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Do firms benefit from university research? Evidence from Italy.

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Abstract.

The aim of this paper is to assess the effect on firm total factor productivity of the university research. Since the impact of universities on firms' performance is subtle and complex, we verify whether territorial context, sector and firm size may influence this relationship. Results show that university R&D does not seem to affect Italian firm productivity. However, if we consider geographical location and sector, we find that university activities have a positive effect on the performance of firms located in the North of Italy or operating in the specialised supplier sector. Several robustness checks confirm the significant role played by universities above all in the North of Italy. The policy implications of these findings are discussed.

Key words: University, R&D, Total Factor Productivity

JEL code: O30, D24, C21.

The authors contributed equally to the writing of this paper.

1. Introduction

The important role played by universities in generating knowledge spillovers is widely recognized (Audretsch et al, 2004). Such spillovers can arise through informal information transmission via the local personal networks of university and industry professionals, participation in conferences and presentations, or other kinds of knowledge transmissions from academia to industry (Varga, 2000).

In this paper we investigate if the positive externalities produced by universities affect the productivity of local firms. Empirical studies that pursue similar research questions have investigated the impact of academic research on innovation (among others, see Acs et al 1992; Anselin et al, 1997; Audretsch et al, 2011; Del Barrio-Castro and García-Quevedo, 2005; Leten et al, 2011; Jaffe, 1989; Piergiovanni et al, 1997) or on regional economic growth (Carree et al, 2012; Duch et al 2011; Goldstein and Ducker, 2006). More similar to our contribution is the study by Audretsch and Lehmann (2005) who, assessing the effect of knowledge generated by universities on the rate of growth of firms' employees, provided the "missing link" between the literature on firm growth and that studying university spillovers.

Unlike previous studies, we assess the effect of the university on firm total factor productivity (TFP). This variable is crucial especially for those countries, such as Italy, which suffer from low productivity (Istat, 2007a; OECD, 2007; Van Ark, O'Mahony e Ypma, 2007).

The key hypothesis of our analysis is that university research, through informal channels, may generate knowledge which spills over to nearby firms fostering their productivity, even those which have no formal relationship with the university. To the best of our knowledge this is the first paper which specifically addresses the effect of university R&D spillovers on firm productivity.

We measure university research by using the total research spending by the university. As a productivity measure, we estimate TFP at firm level by employing the Levinsohn and Petrin (2003) approach and the UniCredit-Capitalia database (2008). Firm data are combined with indicators of university research activities in the province where a firm is located. In so doing, we rely on previous research results which stress that a good deal of knowledge is embodied in people and organisations, and spatially clustered (Jaffe, 1989; Audretsch and Feldman, 1996; Anselin et al, 1997).

We also evaluate if firm size, sector and territorial context may influence the relationship between local universities and firm productivity: in particular, whether university research effects hold uniformly across regions, whether local university spillovers could be specific to certain industries, and whether firm size matters.

Results show that university R&D does not seem to improve firm productivity. However, if we consider geographical location and sector, we find that university activities have a positive effect on the performance of firms located in the North of Italy or operating in the specialised supplier sector. Several robustness checks are performed, confirming the significant role played by universities especially in the North of Italy.

The paper is organized as follows. The following section describes data and indicators employed. We then illustrate methodology and results. The final section concludes.

2. Data and descriptive statistics

2.1 Firm data

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 the information collected by means of a questionnaire

sent to a sample of Italian manufacturing firms.¹ The survey is complemented with balance sheet data for the period 1998-2006.

Information on the sample is reported in Table 1. Sampled firms are mainly small-medium sized, family-owned, belonging to supplier-dominated sectors or specialized suppliers located predominantly in Northern Italy. Table 1 also reports TFP average for 2006 estimated with the Levinsohn and Petrin (2003) approach (see Appendix A). Marked differences emerge across different groups. Productivity appears to be higher for large enterprises, non-family firms, firms belonging to the science based sector and located in the North.

Table 1 – Descriptive statistics of firms in the sample

	N. firms	TFP (2006)
ALL FIRMS	2828	87922
Pavitt Sectors		
Supplier dominated	1364	78076
Scale intensive	549	97415
Specialised suppliers	788	94346
Science based	127	112772
Size		
Small (< 50 employees)	1617	73767
Medium (50-250)	993	97157
Large (>250)	218	150849
Territorial area		
North	2125	89978
Center and South	703	81707
Ownership		
Family firms	1762	84530
Non-family firms	1066	93529

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

2.2 University indicators

Past research underlines the fact that the spillover of human capital and research from universities to industry is mainly in the nature of tacit knowledge (Acs et al, 1992; Jaffe, 1989). Tacit knowledge cannot be easily transferred over large distances or bought via the market. Jaffe (1989) and Audretsch and Feldman (1996) provided evidence that knowledge spillovers are geographically bound and located close to the knowledge source. Furthermore, Anselin et al (1997) prove that the

¹ The survey design includes all firms with a minimum of 500 employees. A sample of firms with between 11 to 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.

geographical scope of knowledge spillovers is restricted to a limited number of neighbouring regions or to regions within a given maximum distance from the region of interest.

