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Short-term effects of new universities on regional innovation

Robin Cowan[1] Natalia Zinovyeva[2]

Abstract

This paper analyzes empirically the channels through which university research affects industry innovation. We examine how the opening of new science, medicine and engineering departments in Italy during 1985-2000 affected regional innovation systems. We find that creation of a new university department increased regional innovation activity 3-4 years later. On average, an opening of a new department in a region has led to a ten percent change in the number of patents filed by regional firms. Given that this effect occurs within the first half decade of the appearance of a new department, it cannot be ascribed to improvements in the quality and quantity of graduates. At the same time, traditional measures of academic research activity can explain only around 30 percent of this effect.

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1 Introduction

How to get more innovation out of a knowledge system is now at the forefront of the minds of European policy makers. In this vein it is often suggested that close interactions between government, industry and academia are necessary to promote innovations and knowledge flows. However, it is far from clear what form these interactions, in particular those involving universities, should take.

There are several mechanisms through which universities might spur regional innovation activity. First, university graduates might improve existing regional human capital. Second, universities might play a significant role in attracting financial resources into the region. Finally, university research itself might have spillovers on the regional innovation system either by bringing in new scientific knowledge or by facilitating the access to this knowledge through a wider research network of university inventors.

There is a debate in the literature on how universities' missions should be integrated into geographically local economic development, and whether there is a tension between universities' traditional missions, and the modern view that they can be engines of (local) innovation and growth. The "academic capitalism" model suggests that the university should participate actively in the market and use as an economic asset the property rights on its research outcomes (the MIT model). By contrast the "open science" model reflects the idea of a "knowledge-driven university". The advocates of this model suggest that there is a big difference between the contribution of university research to technical advance in industry and the involvement of university into commercial process (Foray, 2004).

With respect to the localization of knowledge diffusion, universities have long been considered important institutions both in national and regional innovation systems (Lundvall, 1992; Nelson, 1993; Saxenian, 1985; Saxenian, 1994; Jaffe, 1989). The regional component of university effects has been emphasized in recent policy decisions in many European countries concerning technology and knowledge transfer. Regional governments have now more autonomy in this regard and many regions support innovation policies promoting university-to-industry technology transfer activities. A specific manifestation is that universities are strongly encouraged to open technology transfer offices (TTO) that help professors patent their inventions and create spin-off companies that commercialize their innovations.

From the industry side the straight-forward benefits of the tight relationship with universities are advances in scope (some type of research would not be possible without university participation) and new opportunities for commercialization of the IPRs created through university research. However, if university participation in industrial innovation activity becomes strongly supported by government policies there is a risk that subsidizing of public research organizations would create significant distortion of competition and would crowd out private research. As David, Hall, and Toole (2000) put it for the case of all publicly funded research, "wherever publicly funded R&D is seen to be simply substituting for, or actually "crowding-out" private R&D investment, it obviously is hard to justify such expenditures on the grounds that they exerted an immediate net positive impact upon industrial innovation and productivity growth."

There is a broad empirical literature addressing the effect of university research on industrial innovation. However, identifying the causal link is highly problematic due to a variety of endogeneity concerns. For instance, those academics that are able to produce patents might self-select into highly innovative industrial districts. Alternatively, those academics that are located closer to industrial innovation centres might have more incentives to produce patents. In this paper we are able to use an unusual policy instrument to solve some of these identification issues.

This paper analyzes empirically the role of universities and academic research for regional innovation systems in Italy. Particularly, we study how the creation of new science, engineering and medicine departments during the period 1985-2000 affected both academic and industrial innovation activities in the corresponding geographical areas. The identification strategy relies on the fact that during the analyzed period there was a significant expansion in the supply of higher education and academic research in Italy. Many new universities and university departments were opened and, as was acknowledged by policy makers, the distribution of new departments across the regions was essentially independent of any features of the regional economy.

The paper focuses on the short-term effects of academic research for two reasons. First, it is likely that regional collaboration networks grow at the fastest speed in the first few years after opening of new university departments. Second, considering the short-run effect of universities allows us to identify the direct influence of academic research on innovation activity and to exclude other channels. In particular, the effects of an increased number of graduates in a region are likely to be very diffuse, and extremely difficult to capture econometrically. However, they will certainly only emerge 4 or 5 years after a department opens. Thus if there is any effect within the first half decade of the appearance of a new department, it cannot be ascribed to improvements in the quality and quantity of graduates.

Ultimately we are interested in the effects of university research on industrial innovation, and, following other results on the geographic "reach" of academic research, we do this at the regional level. We measure regions' innovation productivity by the number of patents registered in the European Patent Office by the applicants from each region and the importance of innovation output by the number of citations received by these patents. Our results suggest that there is a significant effect of the creation of new university departments on the regional research and innovation activity. The number of academic publications in international journals on average rises 3-4 years after opening of new departments. The number of patent applications made with the participation of university professors also seems to increase within two years from the creation of new departments. This evidence seems to correspond to the increased number of university professors in the region. In the following two years — in about 3-4 years after opening of new departments — the industrial patenting also increases. On average, one new university departments has led to a ten percent change in the number of patents filed by regional firms. At the same time, academic publishing and patenting activity can explain only around 30 percent of this effect.

The rest of the paper is organized as follows. Section 2 reviews the existent empirial findings concerning the role of academic research in innovation systems. Section 3 describes the the important aspects of Italian institutional background and the way in which the university expansion policy was implemented. Sections 4 and 5 introduce respectively the data and the methodology of the empirical analysis, the results of which are provided in Section 6. Finally, Section 7 concludes.

2 Background literature and hypotheses

Innovation systems studies, whether national or regional, have emphasized the importance of universities. (Lundvall, 1992; Nelson, 1993, Krugman, 1991; Cooke 1992; Storper, 1997). Many studies conclude that the success of such high technology concentrations such as those in Massachusetts and California would have been impossible without the technology transfer from universities in these areas (Saxenian, 1985; Saxenian 1994; Malecky, 1986). Jaffe (1989) tested whether there is an impact of university R&D on industrial R&D constrained geographically to state or smaller regions and found a significant positive effect.[1] Some studies analyzed the degree of the localization of knowledge diffusion considering the geography of patent citations. The overall conclusion in this respect is that geographical proximity matters for knowledge diffusion (Jaffe, Henderson and Trajtenberg, 1993).

