnEMP	0.0465***	0.0541***	0.0510***
	(0.0099)	(0.0106)	(0.0084)
lnK	0.0154*	0.0274***	0.0043
	(0.0079)	(0.0067)	(0.0056)
RD	0.0031*	0.0018***	0.0001
	(0.0016)	(0.0007)	(0.0003)
lnCL	0.0307**	0.0133	0.0160
	(0.0132)	(0.0119)	(0.0099)
Age	0.0005	0.0006*	-0.0001
	(0.0003)	(0.0004)	(0.0003)
TT_Uni	0.0029**	0.0011	0.0024**
	(0.0012)	(0.0013)	(0.0010)
Aggl	0.0736**	0.0399	0.0492**
	(0.0296)	(0.0450)	(0.0214)
North	-0.0335*	-0.0536**	-0.0256*
	(0.0199)	(0.0245)	(0.0147)
Pav	0.0738***	0.0440**	0.0154
	(0.0162)	(0.0183)	(0.0132)
Observations	3,732	3,732	3,732
Wald-Chi2	170.8	134.41	153
Pseudo R2	0.0252	0.0315	0.0281

Note: average partial effects are reported. Standard errors clustered at provincial level in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Table 4.2. Estimation results on the probability to introduce an innovation, multivariate probit estimates, 2004-2006[1]

	Product innovation	Process innovation	Organizational innovation
lnEMP	0.1183***	0.1409***	0.2014***
	(0.0257)	(0.0279)	(0.0334)
lnK	0.0403*	0.0713***	0.0148
	(0.0206)	(0.0175)	(0.0217)
RD	0.0072**	0.0045***	0.0006
	(0.0036)	(0.0015)	(0.0013)
lnCL	0.0804**	0.0368	0.0686*
	(0.0351)	(0.0307)	(0.0394)
Age	0.0013	0.0016*	-0.0003
	(0.0009)	(0.0010)	(0.0011)
TT_Uni	0.0077**	0.0029	0.0091**
	(0.0031)	(0.0035)	(0.0037)
Aggl	0.1914**	0.1111	0.1939**
	(0.0757)	(0.1134)	(0.0831)
North	-0.0884*	-0.1385**	-0.0999*
	(0.0512)	(0.0625)	(0.0543)
Pav	0.1859***	0.1146**	0.0602
	(0.0410)	(0.0474)	(0.0498)
Constant	-1.9870***	-2.0647***	-2.7187***
	(0.2876)	(0.3125)	(0.3654)
rho21	0.6461224		
p-value	*(.)*		
rho31	0.2234697		
p-value	*(.)*		
rho32	0.2730547		
p-value	*(.)*		
Wald-Chi2	474.19		
Observations	3,732	3,732	3,732

Note: Standard errors clustered at provincial level in parentheses;
*** p<0.01, ** p<0.05, * p<0.1;
Likelihood ratio test of rho21 = rho31 = rho32 = 0:
chi2(3) = 836.021

5. CONCLUDING REMARKS

In a knowledge-based economy, universities play a central role as a source of new knowledge. The Triple-Helix model emphasises universities' "third mission", that of working for economic development. Recently, often on the initiative of policy-makers, universities have taken action to develop this "third mission" by facilitating technology transfer. This paper considers the Italian case in order to investigate the role of university TT activities in explaining the probability to innovate of manufacturing firms. Exploring evidence regarding the impact created by university TT activities could inform debates about the role of universities in promoting innovation to justify the prominent position given in both government and university policies.

The impact of universities on innovation activities is subtle and complex and likely to be more indirect than direct. For example, spin-offs may benefit from links with their parent institutions but, at the same time, they may build up links with other local firms and, thus, contribute to the spreading of new knowledge into the local economy. We focus on this spillover effect of university TT activities.

To this end, firm data from the Unicredit-Capitalia database (2008) are combined to indicators of university TT activities in the province where a firm is located. In doing so, we are confident about previous research results which stress that a good deal of knowledge is rather 'sticky', organisation and people embodied, and often spatially clustered.

The results confirm that university TT activities play a role in shaping firms' likelihood to innovate, even in a context like Italy where institutionalised TT activities by universities are a recent phenomenon. Moreover, we find that knowledge flows coming from university research and educational activities play no significant role in firm innovative performance, supporting our assumption that TT activities may facilitate firms in benefiting from knowledge flows coming from university activities.