Considering the relevance of geographic proximity for tacit knowledge, we choose the province (NUTS 3 level)² as the territorial unit for university variables. We use data collected from Italian universities, both public and private, to build university-related indicators: university R&D indicator (RD^{UNIV}).

Total research spending by the u -th university (RD^{UNIV}) is given by:

$$RD^{UNIV} = RDP + F + RDDEP \quad [1]$$

where RDP is the cost for professors and assistant professors (from now on “researchers”), F represents the expenditure for doctoral and post-doctoral fellowships and $RDDEP$ is R&D expenditure by departments. Specific university variables are provided by ANVUR.³

Expenditure for academic research personnel (RDP) is proxied by

$$RDP = \sum_{s=1}^{14} \left[\left(\sum_{p=1}^2 \bar{S}_{pu} N_{psu} \right) t_s \right] \quad [2]$$

with $s = 1 \dots 14$ discipline groups⁴, $p =$ position (1 for professors and 2 for assistant professors) and where:

\bar{S}_{pu} is the average expenditure on personnel for position p and university u ;

N_{psu} is the number of research staff for position p , scientific area s and university u ;

t_s is the percentage of time spent on research by academics for each scientific area s .

The percentage of the time spent on research by university professors and assistant professors for each scientific area (t_s) is published by ISTAT (2007b). These coefficients are the results of the survey on the distribution of working time of Italian academics, primarily the time devoted to teaching and research, for the academic year 2004-2005.⁵

² Provinces are one of the three different levels of government (regions, provinces and municipalities) in Italy. According to the basic principles of the Nomenclature of Territorial Units for Statistics (NUTS) established by Eurostat and used by the European Commission, Italian provinces are NUTS 3 level.

³ The ANVUR Annual survey database relative to 2004 includes 79 universities. Removing from the population two telematic universities and one university with no data on expenditure on personnel brought down the count of research universities to 76. Databases are available at: <http://www.anvur.org/?q=content/rilevazioni-annuali>. Data from private universities have been collected from <https://nuclei.cineca.it/cgi-bin/2005/sommario.pl>.

⁴ MIUR aggregates disciplines in 14 groups (“settori scientifico-disciplinari”): Mathematics and Computer Sciences; Physics; Chemistry; Earth Sciences; Biology; Medicine; Agricultural and Veterinary Sciences; Civil Engineering and Architecture; Industrial and Computer Engineering; Ancient History, Philology, Literature and Art History; History, Philosophy, Pedagogy and Psychology; Law; Economics and Statistics; Political and Social Sciences. In the S&T fields we consider the first nine groups.

⁵ The research activity includes the time spent on research, i.e. the creative work aimed at acquiring new knowledge, and the use of such knowledge in new applications. It also includes the time involved in the coordination of research

As regards F , data on post-doctoral fellowships were available from ANVUR Annual Survey, while doctoral fellowships were calculated by considering the number of PhD students provided by ANVUR and the cost per fellowship in 2004.⁶

The final component of our proxy of university research expenditure is departmental expenses for research, that is

$$RDDEP = \sum_{d=1}^{n_u} Pay_{du} \quad [3]$$

with $d=1 \dots n_u$ departments in university u and Pay_{du} represents total expenditure for research by department d of university u .⁷

The correlation between the ISTAT data on university R&D expenditure available at regional level and our estimates aggregated on a regional basis is very high (0.98) and this gives us confidence that the procedure used is correct.

To pool university indicator with the company dataset, the indicator is aggregated on a provincial basis⁸ and then added to each company dataset based on its territorial location. 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).

Table 2 reports statistics regarding the university indicator aggregated by territorial area: Northern provinces spend, on average, 1.4 times the amount spent by Southern provinces.

Tab 2 University indicators by territorial area

	North	Center	South	Italy
Number of universities	30	22	24	76
RD ^{UNIV} (thousands of euro) (2004)	1,384,302	879,032	932,946	3,196,280
<i>Average per province</i> (thousands of euro)	69,215	87,903	49,102	65,2
<i>Average per researcher</i> (euro)	57,247	55,991	50,693	54,836

Source: elaborations on data from ANVUR and MIUR

projects carried out by researchers and PhD students and in conferences and seminars. For example, chemists spend, on average, 56% of their working time doing research, while academics in the field of medicine spend 29%.

⁶ For the universities where information on postdoctoral fellowships were not available on the ANVUR Annual Survey database, we collect data at <http://www.anvur.org/?q=content/rilevazioni-annuali>.

⁷ Departmental expenditure for research activities represents 26.8% of our university R&D indicator.