There also exists a broad literature that discusses the potential mechanisms through which universities might spur regional innovation activity. First, university graduates might alter existing regional human capital (Malecki, 1986; Jaffe, 1989). In the presence of low pre- and post-educational mobility this mechanism is likely to have a strong effect. Second, universities might play a significant role in attracting financial resources into the region (Florax, 1992). The expenditures of faculty, staff and students might also affect local employment and production. Finally, university research itself might have spillover effects on the regional innovation system. It was claimed that knowledge — and especially it's tacit component — is spread via epistemic communities of local collaboration networks. From this perspective the university has a role in introducing new scientific knowledge or facilitating the access to knowledge by linking local communities to the global research network of university inventors. The effects of knowledge spillovers might be facilitated by technology transfer activities. For instance, industry might formally cooperate with academia in R&D. Alternatively, a university might license it's technology or provide consulting services. Universities may also create high-tech spin-off firms. Finally, universities might prompt industrial inventors to be more open to scientific knowledge. In this case the academic knowledge could be spread through more traditional academic channels such as seminars or (more measurably) scientific publications. In all of these scenarios, university research, through some channel, is seen as an input to industrial R&D.

University patenting is just one of the channels for knowledge transfer, and certainly currently one of the most discussed by researchers and policy makers.

[1] We should add, though that several studies could not confirm this finding (Feldman, 1994; Feldman and Florida, 1994).

The famous U.S. Bayh-Dole Act (1980) gave permission for universities to patent technology developed with federal funds. The underlying rationale was that this would speed up technology transfer. In Europe, as measured by ownership, university patenting has been always much lower than in the US. However, recently things seem to start changing. In many European universities it has become a normal practice to have technology transfer offices with their main task being motivating and helping university researchers to patent their inventions. Though, it does not mean that academics were not involved in technological innovation and patenting activity before. In many European countries - including Italy - university researchers in practice can own individually their patents and thus the information on university patenting is substantially distorted.[2]

Whether knowledge spillovers from university to industrial innovation exist or not is an important empirical question. Obviously, one might expect to find different spillover intensity in different institutional environments. In Europe in general academic researchers can retain full intellectual property rights, and so can fully appropriate the rents from their inventions. In principle this should provide stronger incentives to patent than do systems without professor-patent privilege. Practically, however, most academic patents (that is patents involving an academic inventor) in Europe are owned by firms. It is unclear whether these patents generate the same type of spillover effect as similar patents owned by universities. Presumably, university ownership might help to resolve one of the market failures of firm-owned patents, namely that a firm's most recent patent might cannibalize the rents of its previous patents (Aghion and Tirole, 1994). In any case, given that a patent is a means of knowledge disclosure, the spillover theory would predict the existence of some impact of academic participation in industrial innovation activity either on the amount or on the characteristics of industrial innovations.

The questions that we address in this paper are whether there exist short-run regional effects of universities. In addition, we ask whether these effects are to any extent due to technology transfer through university patenting; through downstream spillovers of academic research, or through increasing awareness of the relevance of academic research on the part of firms. Because "academic patents" tend to be owned by firms in Italy, academic and non-academic patents should have very similar effects on innovation performance. Any catalytic effect operating through academic patents does not operate through the peculiarities of ownership (as might be the case if universities owned the majority of academic patents) but rather through the peculiarities of academic inventors vis-a-vis their industrial counterparts. The effect could be through individual characteristics, or more likely, through their positions in knowledge or collaboration networks.

[2]Balconi, Breschi, and Lissoni (2003), drawing on the data of European patent applications, in which at least one academic professor was among the inventors, show that in 74% of cases the applicant is a private organization.

3 Italian institutional background

3.1 Expansion of the University System

During the 90's there was a significant expansion in the supply of higher education in Italy, many new universities and university departments were opened. But, as was acknowledged by policy makers, the distribution of new degrees across the regions occurred largely independently from regional labour market demands. In this regard, the Observatory for the evaluation of the university system in the Ministry of Education after analyzing the expansion of university system in the beginning of 90s concludes:

> The rules by which new institutions were created does not seem to have followed the logic of tailoring university development to territorial specificities. It seems not to have made reference to a demand for university education (that is, responding to the potential scope of use of the new initiatives), nor does it seem to have made reference to the demand for graduates (the formative needs of the country) or to existing infrastructure. In substance, no rigorous evaluations of the initiatives were done, either in absolute terms, or concerning compatibility with the rest of the system. The criterion actually favoured was geographical re-equilibrium, which aimed to bring the offer of university education and subjects near to the demand, ignoring not only the "real" size of this demand (which sometimes turned out to be less than the minimum requirements for the initiative to be efficient and effective), but also the importance of the transportation system, the receptive capacity of the population of students and students' financial support in determining access to university establishments. So, [...] at least to a large extent, the prevalent logic was the one of incremental expansion and distribution "by drops of rain", without giving evaluation opportunity to the suppressed initiatives [...]. (p.3, Verifica dei piani di sviluppo dell'universita 1986-90 e 1991-93, Osservatorio per la valutazione del sistema universitario, MURST, 1997; authors' translation).

Around 130 new university departments (66 of which are in sciences, medicine and engineering) were opened for enrolment between 1985 and 2001 (see Figure 1). In most cases the new departments were opened within previously existing universities, but in several of these cases the new departments were located in the towns different from the location of the main university campus. With time some of these departments were given the status of an independent university (i.e. University of Eastern Piedmont was founded in 1998 on the basis of departments of University of Turin located in Vercelli, Alessandria and Novara). In a few cases the new universities have appeared as a result of the split of overcrowded universities in big megalopolises (i.e. University of Rome III was founded in 1992 simply taking part of the staff from University of Rome *La Sapienza*). There are very few examples of opening completely new universities from scratch (one such is the University of Teramo founded in 1993).