Nevertheless, the effect of university TT activities depends upon some characteristics of the firm and the external environment. It appears that firm size, sector and territorial context are important factors that influence the impact of TT activities on firms' innovative performance. In particular, the results suggest that the contribution of university TT activities to firms' probability to innovate is likely to be concentrated in some territorial areas (North-East and Centre), in some sectors (science based and scale intensive) and among firms that are large.

From a policy perspective, as a whole our empirical analysis provides support for the Triple Helix model: university TT activities play a role in promoting firm's innovation in the manufacturing sector. However, there are three main policy related lessons that can be drawn from our results.

First, the mechanism leading to successful university influence appears to be highly context specific. In line with evidence from literature (see Harrison e Leitch, 2010), in the South of Italy, an economically less developed regional context, universities do not affect firms' probability to innovate perhaps due to the lack of a local context which is "fertile" enough to leverage academic resources. Therefore, in an economically less developed regional context, with poorly functioning entrepreneurial systems, university TT does not represent a platform for sustained economic transformation.

Second, it is necessary to distinguish the conditions under which commercialisation activities may generate or inhibit widespread industrial benefits. In the North-East and the Centre of Italy, universities emerge as an important knowledge source. However, university "third mission" activities seem surprisingly to have a negative effect in the North-West of Italy, the most industrialised area of the country. In this area of the country, where the two main polytechnics are located, universities may be more commercially orientated and, thus, the interest that sponsoring companies have in protecting the results of research may inhibit the transfer of technology (Colombo et al, 2010). This result might justify the concern of some scholars that with greater enterprise comes greater secrecy at the expense of the dissemination of scientific knowledge and that this might reduce the pool of technological opportunities available to the industrial sector for innovative activities.

Finally, some of the key questions for policy makers who are looking for ways to support innovation are how they can foster growth in the size of existing small and medium-sized firms and how they can promote the entry of new firms into science based sectors. In effect, our findings show that, in order to take advantage of TT university activity, firms need either to be large, since large firms are more likely to have the resources (staff with science and engineering skills, financial resources, etc.) to exploit external knowledge sources, or to operate in science intensive sectors.

This aspect is not only relevant for Italy, but also for Europe as a whole. As stressed by Dosi et al (2006), one of the causes of the European Paradox lies in European industrial weakness in comparison with US industry. The European pattern of specialisation tends to be less "science based" and corporate actors are generally smaller with a weaker participation in international oligopolies than their American counterparts.

Nevertheless, since institutionalised TT activities by universities are a recent phenomenon in Italy, our analysis cannot give a comprehensive answer to the question of whether the policies of promoting university TT activities foster innovation. It would be interesting to test whether our results find support with more recent data, but this must remain an objective for future research.

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APPENDIX A

Table A.1. List and description of variables used in the empirical investigation

VARIABLE	DESCRIPTION
Inno	dummy equal to one when a firm reports introducing at least one innovation (product, process or organizational innovation) during the 2004-2006
Product innovation	dummy equal to one when a firm reports introducing at least one product innovation during the 2004-2006
Process innovation	dummy equal to one when a firm reports introducing at least one process innovation during the 2004-2006
Organizational innovation	dummy equal to one when a firm reports introducing at least one organisational/gestional innovation during the 2004-2006
lnEMP	firm size as measured by its number of employees in 2005 (in log)
lnK	stock of physical capital at firm level proxied by 2005 tangible fixed assets (in log)
RD	average 2004-2006 R&D intensity (R&D expenditures as a share of sales) of firms
lnCL	2005 cost of labour per employee as a proxy of labour quality (in log)
Age	number of years of the firm
Aggl	province’s industry density (number of firms per 100 inhabitants n the province in which each firm is located) in 2004
North	dummy equal to one if a firm is located in the North of Italy
Pav	dummy equal to one if a firm is in the specialised or science based sector according to the Pavitt taxonomy
TT_Uni	indicator on research upgrading and transfer activities based on the first Italian Research Evaluation Exercise for the years 2001-2003 (VTR 2001-03)
Patents	number of patents that are active up to the end of 2003
Spinoff	number of spin-offs activated over the 2001-2003 period
R&D_UNI	total research spending by the university in the same province in which the firm is located in 2004
share_ResST	share of professors and assistant professors in science and technology fields (S&T) in 2004
share_gradST	S&T graduates as a share of the graduates in all fields in 2004