⁸ For the multi-campus universities with an organized central campus and several peripheral ones, we refer the data to the province of the central location of the multi-campus university, since in most cases teaching activity alone is performed locally, whereas research is retained at the central location (one exception is “Università Cattolica del Sacro Cuore”).

3. Empirical strategy and results

3.1 Empirical strategy

The baseline model considered in our analysis is the following:

$$\ln \omega_{ij} = \beta_0 + \beta_1 RD_j^{UNIV} + \beta_2 Int_assets_{ij} + \beta_3 \ln CL_{ij} + \eta_1 D_small_{ij} + \eta_2 D_pav_{ij} + \eta_3 D_North_{ij} + \eta_4 D_fam_{ij} + \varepsilon_{ij} \quad [4]$$

for $i=1, \dots, N$ firms and $j=1, 2, \dots, P$ provinces.

ω indicates the firm TFP in 2006 estimated by the Levinsohn and Petrin (2003) approach, *Int_assets* indicates the 2005 intangible assets per employee (in millions of euro), *CL* is the 2005 cost of labour per employee as a proxy of labour quality,⁹ *D_small* takes the value one if the firm is small (less than 50 employees) and zero in other cases, *D_pav* is equal to one if the firm is in the supplier dominated sector according to the Pavitt taxonomy, *D_North* assumes the value of one if the firm is located in the North of Italy, and *D_fam* takes the value of one in the case of a family-owned firm. Finally, ε_{ij} is the error term. In order to address the effect on TFP of university research, we have included in the equation [4] RD^{UNIV} which stands for the intensity of R&D at universities located in the same province as the firm in 2004.¹⁰

As regards the estimation method, since firms from the same province are likely to be more similar to each other than firms from different provinces (because of socio-economic factors for example) the assumption that the errors are independent might be violated. For this reason we control for the potential downward bias in the estimated errors by clustering firms at provincial level. The regression with the cluster option relaxes the assumption of independence and, therefore, compared with the OLS without clustering, increases the error term to accommodate the lack of independence of firms within each province.

3.2 Results

Estimates of equation [4] are reported in column (1) of Table 3. Results show that firms in the supplier dominated sector and small firms have, ceteris paribus, a lower TFP while firms located in Northern Italy exhibit higher productivity, as already stressed by the literature (Aiello et al, 2014, Ascari and Di Cosmo, 2005, Byrne et al, 2009). Moreover, as expected, family firms are less efficient (Cucculelli and Marchionne, 2012 and Cucculelli et al, 2014), TFP is positively affected by labour quality (Ascari and Di Cosmo, 2005; Ciccone, 2004) while intangible assets have no significant effect. As regards the specific variable of interest, we find that research carried out by

⁹ Cost of labour per employee should be correlated with skill intensity if more skilled workers receive higher wages.

¹⁰ Intangible assets per employee and cost of labour are deflated by considering producer price index for industrial products and consumer price index for families of workers and office workers from ISTAT, respectively.

universities does not significantly affect firm TFP, confirming the difficult relationship between universities and industry in Italy (Poma and Ramaciotti, 2008).

It is difficult to compare our results with those obtained by other contributions, since- to the best of our knowledge- this is the first paper which specifically addresses the effect of University R&D spillovers on firm productivity.¹¹ Indeed, empirical studies that pursue similar research questions have investigated the impact of academic research on innovation (among others, see Acs et al 1992; Anselin et al, 1997; Audretsch et al, 2011; Del Barrio-Castro and García-Quevedo, 2005; Leten et al, 2011; Jaffe, 1989; Piergiovanni et al, 1997) on firm's growth in terms of number of employees (Audrestch and Lehmann, 2005) or on regional economic growth (Carree et al, 2012; Duch et al 2011; Goldstein and Drucker, 2006). The results suggest a positive relationship between universities and firm performance.

However, regional specificities may affect the university-firms relationship. A relevant question is whether the effects of university research hold uniformly across regions or whether regions with different levels of economic development respond differently. Considering the dualistic nature of Italian economy, this aspect is relevant: the regions of the North are as prosperous as those of Central and Northern Europe, while the South is the largest backward region within the EU-15 (Iuzzolino et al, 2011). The key question is whether communities near universities have the capabilities to absorb and exploit the knowledge that universities generate. Even though new knowledge is generated in many places, only those regions that can absorb and apply such ideas are able to turn it into economic wealth.

Moreover, local university spillovers could be specific to certain industries: knowledge spillovers appear to be particularly relevant in sectors where new knowledge can be assumed to be of special importance (Anselin et al, 2000a; Doring and Schnellenbach, 2006).

Finally, firm size also matters. Smaller firms do not have the resources to maintain large scale R&D departments and, therefore, spillovers from the research activities of universities could, in theory, play a more decisive role for them (Acs et al, 1994). However, other scholars argue that large firms are more likely to have the capability to exploit university research since they employ staff with science and engineering background who are able to exploit the results of university research (Cohen et al, 2002; Laursen and Salter, 2004).