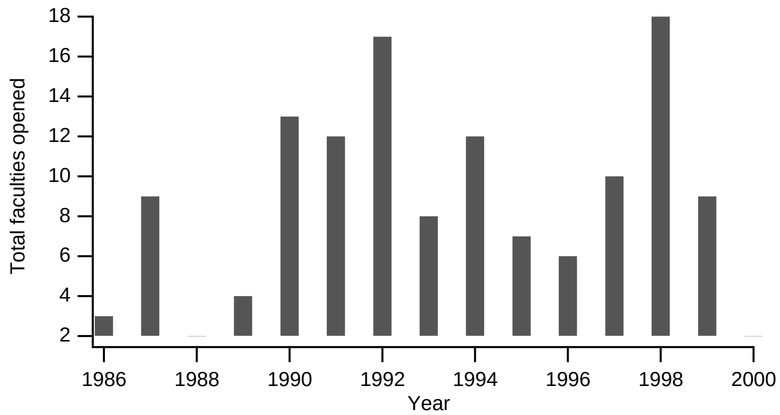

Figure 1: Number of new university departments, 1985-2000

As was suggested by MURST, quoted above, the correlation between the occurrence of opening of new university departments in specific disciplines and any measure of regional development of the corresponding economic sectors appears to be very low. Similarly, the opening of new departments does not seem to be related to the demand for certain type of professions. Using data from the survey on Italian graduates of 1992 run three years after their graduation, we constructed the ratio of the number of 1992 graduates working in a particular discipline in a region in 1995 to the number of graduates in this discipline that were produced by that region.[3] A ratio larger than 1 implies that the region is importing graduates in a particular discipline and could thus perhaps benefit from the creation of a faculty in that discipline. If faculty creation is in response to labour market mismatch, then there should be a positive correlation between faculty creation and this labour market mismatch. The correlation between this measure and the number of new departments in a corresponding discipline in a region is on aggregate -0.055, and varies across disciplines between -0.511 (in Architecture) and 0.349 (in Chemistry and Pharmacy). This lack of correlation in general is visible in Figure 2. Again, this is consistent with the MURST analogy between department creation and drops of rain.

3.2 Public and Private R&D: state and regional policies

Promotion of applied research in Italy until very recently had been under the full responsibility of the State. Science and technological policy received a strong impetus in 1989 when the Ministry of Universities and Scientific and Technological

[3]The data come from the the survey run each 3 years by the Italian National Statistical Bureau (ISTAT). It covers the information concerning graduates' university-to-work transition. The data are accessible in ISTATA ADELE Laboratory in Rome. The description of the data could be found in Bagues, Sylos Labini, Zinovyeva (2007).

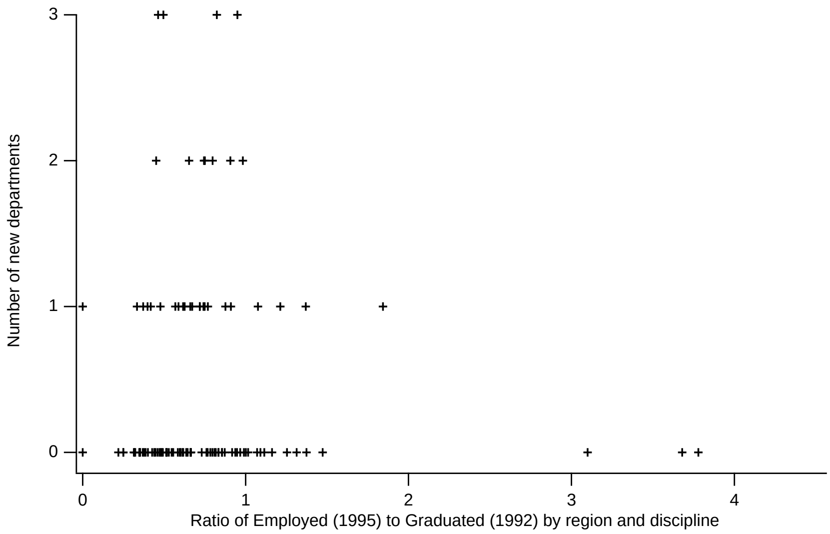

Figure 2: Number of new departments open between 1984 and 2000 by regional demand for corresponding professions

Research (MURST) was created. However, even after creation of MURST until almost 1998 there was neither a clear model for the development of the national innovation system, nor a system of coordination and control for the policies undertaken. One of the biggest projects of MURST was development of science and technology parks, which were opened during the 90's across all Italian regions. At the same time, regional governments were only able to influence innovation activity by the way they implemented specific decisions taken at the national level. Thus even though the national policy was somewhat chaotic, regional governments were very restricted in their abilities to implement policies either to respond to the national initiatives, or simply to attempt to improve regional performance per se. Nonetheless, several regions have attempted to develop legislation dedicated specifically to interventions concerning innovations and technology transfer: Abruzzo (1991), the province of Bolzano (1992), Valle D'Aosta (1992), Lombardy (1993), Campania (1994), Emilia Romania (1994) and Veneto (1997).

Only in 1997 with law l.59/97 have regions been permitted to initiate policies concerning innovation and technology transfer programs. However, the law has left the national State in complete control of scientific research, secondary and tertiary education. Moreover, the State has maintained it's right to impose the criteria for the distribution of funds and to control the amount of regional funding spent on innovation policies. This situation has been partially changed since 2001 when regional responsibility concerning scientific and applied research was substantially increased, though still leaving in State competence 75 percent of resources.

The important observation with regard to our study is that any effects of the creation of a new university in a region are thus for the most part due to the university itself, rather than to regional policies aimed either at attracting new faculties (to respond to employment mis-matches or industrial needs for example) or to regional responses (in terms of science and innovation policy) aimed at taking advantage of the (serendipitous) arrival of new academic research.

4 Data

The present empirical analysis is performed using Italian data at the regional level. The database includes characteristics of the university system, indicators of industrial and academic innovation activity, information about regional initiatives concerning innovations and technology transfer and economic indicators observed for 20 Italian regions between 1985 and 2000. The descriptive statistics for the main variables could be found in Table 1.

Our main indicator of the intensity of academic research in the region is the number of university departments in science, medicine and engineering. We consider the year when students for the first time were enrolled to the degree program of the department as the date of the creation of this department. Information about the number of first-year students at the department level was obtained from different issues of the Italian National Statistical Bureau bulletins *La universita in cifre* and *Lo Stato dell'Universita*. Those departments that were created while splitting the megalopolis universities are not considered as new.