Table A.2. Descriptive statistics

Variable	Mean	Std. Dev.	Min	Max
Inno	0.671222	0.469832	0	1
Product innovation	0.534566	0.498871	0	1
Process innovation	0.463826	0.498757	0	1
Organizational innovation	0.185691	0.38891	0	1
lnEMP	3.520441	1.010072	1.098612	6.873164
lnK	13.60158	1.698505	8.92655	17.97261
RD	1.819798	13.23855	0	603.2902
lnCL	10.22856	0.715934	2.954395	15.88431
Age	27.80091	22.65181	0	256
Aggl	1.136972	0.333503	0.436731	3.080904
North	0.716238	0.450883	0	1
Pav	0.32074	0.466823	0	1
TT_Uni	3.103362	5.299237	0	16.86809
Patents	20.7232	36.96853	0	117
Spinoff	2.378885	3.905279	0	12
R&D_UNI	0.002158	0.002531	0	0.014444
share_ResST	0.405166	0.319722	0	0.931559
share_gradST	0.234457	0.202389	0	0.659824

Table A.3. Correlation matrix

	lnEMP	lnK	RD	lnCL	Age	Aggl	North	Pav	TT_Uni	Patents	Spinoff	R&D_UNI	share_ResST	share_gradST
lnEMP	1													
lnK	0.6394	1												
RD	-0.0022	-0.0728	1											
lnCL	0.0655	0.3579	-0.1288	1										
Age	0.2381	0.2278	-0.0239	0.1343	1									
Aggl	0.0129	-0.068	0.0162	0.0586	0.0186	1								
North	0.0432	-0.014	-0.0048	0.1278	0.1386	0.1839	1							
Pav	0.0687	-0.067	0.0142	0.0639	0.0077	0.022	0.1575	1						
TT_Uni	-0.0317	-0.0762	-0.0069	0.0939	0.1304	-0.1382	0.1723	0.1068	1					
Patents	-0.0209	-0.0619	-0.0054	0.0945	0.1272	-0.1955	0.174	0.1084	0.9697	1				
Spinoff	-0.0298	-0.076	-0.0118	0.0945	0.1269	-0.1058	0.225	0.1089	0.9635	0.9038	1			
R&D_UNI	-0.0383	-0.0453	-0.0064	-0.0269	-0.0017	-0.2231	-0.2952	-0.018	0.3485	0.2756	0.3341	1		
share_ResST	-0.0192	-0.0254	-0.021	0.034	0.0647	-0.1896	-0.0179	0.0466	0.4936	0.4609	0.5273	0.6429	1	
share_gradST	-0.0216	-0.018	-0.0256	0.0262	0.049	-0.1224	0.0137	0.0353	0.3632	0.3114	0.4326	0.5943	0.9488	1

Table A.4. Estimation results on the probability to introduce an innovation by exporting status and for younger and older firms, 2004-2006

	Exporters	No exporters	Young <= 10 years	Old > 10 years
lnEMP	0.0596***	0.0540***	0.0985***	0.0596***
	(0.0111)	(0.0188)	(0.0224)	(0.0098)
lnK	0.0149*	0.0218**	0.0025	0.0205***
	(0.0085)	(0.0096)	(0.0122)	(0.0078)
RD	0.0031	0.0104**	0.0045	0.0074**
	(0.0026)	(0.0053)	(0.0035)	(0.0035)
lnCL	0.0176	0.0611**	0.0732***	0.0234*
	(0.0153)	(0.0248)	(0.0233)	(0.0134)
Age	0.0006	0.0005		
	(0.0004)	(0.0007)		
TT_Uni	0.0028*	0.0015	0.0065*	0.0030**
	(0.0015)	(0.0020)	(0.0036)	(0.0012)
Aggl	0.0749**	0.0505	-0.0587	0.0955***
	(0.0342)	(0.0453)	(0.0652)	(0.0355)
North	-0.0572**	-0.0491*	-0.0020	-0.0512**
	(0.0245)	(0.0296)	(0.0442)	(0.0204)
Pav	0.0690***	0.0420	0.0949**	0.0628***
	(0.0201)	(0.0315)	(0.0387)	(0.0207)
Observations	2,319	1,390	697	3,113
Wald-Chi2	159.55	50.98	62.53	135.42
Pseudo R2	0.0402	0.0374	0.065	0.0403

Note: average partial effects are reported. Standard errors clustered at provincial level in parentheses; *** p<0.01, ** p<0.05, * p<0.1

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