¹¹ The impact of university knowledge on firm productivity is considered in Belderbos et al (2004); Harris et al (2011) Medda et al (2005), but they focused on the formal R&D co-operation and, therefore, are not comparable with our analysis.

In order to consider these aspects we have estimated equation [4] by considering geographical location, sector and firm size. Results of these estimations are reported in Table 3 as well.

When we consider the location (columns 2-3), we find that universities have a positive effect on the performance of Northern firms only: university activities seem to affect firm performance only in an industrialized context, such as the North of Italy. In more detail, for Northern firms we observe a positive and significant impact on TFP of R&D by universities located in the same province. Hence, results suggest that proximity to a university is not a sufficient condition for a significant effect on industry of academic spillovers. This is in line with the concept of “the critical mass of agglomeration” suggested by Varga (2000) according to which there is a need of a certain level of agglomeration, in particular of concentration of high technology production, in a metropolitan area in order for local academic knowledge transfers to be effective. Furthermore, our result is supporting evidence for the conjecture that regions that already have a relatively higher productivity level and a larger stock of knowledge, as the Northern regions of Italy, absorb incoming knowledge relatively easier (Döring and Schnellbach, 2006). Finally, our results are in line with those obtained by Carree et al (2012), who measuring the contribution of teaching, publication and intellectual property rights on the growth of value added for Italian provinces between 2001 and 2006, show that universities play a key role when they are associated with sustained entrepreneurial activities in the province. Similarly to our findings, Arvanitis et al (2008) found that university knowledge and technology transfer to firms imply, *ceteris paribus*, higher labour productivity for a sample of Swiss firms over the period 2002-2004.

Unfortunately our results do not help us discern whether the effect of university research is greater for small-medium or large companies: the coefficients of university indicators are always not significant when we split our sample on the basis of size (columns 4-5).

As Anselin et al (2000a) for US, we do not find that academic externalities are uniform across sectors.¹² Only for the specialised suppliers, is there a positive and significant effect of university research on TFP (columns 6-9). Our findings, however, are not in line with Anselin et al (2000b).¹³ Indeed, they find an effect of university research only in the electronics sector (science based), while there is no effect for the machinery and instruments sectors (specialised suppliers). Our findings could reflect the Italian pattern of specialisation that tends to be less “science based”

¹² It is worth noting that for Anselin et al (2000a) the dependent variable is the count of innovations.

¹³ In order to compare Anselin et al (2000b) with our results, we use the concordance between two-digit SIC (US) and Pavitt’s categories based on Greenhalgh and Rogers (2004).

and more concentrated in the machinery sector the backbone of Italy's exports, and in traditional sectors.

Table 3 – Estimation results. Dependent variable: (logarithm of) TFP, 2006.

	Italy	North	Center-South	Small (11-50 employees)	Medium-large (>50)	Supplier dominated	Scale intensive	Specialised suppliers	Science based
RD ^{UNIV}	3.524 (3.699)	8.813* (4.678)	-1.499 (6.380)	6.790 (4.946)	-1.883 (5.393)	1.608 (5.595)	-3.870 (8.452)	12.612* (6.980)	-11.661 (19.030)
Int_assets	0.114 (0.082)	0.091 (0.067)	0.535*** (0.124)	0.121 (0.098)	0.100 (0.081)	0.093 (0.096)	0.920** (0.392)	0.116*** (0.042)	0.824*** (0.218)
lnCL	0.229*** (0.015)	0.218*** (0.015)	0.240*** (0.031)	0.196*** (0.018)	0.286*** (0.032)	0.223*** (0.021)	0.229*** (0.035)	0.207*** (0.032)	0.193*** (0.037)
D_Small	-0.357*** (0.017)	-0.361*** (0.020)	-0.345*** (0.035)			-0.304*** (0.023)	-0.451*** (0.031)	-0.354*** (0.030)	-0.579*** (0.076)
D_Pav	-0.142*** (0.017)	-0.139*** (0.021)	-0.142*** (0.032)	-0.103*** (0.021)	-0.189*** (0.024)				
D_North	0.079*** (0.028)			0.085** (0.033)	0.064* (0.038)	0.079** (0.034)	0.020 (0.041)	0.164*** (0.046)	0.032 (0.089)
D_Fam	-0.059*** (0.015)	-0.058*** (0.018)	-0.068** (0.034)	-0.048** (0.021)	-0.075*** (0.024)	-0.044** (0.022)	-0.066* (0.037)	-0.060** (0.026)	-0.035 (0.078)
Constant	4.502*** (0.153)	4.691*** (0.160)	4.407*** (0.325)	4.451*** (0.179)	3.976*** (0.318)	4.392*** (0.212)	4.611*** (0.365)	4.637*** (0.328)	5.140*** (0.399)
Observations	2,683	2,016	667	1,531	1,152	1,300	510	757	116
R-squared	0.277	0.278	0.257	0.153	0.216	0.193	0.302	0.275	0.475
F-test	120.0	101.3	83.73	34.21	43.23	49.64	52.54	71.39	57.88
p-value	0	0	0	0	0	0	0	0	0

Robust standard errors clustered at provincial level in parentheses; *** p<0.01, ** p<0.05, * p<0.1

3.3 Robustness checks

We performed a number of robustness checks in order to test the stability of the results.