The newly opened departments were of very different size. The size of the enrolment for the first year courses in newly opened departments varied from 14 to 624 students depending on the size of the region and the demand for higher education. The number of professors has also varied significantly across the departments. However, the data on the academic staff are not available prior to 1996. Therefore we restrict our attention to the number of university departments. The information on the amounts of funding received yearly by universities from the Ministry of Education was also collected.

We measure regions' innovation productivity by the number of patents registered in the European Patent Office by the applicants from each region and the importance of innovation output - by the number of citations received by these patents. We use the number of non-patent literature citations done by local patents as a proxy or the general awareness within the local industry about the advances of scientific research.[4] The academic research output is measured with the use of KEINS data on academic patenting (Lissoni, Sanditov and Tarasconi, 2006). In contrast to the US case, in Italy up to now universities generally were not preserving the property rights on inventions done by their researchers. Often " IPRs over inventions derived from sponsored research programmes were left to the sponsors" (see Balconi, Breschi, and Lissoni (2002)). This has made it difficult to attach patenting activity to university research. However, the KEINS EP-INV database matches by name and surname all EPO applications, reclassified by applicant and inventor, with a list of university professors. Thanks to this methodology, the KEINS database includes not only any patent owned by universities, but also all patents that originate from university scientists, whether they are owned by

[4]Note that the number of NPL citations refers to the total NPL citations done by local patents irrespectively of the origin of the cited source.

business companies, public research organizations, or the scientists themselves.[5]

Finally, the number of publications in journals that are listed in Science Citation Index (SCI) is used to measure the scientific productivity of regions.[6] At the same time, the extent to which technological innovations rely on scientific knowledge is measured by patents propensity to cite non-patent literature (NPL).

5 Methodology

Identifying the effect of universities on regional characteristics is problematic due to variety of endogeneity issues. Most evidently, the faculties might be created in response to local labour market or industrial conditions. However, the MURST evaluation argues that this was not the case in Italy, so from that point of view faculty creation can be considered exogenous with regard to industrial innovation activity. Taking advantage of this "natural experiment", we analyze how the creation of new science, engineering and medicine departments during this period affected both academic and industrial innovation activities in the corresponding geographical areas.

First, we consider correlations between the number of university departments in the region on the one hand and the number of patents produced by regional industry and the number of citations received by these patents on the other hand. In order to rule out major size and time effects we condition these correlations on regional population and year dummies.

One might expect that the effect of the opening of a new department takes some time to realize. We analyze whether the increase in industrial patenting is observed 3-4 years after a new department is opened in a region:

$$E(\Delta \log p_{it} | \Delta U_{it}, \Delta U_{i,t-1}, ..., \Delta \mathbf{s_{it}}, \Delta \mathbf{s_{i,t-1}}, ..., t) = \sum_{\tau=0}^{4} (\beta_\tau \Delta \log U_{i,t-\tau}) + \sum_{\tau=0}^{4} (\gamma'_\tau \Delta \mathbf{s_{i,t-\tau}}) + \alpha_t \quad (1)$$

where p_{it} is the number of patent applications made by inventors from region i in year t, U_{it} is the number of university departments present in region i in year t and $\mathbf{s_{it}}$ includes observable regional characteristics, namely, population and GDP. Note that exploiting the time dimension of the data in equation (1) allows us to control for regional time-invariant unobserved heterogeneity.

Equation 1 does not take into account the count nature of the dependent variable.[7] Therefore we proceed by estimating conditional negative binomial model —

[5] More precisely, the database includes all patent applications that passed a preliminary examination in the EPO. The assigned date of the patent is the priority date, which is the date of the first filing world-wide.

[6] The Thomson ISI data on publications was obtained for 1985-1994 from the National Science Indicators on Diskette (NSIOD) purchased by MERIT and for 1995-1999 from the Conference of Italian University Rectors (CRUI) aggregated data (Breno et al., 2002)

[7] Unlike the classical regression model, in this case the dependent variable is distributed in such a way that probability mass is placed at nonnegative integer values only.

the methodology proposed by Hall, Griliches, and Hausman (1986) and designed for panel data with count dependent variables:

$$E(p_{it}|U_{i,t-1}, U_{i,t-2}, ..., \mathbf{s_{i,t-1}}, \mathbf{s_{i,t-2}}, ..., t) = \\ \exp(\sum_{\tau}(\beta_{\tau} \log U_{i,t-\tau}) + \sum_{\tau}(\gamma_{\tau}' \mathbf{s_{i,t-\tau}}) + \alpha_t) \quad (2)$$

Similarly to the model of equation 1, conditional negative binomial permits taking into account firms' time-invariant unobserved heterogeneity that might be correlated with university supply.

Note that estimation of the lag structure without controlling for permanent differences might produce biased estimates if these differences are correlated with the variables measuring university research outcomes. In particular, such estimation might produce a large coefficient of the last lag which could be explained by the correlation of the last university creation variable with earlier research outcomes. In this respect Hall, Griliches, and Hausman (1986) demonstrate that conditional negative binomial is better fit to deal with the lag truncation bias than other models.

We exclude contemporaneous effects of opening new university departments on patenting as we would not expect the effect to occur instantaneously. Additionally, inclusion of the contemporaneous effects could lead to inconsistent estimates if there remain some unobserved time-variant sources of endogeneity.

Inclusion of several lags of the number of departments might result in multicollinearity problem, because the independent variables will tend to be highly correlated. In this situation it is difficult to identify the impact of each particular lag on the dependent variable. This problem could be especially serious if the time structure of the analyzed effect is not clear-cut or the lag length chosen in the model is shorter than the relevant one. We would expect the effect of new departments to be quite inertial and therefore we define the lag length t to be equal to 2 years.

In addition to the effect of universities on industrial patenting, we also analyze the effect of university presence on other measures of academic and industrial innovation activity estimating models similar to the one described by equation (2).