Theories dating back to Marshall suggest that agglomeration may result in greater firm efficiency by providing industry specific complementary assets and activities that may either lower the cost of supplies to the firm or create greater specialisation in both input and output market (Feldman, 1999). In our case, overall agglomeration economies could also play a role since the high concentration of companies and industries in the Northern part of the country creates more capacity to exploit university products providing better infrastructure for developing innovation. As regards this aspect, we have included, in equation [4], the ratio of number of firms in the restricted industry (manufacturing, mining, and energy) located in the province to population as agglomeration indicators. The results show that inclusion in the equation of this indicator does not affect either the sign nor the significance of the university indicator in the case of the Italian sample as a whole, or when the sample is split on the basis of territorial area (table 4). This means that University R&D positively affect TFP of Northern firms only. However, we now find that University R&D has a positive and significant effect for small firms too, while the effect is never significant when we split the sample according to the Pavitt taxonomy.

We have considered whether the knowledge flows from universities located in a larger geographical context than the provincial level may also play a role in firm TFP. We have estimated eq. [4] by using university R&D indicator referring to the other provinces of the same region in which each firm is located. Results, available upon request, show that the relative coefficient is never significant. Moreover, the effect of university R&D of the province in which firm is located is once again significant for Northern firms but not for specialized suppliers.

As a further robustness check, we have also considered another indicator of university research, that is the ratio of S&T researchers to employment in the restricted industry located in the same province of each firm. Hence, we have estimated equation [4] with the inclusion of this indicator instead of University R&D.¹⁴ Results, reported in table 5, confirm those obtained when R&D university is used: academic research positively and significantly affects productivity of Northern firms and firms in the specialized suppliers sector.

As highlighted in the seminal articles of Mansfield (1991, 1995) the higher the quality of academic research the more likely it is to contribute to industrial innovation. We have also considered the effects of academic research performance including in equation [4] a proxy of the

¹⁴ Data on S&T researchers comes from ANVUR. In the S&T fields we consider the first nine groups: Mathematics and Computer Sciences; Physics; Chemistry; Earth Sciences; Biology; Medicine; Agricultural and Veterinary Sciences; Civil Engineering and Architecture; Industrial and Computer Engineering.

quality of university research as academic research indicator. Research performance indicators are based on the evaluation of research output carried out over the period 2001-2003 by CIVR-VTR (MIUR, 2007) which produced a composite indicator for the various universities.¹⁵ The effect of the CIVR indicator is positive and significant for the whole sample and for almost all groups considered (table 6). From our results it seems that the higher is the quality of universities located in the province the more widespread is the effect on the firm's performance. Quality research seems to affect not only Northern firms and firms in the specialized suppliers sector, but also small firms, those located in the Centre - South, and businesses operating in the supplier dominated sector.

¹⁵ The composite indicator, suitable to be used for the allocation of state funds, includes: quality of the products; property rights on the products; international mobility propensity; advanced training propensity; ability to attract financial resources; ability to use available funds to finance research projects.

Table 4 – Estimation results with agglomeration indicator. Dependent variable: (logarithm of) TFP, 2006.