Finally, we attempt to decompose the apparent effect of new faculties on regional industrial innovation into various constituent parts. We proceed using the following logic. Having constructed the data so as to avoid the effect of graduates changing the composition of the labour force, we postulate three "indirect" channels through which a university might affect industrial R&D: basic research is used as building blocks for industrial innovation; applied R&D in universities spurs industrial innovation; and spillovers through which industry is brought into closer contact with academic research generally, through the broader networks of academic researchers. These, incidentally, are the channels towards which policymakers have directed their attention, in their attempts to bring universities and industry "closer together". Operationally, the first channel should be visible through the effect of academic publications on industrial patents; the second through effects of academic patents on industrial patents; and the third through an observed increase in the citations by industrial patents of non-patent literature. If, controlling for these indirect channels we still observe a significant direct effect of universities on industrial patenting, we might conclude that there is something beyond the effects on which policy-makers have been focusing.

Note that while university activity might induce industrial activity, the reverse could also be true. An active industrial R&D sector could have spillover effects inducing university activity, perhaps directly as industry seeks partners, or through some less direct, spillover mechanism. The simple expedient of using a lag structure to determine which causal direction being measured is tricky here, since there is a lag between industrial activity and our measure of it, namely patenting. This suggests that estimates of the strength of any of these indirect channels from university to industry may well be overestimates. Of course this further implies that the "residual" estimate of any direct channel will be an underestimate.

Finally, it is important to make one technical notice about the citation data that we employ for our analysis. Naturally, citations are subject to a truncation bias since the number of citations any patent receives grows with time, and our data include citations received only until 2004 independently of when exactly the corresponding patent applications were done.[8] We employ the method for the correction of the truncation bias proposed by Hall, Jaffe, and Trajtenberg (2000) in the version where the diffusion process is assumed to have the same shape in all technological sectors. Figure 3 shows the evolution of the number of patents, patent citations and corrected citations in industrial and academic sectors. Patents, both industrial and academic, and citations to them grew steadily over the period.

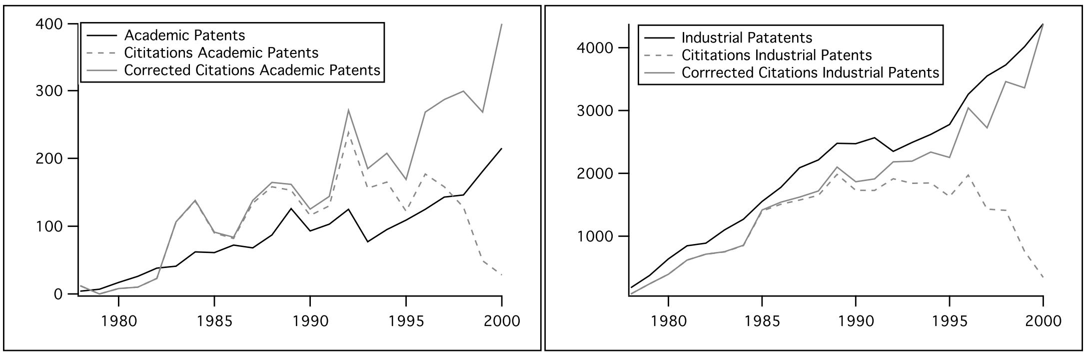

Figure 3: Evolution of academic (left panel) and industrial (right panel) innovation outcomes, 1985-2000

[8]More precisely, citation variables count the number of citations received by regional patents from all Italian patents until 2004.

6 Empirical results

Table 2 presents the correlation coefficients calculated for the residuals obtained from the regressions of various measures of innovation activity on year dummies and regional population. This was done to rule out major size and time effects. Not surprisingly, industrial patents, university patents, and citations of them are all strongly positively correlated. This means that regions that have active innovation systems produce relatively more of both industrial and university patenting. The number of university departments in the regions is positively and significantly associated with the measures of academic research productivity (the number of patents and publications) and positively — though insignificantly — correlated with the measures of industrial innovation. This might suggest that the opening of new university departments might increase academic research and innovation output, but would not provide significant instantaneous effects on industrial innovation.

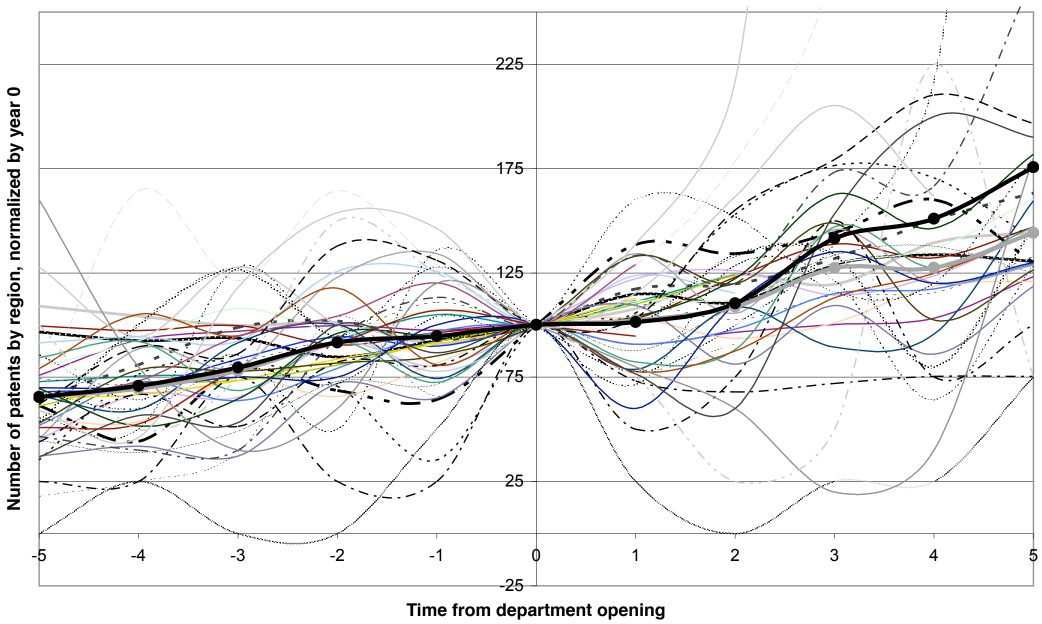

Figure 4: Evolution of regional industrial patenting around the date of the creation of a new department

The points in the graph represent the evolution of the number of industrial patents produced by each region in a period of 10 years — 5 years before and 5 years after the opening of a new department. The number of patents is normalized to the number of patent application done at the year when a new department was opened. On the abscissa the number of years to and from the opening of a department is indicated. The number of times that each region is represented on the graph corresponds to the number of departments opened between 1985-2000 in this region. The thick black curve represents the mean trajectory. The grey thick curve indicates the mean trajectory calculated after exclusion of one lower and four upper outlying observations.