VARIABLES	Italy	North	Center-South	Small (11-50 employees)	Medium-large (>50)	Supplier dominated	Scale intensive	Specialized suppliers	Science based
RD ^{UNIV}	4.963 (3.571)	9.832** (4.862)	-0.021 (5.683)	8.489* (4.453)	-1.452 (5.493)	4.395 (4.926)	-3.320 (8.645)	10.955 (7.163)	-11.578 (19.781)
Int_assets	0.116 (0.082)	0.091 (0.068)	0.538*** (0.129)	0.123 (0.100)	0.100 (0.081)	0.094 (0.096)	0.921** (0.395)	0.114*** (0.041)	0.826*** (0.225)
lnCL	0.229*** (0.015)	0.218*** (0.015)	0.237*** (0.031)	0.196*** (0.018)	0.285*** (0.031)	0.221*** (0.021)	0.229*** (0.035)	0.207*** (0.032)	0.193*** (0.038)
D_Small	-0.357*** (0.017)	-0.360*** (0.020)	-0.346*** (0.033)			-0.306*** (0.022)	-0.451*** (0.030)	-0.354*** (0.030)	-0.579*** (0.077)
D_Pav	-0.143*** (0.017)	-0.139*** (0.021)	-0.149*** (0.031)	-0.106*** (0.021)	-0.190*** (0.024)				
D_Fam	-0.060*** (0.015)	-0.058*** (0.017)	-0.067* (0.034)	-0.048** (0.021)	-0.075*** (0.025)	-0.044** (0.022)	-0.066* (0.037)	-0.059** (0.026)	-0.035 (0.078)
D_North	0.077*** (0.028)			0.083** (0.032)	0.064 (0.038)	0.079** (0.031)	0.018 (0.042)	0.164*** (0.046)	0.031 (0.099)
Agglomeration	4.308 (3.388)	2.555 (4.565)	5.284 (4.463)	5.694 (4.793)	1.110 (4.594)	8.519** (3.269)	1.178 (6.693)	-5.058 (5.218)	0.331 (13.290)
Constant	4.456*** (0.162)	4.658*** (0.182)	4.375*** (0.326)	4.389*** (0.181)	3.964*** (0.339)	4.302*** (0.211)	4.602*** (0.374)	4.699*** (0.338)	5.137*** (0.392)
Observations	2,683	2,016	667	1,531	1,152	1,300	510	757	116
R-squared	0.278	0.278	0.260	0.155	0.216	0.198	0.302	0.276	0.475
F-test	109.3	87.40	74.25	30.80	39.28	47.69	49.10	61.22	54.01
p-value	0	0	0	0	0	0	0	0	0

Robust standard errors clustered at provincial level in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Table 5 – Estimation results with S&T researchers indicator. Dependent variable: (logarithm of) TFP, 2006.

	Italy	North	Center-South	Small (11-50 employees)	Medium-large (>50)	Supplier dominated	Scale intensive	Specialized suppliers	Science based
S&T_ Researchers	1.584 (1.393)	3.402* (1.708)	0.670 (2.024)	2.647 (1.664)	0.297 (2.060)	-0.166 (1.945)	1.519 (2.184)	4.894** (1.969)	-0.414 (4.057)
Int_assets	0.114 (0.082)	0.091 (0.067)	0.534*** (0.120)	0.121 (0.097)	0.102 (0.082)	0.093 (0.096)	0.938** (0.376)	0.117*** (0.041)	0.802*** (0.216)
lnCL	0.230*** (0.015)	0.218*** (0.015)	0.241*** (0.031)	0.197*** (0.017)	0.285*** (0.031)	0.223*** (0.021)	0.227*** (0.034)	0.207*** (0.032)	0.195*** (0.036)
D_Small	-0.357*** (0.017)	-0.361*** (0.020)	-0.345*** (0.035)			-0.304*** (0.023)	-0.450*** (0.031)	-0.354*** (0.030)	-0.571*** (0.078)
D_Pav	-0.140*** (0.017)	-0.138*** (0.020)	-0.141*** (0.032)	-0.100*** (0.021)	-0.188*** (0.024)				
D_Fam	-0.059*** (0.015)	-0.057*** (0.018)	-0.067* (0.034)	-0.049** (0.021)	-0.074*** (0.025)	-0.044** (0.022)	-0.065* (0.037)	-0.060** (0.026)	-0.035 (0.077)
D_North	0.086*** (0.027)			0.095*** (0.033)	0.070* (0.038)	0.074** (0.031)	0.039 (0.040)	0.176*** (0.048)	0.040 (0.119)
Constant	4.490*** (0.150)	4.690*** (0.160)	4.383*** (0.314)	4.438*** (0.180)	3.967*** (0.310)	4.401*** (0.211)	4.602*** (0.357)	4.622*** (0.329)	5.075*** (0.413)
Observations	2,683	2,016	667	1,531	1,152	1,300	510	757	116
R-squared	0.278	0.278	0.257	0.154	0.216	0.193	0.302	0.277	0.473
F-test	120.1	105.2	89.04	35.40	46.80	49.38	54.87	72.68	58.45
p-value	0	0	0	0	0	0	0	0	0

Robust standard errors clustered at provincial level in parentheses;*** p<0.01, ** p<0.05, * p<0.1

Table 6 – Estimation results with research performance indicator. Dependent variable: (logarithm of) TFP, 2006.

VARIABLES	Italy	North	Center-South	Small (11-50 employees)	Medium-large (>50)	Supplier dominated	Scale intensive	Specialized suppliers	Science based
Research performance	0.020*** (0.007)	0.018*** (0.006)	0.027* (0.016)	0.022*** (0.006)	0.017 (0.012)	0.019* (0.010)	0.014 (0.011)	0.025*** (0.006)	0.006 (0.022)
Int_assets	0.118 (0.083)	0.093 (0.067)	0.549*** (0.125)	0.124 (0.097)	0.112 (0.084)	0.094 (0.095)	0.932** (0.372)	0.123*** (0.042)	0.804*** (0.214)
lnCL	0.227*** (0.015)	0.216*** (0.015)	0.240*** (0.031)	0.194*** (0.017)	0.282*** (0.032)	0.222*** (0.021)	0.225*** (0.034)	0.202*** (0.032)	0.197*** (0.036)
D_Small	-0.359*** (0.018)	-0.362*** (0.020)	-0.346*** (0.035)			-0.306*** (0.023)	-0.452*** (0.030)	-0.358*** (0.031)	-0.569*** (0.079)
D_Pav	-0.133*** (0.017)	-0.134*** (0.019)	-0.134*** (0.034)	-0.094*** (0.021)	-0.182*** (0.024)				
D_Fam	-0.059*** (0.015)	-0.058*** (0.018)	-0.063* (0.035)	-0.048** (0.021)	-0.072*** (0.025)	-0.044** (0.022)	-0.063* (0.037)	-0.063** (0.027)	-0.034 (0.076)
D_North	0.075*** (0.024)			0.075** (0.029)	0.070** (0.034)	0.078** (0.031)	0.023 (0.037)	0.142*** (0.040)	0.047 (0.094)
Constant	4.512*** (0.152)	4.705*** (0.159)	4.354*** (0.318)	4.464*** (0.175)	3.976*** (0.323)	4.390*** (0.211)	4.622*** (0.358)	4.701*** (0.331)	5.038*** (0.399)
Observations	2,683	2,016	667	1,531	1,152	1,300	510	757	116
R-squared	0.281	0.280	0.263	0.157	0.218	0.196	0.303	0.278	0.473
F-test	119.6	107.7	86.35	42.62	39.79	51.83	57.07	71.06	57.95
p-value	0	0	0	0	0	0	0	0	0

Robust standard errors clustered at provincial level in parentheses; *** p<0.01, ** p<0.05, * p<0.1

4. Conclusion and policy implications

The relationships between university and industry have become a central concern for applied economics in the recent years. On one hand, some supporters of Open Science consider that greater commercial orientation of university research hinders the generation of positive externalities from university research to other firms, thereby inhibiting knowledge transfer, e.g. as a result of patented research, as 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). On the other hand, other scholars agree with the so-called Triple Helix model (Etzkowitz and Leydesdorff, 2000) and consider that greater commercial orientation may facilitate the absorption by local firms of knowledge produced by universities encouraging the latter to produce knowledge of commercial value (Di Gregorio and Shane, 2003), as well as to become directly involved 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).

An increasing number of studies examine the effect of universities on innovation or growth, while the impact of universities on firm productivity is rarely investigated. None of these studies refers to Italy. Nevertheless, empirical evidence documenting the disappointing performance of the Italian economy highlights the role of TFP as a key factor in the decline of labor productivity in Italy over recent decades. We contribute to this debate by assessing the role of universities in fostering the productivity of Italian firms, but we are aware that these issues could be of interest for many other European countries.

Overall, results show that universities do not seem to play a significant role in improving firm productivity. Universities matter only through the mediation of other actors.

Firstly, a local context is required in which the knowledge that the universities generate can be exploited: only where there is a dynamic industrial system, as in the North of Italy, can universities have a positive effect on firm productivity. This does not mean that universities may not be able to foster economic growth of weak economies. Indeed, publicly funded research could be crucial if we are to avoid increasing the divide between areas with different levels of development. That said, clearly other policies measures are also needed in order to improve the economic context and fully benefit from the positive influence of university research.

Secondly, local university spillovers are specific to certain industries: only for the specialised supplier sector does university research have a positive effect on productivity, while there is no effect for the science based sector, which, however, is the sector where the interaction between universities and industry should be greater. Our findings could reflect the Italian pattern

of specialisation that tends to be more concentrated in the machinery sector, the backbone of Italy's exports, rather than in the science based one. This result suggests a similar conclusion to the previous one: university-firm interactions are effective where sectors are able to exploit the opportunities that university research can offer.

Several robustness checks confirm these results. In particular, three robustness checks deserve more attention: the first regards the inclusion of an indicator of provincial firm agglomeration which confirms the positive results of university R&D obtained for Northern firms and, in addition, determines a positive and significant effect also for small firms, while the effect is never significant when we split the sample according to the Pavitt taxonomy. The second refers to the inclusion of another indicator of academic research, that is S&T researchers per employees in the restricted industry. In this case, the results confirm those obtained when university R&D is used. Finally, the inclusion of an indicator of the quality of university, positively affects the performance of all firms except medium-large enterprises and firms operating in the scale intensive or science based sector. University quality matters maybe because high-quality universities are likely to offer the most valuable resources and capabilities.