Figure 4 presents the prima facie case that universities contribute to industrial innovation activities with a lag of several years. For each new faculty opened, we plot the number of patents in that region for a ten year interval, centred around the year in which the faculty is opened. Numbers of patents are normalized by the number in the year in which the faculty was opened. The thick black curve represents the year-by-year mean. We make two observations about this figure. First, the series are very noisy; patent numbers change a lot from year to year. The striking visual manifestation is driven in part, though, by the fact that some regions, i.e. Abbruzzo, Camerino, Trentino, Sicily, have very few patents, and a change by a small number of patents can produce a dramatic change proportionally. The second observation is that there does seem to be an effect of opening a new faculty. Roughly three years after faculties open we can see an increase relative to the trend in the number of patents in a region. We also show the mean calculated after excluding the five observations corresponding to regions that go "off the scale" at the right hand edge of the figure, in a thick grey curve. Even excluding the effects of these outliers (which may or may not be artefacts) we can still observe an effect.

Table 3 presents the estimation results for equation (1) and confirms that the visual step-wise positive effect of new university departments on industrial innovation with a lag of three years is statistically significant.[9] Numerically, one percent increase of the number of university departments in a region results in about one percent increase in the number of patent applications filed by firms of this region three years later. Given that on average there are about 9 university departments per region (see Table 1), it means that a new department in a region on average leads to a more than ten percent increase in the number of industrial patents three years later.

In order to take into account the discrete nature of the dependent variable we estimate the conditional negative binomial model described by equation (2). The corresponding estimates are presented in Table 4. Once again, the effect of new departments on the amount of regional patents could be observed with a lag of 3-4 years (Column 1-3). This effect seems to be fully driven by an increase in industrial patenting (Columns 7-9).[10] Academic patenting increases only insignificantly 1-2 years after opening of new departments; that the effect on academic patenting is faster than the effect on university patenting would not be surprising, though the absence of a significant effect is. The quality of both academic and industrial regional patents — as measured by the total number of received citations per patent — does not seem to be affected by the presence of universities in the short run (Table 5). Overall, as concerns innovation activity our results suggest that university presence may induce industrial R&D, but so far says nothing about the channel through which it happens.

Apart from academic innovation activity, the positive effect of universities on

[9]Note that estimation of equation (1) on a sample without outliers detected on Figure 4 produces statistically similar results.

[10]This result is robust to different model specifications: considering logarithmic estimation model instead of the negative binomial, substituting the number of university departments with the number of university departments per capita, etc.

industrial innovation might be explained by the catalyzing role of the scientific knowledge in-flow into the region. Naturally, the assumption here is that there exists a positive impulse of the number of university departments on regional scientific production. In fact, as Table 6 shows, the number of academic publications increases significantly when new departments are opened in the region. The above effect could be observed with a lag of 3-4 years. However, it is important to remember that the period between the submission of a paper and the date when it eventually gets published varies across journals and scientific disciplines and in many cases approaches 2 years. Therefore we can conclude that the positive effect of university presence on the amount of scientific research could be observed already after 1 or 2 years.

Before moving on to the analysis of how much academic scientific and innovation activity explains the overall impact of universities on the amount of industrial innovation, we examine the impact of university presence in the region on the propensity of industrial patents to cite scientific literature. Proximity to university could raise awareness within the local industry that academic basic science may be a useful source of knowledge. If this happens, we might expect to see an increase of non-patent literature (NPL) citations done by industrial patents.

Contrary to the above hypothesis, Table 7 suggests that the propensity of industrial patents to cite non-patent literature does not increase and actually tends to decrease significantly in the short-run after opening new departments.[11] Most likely this effect reflects the deep change in the collaboration pattern between the industry and the university when the degree of proximity between them increases. One explanation may be that from the point of view of industrial research, reading academic literature and face-to-face contact with academics are substitutes. If this is so, then with regard to NPL-citation, the appearance of a new university should have a greater impact on industrial patents than it does on academic patents (since the former will now be able to make the substitution, whereas the latter already have). While this is consistent with the results presented in Table 7, it is not clear how much faith to have in it as an explanation. Of course, more evidence is needed to understand this relationship. In any case, given that the propensity to cite non-patent literature might reflect the reactiveness of a region towards expansion of the university system and the degree of generality of regional technologies, we use this measure as a control in the following analysis.

Finally, we disentangle the channels through which the quantity of industrial patents is affected by university creation. Table 8 summarizes the evidence concerning this question. The analysis presented in this Table is based on the following logic. Given that (conditional on regional size, growth and time-invariant characteristics) the decisions about opening new departments were done almost randomly (see Section 3), the positive significant coefficient in the regression of the number of new university departments on industrial patenting signals the existence and magnitude of the causal relationship between the two variables. By contrast, the positive coefficients of other measures of research activity (like scientific publica-

[11]Note that it does not mean that the overall quantity of NPL citations drops after the new departments are introduced, because the total number of industiral patents also tends to increase.

tions, academic patenting, etc.) just provide evidence on the association between the variables, but do not give any clear conclusion on the direction of the effect. However, if the inclusion of these measures into the estimation model reduces significantly the size of the coefficient for new university departments, than we can claim that the underlying processes represents one of the channels through which university affects regional innovation.

Column 1 of Table 8 duplicates Column 8 of Table 4.[12] It provides the baseline effect of universities on industrial patenting. In the paragraphs that follow, we ask how much of that effect is attributable to the different channels we have identified.