In a nutshell, despite the enthusiasm for university–industry links, we found that only a limited number of firms actually benefit from the presence of universities. The results do not imply that universities make no contribution to firm productivity, but rather suggest that their contribution is concentrated in certain specific geographical areas and in a few industrial sectors. Our results contribute to the ongoing discussion on the effectiveness of academic research to enhance firm performance and to stimulate economic growth. In that sense, they can provide information to policy makers on the context in which the transfer of knowledge from universities may be effective. Policies aimed at increasing knowledge transfer from universities to businesses have, up till now, been formulated without taking regional and sectorial policies into account. We believe, on the contrary, that it is necessary to redefine them considering the close interconnections between the different policies. Otherwise the risk is, on the one hand, to exclude certain areas and sectors from the benefits of university research and, on the other, to hold researchers to account for failings they are not responsible for. In other words, universities can carry out a complementary role, but cannot substitute policy actors at regional and sectoral level.

Appendices

Appendix A - A measure of TFP

The TFP used in this paper has been estimated in Aiello et al (2012). Before estimating the TFP, a data cleaning procedure on Unicredit-Capitalia database was carried out: firms with negative values of value added from the original archive and firms with a growth rate of value added and of employees below the first or above the ninety-ninth percentile of the distribution were eliminated. Finally, firms for which data regarding employees was not available for at least 7 years were also excluded. In order to compute the TFP at firm level, we first estimated the following log-linear specification of a production function by using Levinsohn and Petrin (2003) approach:

$$y_{it} = \beta_0 + \beta_K^{MAT} k_{it}^{MAT} + \beta_L l_{it} + u_{it} \quad [A1]$$

with $i = 1, \dots, N$ firms, $t = 1998, \dots, 2006$ and where y represents the value added, l the number of employees, k^{MAT} the stock of physical capital, β_0 measures the average efficiency and u_{it} represents the deviation of firm i from this average at time t . The error term can be decomposed into two parts:

$$u_{it} = \omega_{it} + \eta_{it} \quad [A2]$$

where the term ω_{it} represents the productivity of firm i at time t and η_{it} is a stochastic term which includes not only the measurement error, but also the shocks which are unobservable to firms, and, therefore, do not correlate with inputs.

Productivity ω_{it} is known to the firm which, therefore, in the case of positive shocks, can decide to increase production by raising the level of inputs. This determines a problem of simultaneity which Levinsohn and Petrin (2003) resolved by identifying, in the demand for intermediate goods, a proxy related to the variations in TFP known to firms.

Equation [A1] was estimated by utilizing as proxy for the stock of physical capital the tangible fixed assets and the demand for intermediate goods was measured by the operating costs. The value added has been deflated by using the ISTAT production price index available for each ATECO sector. As regards the tangible fixed assets, data 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. For the operating costs, we adopt the intermediate consumption deflator calculated by using data from ISTAT.

Appendix B

List and description of variables used in the empirical analysis

Variable	Description
ω	TFP in 2006
RD^{UNIV}	university research spending intensity in the same province in which the firm is located in 2004 (university R&D/Added Value)
S&T_ Researchers	ratio of professors and assistant professors in science and technology fields (S&T) to employees in the restricted industry in 2004
D_Small	dummy equal to one if the firm is small (less than 50 employees) and zero in the other cases
D_Pav	dummy equal to one if the firm is in the supplier dominated sector according to the Pavitt taxonomy
D_North	dummy equal to one if a firm is located in the North of Italy
D_Fam	dummy equal to one in the case of a family-owned firm
Int_assets	2005 intangible assets per employee (millions of euro)
lnCL	2005 cost of labour per employee as a proxy of labour quality (in log)
Regional RD^{UNIV}	university R&D intensity of the other provinces in the region in which each firm is located
Agglomeration	ratio of the number of firms in the restricted industry to population in the province in which each firm is located in 2004
Research performance	2001-2003 CIVR-VTR indicator

Table B.1 Descriptive statistics of variables used in the estimations.

Variable	Obs	Mean	Std. Dev.	Min	Max
ln ω	2828	6.65	0.495	4.07	8.90
RD^{UNIV}	3019	0.00	0.002	0	0.01
Int_assets	2824	0.01	0.157	0	6.48
lnCL	2921	10.41	0.672	6.59	15.88
D_Small	3019	0.57	0.496	0	1.00
D_Pav	3019	0.49	0.500	0	1.00
D_Fam	3019	0.62	0.486	0	1.00
D_North	3019	0.75	0.435	0	1.00

Table B.2 Correlation matrix between regressors included in the estimated models

	RD ^{UNIV}	Int_assets	lnCL	D_Small	D_Pav	D_Fam	D_North
RD ^{UNIV}	1						
Int_assets	-0.0095	1					
lnCL	0.0085	0.3058	1				
D_Small	-0.0104	0.0077	0.0728	1			
D_Pav	-0.0261	0.006	-0.1246	0.0274	1		
D_Fam	-0.0228	0.0018	-0.0172	0.0357	0.0346	1	
D_North	-0.3034	0.0045	0.0966	0.0045	-0.0946	-0.0028	1

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