From Table 8 we immediately observe two things. First, the effect of R&D spending is strong and robust: industrial patenting responds positively to local R&D spending. Introducing R&D also reduces the estimated effect of universities on industrial patenting 3-4 years later by roughly 16 percent. This suggests that new universities in fact attract new public funds for research and prompt the industrial sector to invest more in R&D. Second, after correcting for the effects of local R&D, the effect of university activity with a 3 to 4 year lag is also robust. Regardless of the specification, the coefficient on number of university departments (lagged 3-4 years) is statistically significant, and stays between 0.350 and 0.565. By examining separately each of the columns of Table 8, we can analyze individually the effects of each of the proposed channels.

Academic patents appear to be significantly positively correlated with the number of industrial patents (Column 3). Including them as an identified channel of effect of universities on industrial innovation, (Column 4) we see that they do appear to be active: including them decreases the coefficient for new departments from 0.496 to 0.411 (Column 4 versus Column 2). Nonetheless, the "unexplained" part of the university effect remains substantial.

An increase in academic scientific research activity — as measured by the number of publications in refereed journals — also explains part of the effect and the coefficient for new departments decreases to 0.454. This direct measurement suggests that the effect of publications is smaller than the effect of academic patents.

Comparing Columns 2 and 9, we can see that together, academic patenting and publication activity explain only about 30 percent of the university effect. This implies that a larger part of the mere presence of universities in a region can not be accounted for by conventional channels.

In principle different regions might have very different potential to take advantage of a university presence. Certainly some of this potential is derived through variables for which we control directly, such as regional GDP and R&D spendings. However, there could be other factors such as the industrial structure of the region, but also of the technological profile of the region and the potential of dominant technologies to take advantage of science-based research. We can control for any time-invariant part of these factors by including regional fixed effects. As a way to control for at least part of the time-varying effects we include, in columns 7

[12]Column 8 does not include the 1-2 year lagged effect of univeristies as it is not found to be significant. Including this effect in what follows changes coefficients only insignificantly, and does not change the overall message.

and 8, the number of non-patent-literature citations made by regional patents. Comparing Columns 8 and 10 of Table 8 we find that academic publication and patenting again account for about 30 percent of the observed effect of universities on regional innovation performance. If we treat non-patent literature as a channel of influence instead of as a control, we compare Columns 2 and 10. Here we see that the three channels jointly account for about 15 percent of the total effect.The statistical explanation for this curious decrease in the explained part of the effect when controlling for the propensity to cite scientific literature by regional industrial patents result is the negative correlation between universities and NPL citation. As we discussed above, a more intuitive explanation remains elusive.

7 Conclusions

It is often suggested that close interactions between government, industry and academia are necessary to promote innovations and knowledge flows. Recently many regions in Europe begun to support innovation policies aimed at promoting university-to-industry technology transfer activities. Technology transfer offices, encouraging professors to patent their inventions and providing support for spin-offs are all present to a greater and greater degree, throughout the industrialized world.

In this paper we focus on the economic effects of universities, and in particular on their effects on innovation. It is strongly believed that the presence of a university in a region would be beneficial for industrial innovation activity. But how is this benefit created? Marshall might suggest that it arises simply from the agglomeration of agents pursuing related activities; Mike Lazaridis[13] asserts that it arises through the production of highly trained graduates; writers of the Bayh-Dole act assert that it comes from controlled technology transfer through academic patenting.

In this paper we have taken advantage of certain features of university system expansion in Italy during the 80's and 90's to attempt to identify some of these different channels. Specifically, according to ex post evaluation of the expansion programmes, university departments were created "like rain", independently of underlying economic features of the regions. This experiment permits a nice way out of standard endogeneity problems.

Our first result indicates that there is indeed a significant effect of the creation of new university departments on the regional innovation activity. In response industrial patenting activity in the region increases quite significantly with a 3 to 4 year lag.

One curious finding is the negsative correlation between the presence of universities and the citation of non-patent-literature by industrial patents. One possible explanation is a substitution —in the absence of a university, industry devotes resources to searching the academic literature for valuable results. A nearby university permits industry to find these results through face-to-face contacts with

[13]Founder and CEO of Research in Motion, maker of the Blackberry.

academic researchers. While this may be a positive effect in the short run, the long run effect remains unclear as it may seduce industry into ignoring its continued development of absorptive capacity.

The gross short term effect of a university in a region can be decomposed into several channels of influence. We have constructed our analysis to exclude the channel corresponding to quality and quantity of university graduates, and have looked at the direct effects of both applied and basic academic research. What we find that at maximum roughly 30 percent of the overall university effect on industrial innovation can be attributed to these channels. From this analysis we must conclude that in the short and medium term, there is a lot more to technology or knowledge transfer than industry picking up knowledge created by universities, and turning it into new products or processes. Perhaps Marshall was right, and that a big part of the effect of a university is to create something "in the air".

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Table 1: **Descriptive statistics**

	Period	Mean	Std. dev.	Min	Max
Number of regions		20			
Population	1985-2000	2838176	2225958	112498	8971154
GDP	1985-2000	39325.97	35568.22	1342.467	208075.6
University departments	1985-2000	8.728	5.405	0	24
New departments per year	1986-2000	0.163	0.413	0	2
Academic patents	1985-2000	5.7	9.395	0	75
Citations of academic patents	1985-2000	10.156	21.218	0	149
Publications	1985-1999	968.263	1022.941	0	5214
Industrial patents	1985-2000	138.506	235.17	0	1474
Citations of industrial patents	1985-2000	119.103	229.576	0	1733
Non-patent literature (NPL) citations	1985-2000	101.356	213.486	0	1309

Notes: The number of academic and industrial patent citations is corrected for truncation bias.

Table 2: **Conditional correlations between the measures of innovation outcomes**

	Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1)	Number of departments	1								
(2)	Number of industrial patents	0.086	1							
		(0.124)								
(3)	Number of academic patents	0.156	0.512	1						
		(0.005)	(0.000)							
(4)	Citations of industrial patents	0.076	0.896	0.507	1					
		(0.176)	(0.000)	(0.000)						
(5)	Citations of academic patents	0.010	0.548	0.612	0.570	1				
		(0.865)	(0.000)	(0.000)	(0.000)					
(6)	Corrected citations of industrial patents	0.085	0.921	0.511	0.987	0.554	1			
		(0.130)	(0.000)	(0.000)	(0.000)	(0.000)				
(7)	Corrected citations of academic patents	0.022	0.565	0.652	0.561	0.956	0.568	1		
		(0.690)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)			
(8)	Number of university publications	0.564	0.374	0.175	0.262	0.104	0.278	0.113	1	
		(0.000)	(0.000)	(0.000)	(0.000)	(0.072)	(0.000)	(0.051)		
(9)	Non-patent literature citations	0.062	0.718	0.528	0.658	0.603	0.679	0.633	0.259	1
		(0.268)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	

Notes: P-values in parentheses. Number of observations - 320. Corrected citations stand for the numnber of citations corrected for truncation bias. The Table shows the correlation coefficients between the residuals from regressions of the logarithms of variables on the year dummies and the logarithm of regional population.

Table 3: **Annual change in the number of industrial patents**

Δ Log University Departments, t	0.149
	(0.557)
Δ Log University Departments, t-1	-0.870
	(0.572)
Δ Log University Departments, t-2	-0.071
	(0.579)
Δ Log University Departments, t-3	0.973**
	(0.420)
Δ Log University Departments, t-4	-0.349
	(0.382)
Δ Log Population, t, t-1, t-2, t-3, t-4	Yes
Δ Log GDP, t, t-1, t-2, t-3, t-4	Yes
Year dummies	Yes
N	220

Notes: * p-value<0.100, ** p-value<0.050, *** p-value<0.010.

Table 4: **Number of patents**

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Total	Total	Total	Academic	Academic	Academic	Industrial	Industrial	Industrial
Log University Departments,	0.102		-0.415*	0.547		-0.012	0.143		-0.356
t-1 and t-2	(0.209)		(0.248)	(0.553)		(0.807)	(0.209)		(0.245)
Log University Departments,		0.577**	0.780***		0.347	0.231		0.573**	0.747***
t-3 and t-4		(0.225)	(0.262)		(0.587)	(0.771)		(0.227)	(0.261)
Log Population, t-1, t-2, t-3, t-4	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Log GDP, t-1, t-2, t-3, t-4	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	280	240	240	238	204	204	280	240	240

Notes: * p-value<0.100, ** p-value<0.050, *** p-value<0.010.

Table 5: **Citations per patent**

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Total	Total	Total	Academic	Academic	Academic	Industrial	Industrial	Industrial
Log University Departments,	0.081		-0.123	-0.104		-0.635	0.016		-0.110
t-1 and t-2	(0.228)		(0.392)	(0.217)		(1.345)	(0.232)		(0.420)
Log University Departments,		-0.157	-0.109		-0.153	0.093		-0.224	-0.181
t-3 and t-4		(0.247)	(0.290)		(0.286)	(1.017)		(0.265)	(0.311)
Log Population, t-1, t-2, t-3, t-4	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Log GDP, t-1, t-2, t-3, t-4	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	280	240	240	238	204	204	280	240	240

Notes: * p-value<0.100, ** p-value<0.050, *** p-value<0.010.

Table 6: **Academic publications**

	(1)	(2)	(3)
Log University Departments, t-1 and t-2	0.113		-0.129
	(0.087)		(0.121)
Log University Departments, t-3 and t-4		0.190**	0.310***
		(0.083)	(0.106)
Log Population, t-1, t-2, t-3, t-4	Yes	Yes	Yes
Log GDP, t-1, t-2, t-3, t-4	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes
N	247	209	209

Notes: * p-value<0.100, ** p-value<0.050, *** p-value<0.010.

Table 7: **Non-patent literature citation intensity**

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Type of patents:								
	All	All	All	Academic	Academic	Academic	Industrial	Industrial	Industrial
Log University Departments,	-0.605		-0.716	-1.899		-1.755	-0.842**		-1.126*
t-1 and t-2	(0.416)		(0.737)	(2.007)		(3.624)	(0.347)		(0.647)
Log University Departments,		-0.921**	-0.644		-3.416	-2.738		-0.742*	-0.307
t-3 and t-4		(0.465)	(0.545)		(2.282)	(2.682)		(0.410)	(0.478)
Log Population, t-1, t-2, t-3, t-4	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Log GDP, t-1, t-2, t-3, t-4	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	280	240	240	266	228	228	280	240	240

Notes: * p-value<0.100, ** p-value<0.050, *** p-value<0.010.

Table 8: **The channels of the university effect on medium-term industrial patenting**

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Log University Departments,	0.573**	0.496**		0.411**		0.454**		0.565***	0.350**	0.413**
t-3 and t-4	(0.227)	(0.245)		(0.200)		(0.214)		(0.284)	(0.209)	(0.190)
Log Academic patents,			0.084***	0.076**					0.082**	0.080**
t-1 and t-2			(0.032)	(0.034)					(0.035)	(0.033)
Log Academic patents,			-0.010	-0.012					-0.013	-0.003
t-3 and t-4			(0.030)	(0.031)					(0.032)	(0.029)
Log Academic Publications,					-0.215	-0.185			-0.277	-0.224
t-1 and t-2					(0.185)	(0.184)			(0.187)	(0.191)
Log Academic Publications,					0.347**	0.304**			0.334**	0.305**
t-3 and t-4					(0.148)	(0.147)			(0.146)	(0.148)
Log NPL citations in industrial							0.118***	0.129***		0.121***
patents, t-1 and t-2							(0.028)	(0.028)		(0.027)
Log NPL citations in industrial							0.062**	0.055**		0.056**
patents, t-3 and t-4							(0.025)	(0.025)		(0.025)
Log Regional R&D†		0.145***	0.140***	0.142***	0.132***	0.134***	0.125***	0.123***	0.132***	0.111***
		(0.033)	(0.031)	(0.032)	(0.033)	(0.034)	(0.030)	(0.030)	(0.033)	(0.030)
Log Population, t-1, t-2, t-3, t-4	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Log GDP, t-1, t-2, t-3, t-4	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	240	240	240	240	240	240	240	240	240	240

Notes: * p-value<0.100, ** p-value<0.050, *** p-value<0.010. †Other lags of R&D investment are not significant and this is largely consistent with previous findings (Hall, Griliches, Hausman, 1986)

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