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Variables Influencing Industrial Funding of Academic Research in Italy. An empirical analysis

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1. Introduction

In recent years, the debate on industry – university relations has been a crucial issue in regional, as well as in science & technology and industrial policy. Universities have become to be considered as key agents in the promotion of economic growth and in the transition to new knowledge-based economic activities both at the regional and national level.

Policies of various kind have been implemented to favour closer links between academia and industry. In particular, emphasis has been attributed to the need of developing incentives and organisational structures for enhancing such links. In Europe, (and especially in Continental Europe), a doctrine – known as the "European Paradox" has become extremely influential, and it has also been made official through the publication by the European Commission in 1994 of the White Book on Innovation (CEC, 1994): that is to say, Europe produces research comparable to the American one, but it is unable to translate such research into successful technological innovation.

Thus, an enormous variety of initiatives has been launched with the explicit aim to favour applied research as opposed to basic research, to strengthen the so-called "technology transfer", to promote the so-called "entrepreneurial university". These initiatives have typically involved the creation of science and technology parks, technology transfer offices, incubators, etc. - as well as, in some instances, a cut in public funds to academic research and above all their restructuring towards forms of contractual funding (Geuna, 2001). Moreover, universities and individual academic researchers have been encouraged to seek industrial funding and to patent the results of their research activities.

As known, the results of these efforts are mixed under every respect. Besides some success stories, in many other instances these experiences have not (yet?) delivered the expected outcomes.

In this paper, we begin to investigate the relevance of some possible factors influencing the intensity of university – industry relations, in the specific case of Italy[1]. Specifically, we focus on (proxies of) industrial funding to academic research and try to identify some variables that make it more likely for academic institutions to attract funding from industrial sources. Simple as the question and especially our exercise might be, we are not aware of many other studies taking the same perspective, at least as European countries are concerned.

Our analysis is conducted at the level of the individual departments or institutes and it is based on a unique database provided by the Conference of the Rectors of the Italian Universities (CRUI) for the academic years 1992-93, 1993-94 and 1994-95. This database, however, while providing invaluable – and otherwise unavailable - information on Italian universities at a highly disaggregated level , constrains the choice of the specification of our equations to only a small subset of the potentially relevant variables. Yet, once again we are not aware of systematic studies conducted at this level of disaggregation, the typical units of analysis usually take being either universities as a whole or individual researchers.

Given all the limitations of this exercise, we still believe that the results can be useful both for the policy debate and for more theoretical issues. Indeed, the identification of some of the determinants of industrial funding to universities could at least confirm or question the basis of the conventional wisdom in this area. Actually, our result show that the prevailing doctrine and its policy implications are likely to be seriously flawed, both empirically and conceptually and that – if anything – university – industry relations are closely influenced by the quantity and quality of scientific academic research.

The paper is organized as follows. Section 2 sets the scene, by briefly discussing the main features of the development of the debate on university-industry relations. Section 3 presents the database and the econometric methodology used in this paper. Section 4 discusses the results. Section 5 concludes the paper.

2. **The background**

2.1 Origins and motivations for stronger university-industry-ties

As it is well known, after World War II, and until the 1970s, in Italy as in all European countries academic research was predominantly funded by public sources. This attitude basically reflected the so-called "Arrow-Nelson" model, according to which scientific research is essentially a public good and therefore worthy of government support also under criteria of economic efficiency. Moreover, interaction with industry was not perceived to be a fundamental mission of

[1] See, for a more comprehensive discussion and analysis Bruno and Orsenigo (2002)

universities, which was thought to reside essentially in teaching and in free, pure research. In practice, university-industry interactions were certainly not uncommon, especially in the fields of chemistry, in the medical and in engineering schools and involved both rather simple and down-to-earth activities like testing of machinery, materials, etc., but also big science (the collaboration between Giulio Natta of the Milan Polytechnic and Montecatini for the discovery of polypropylene – which led to the Nobel prize- is the most frequently cited example). Moreover, consultancy was a rather widespread activity among university professors. Yet, most of these activities were largely informal and not systematically organized. Funding from private sources was not disencouraged, but regulated, especially in order to avoid excesses in the consultancy activities of faculty members at the expense of teaching and research.

This situation began to be increasingly questioned since the Seventies onwards. Various factors contributed to this changing attitude and it is not possible to discuss them in any detail.

First, in all Europe the diffusion of mass academic education coupled with stricter budgetary constraints put the efficiency of the academic structures under severe pressures, not only financially but also in terms of the quality of teaching and research. At the same time, the industries that had traditionally been more active in linking with academic research – the typical example being chemicals – underwent a deep crisis, further contributing to the weakening of university-industry relations.

Moreover, and especially in the face of the financial constraints, universities were increasingly asked to contribute more directly to technical innovation and economic growth. Coupled with the increasing recognition of the role that innovation has in generating economic growth, all this led to pressures for producing research which could be more valuable for industry and in general for establishing closer linkages with the business community.

Finally, and perhaps even more importantly, the upsurge of university-industry relations in the USA in the 1980s, the examples of the Silicon Valley and of the take-off of biotechnology – in general, the American science-based model of economic growth – provided a further and even more powerful argument for the promotion of a stronger involvement of universities in activities closer to the industrial world. The notion that universities could and should become key agents of economic growth at the national – and even more so – at the local level quickly became one of the leading policy recipes.

These policies were largely based on a particular conceptualization of how the goal of closer university-ties could be achieved, i.e. on the notion of technology transfer and on the attempt at replicating the "American model" to the European scene. In a nutshell, this model assumes that the key problem in establishing closer relation university-industry ties rests on the "distance" between the academic and the industrial world and that appropriate incentives and organizational structures should be developed in order to bridge this gap.

Different arguments – in some cases clearly inconsistent with each other -. have been used to justify this approach.

First, it is claimed that universities are engaged too much in basic research as contrasted to more applied research, especially that supporting small and medium sized companies in “traditional industries”.

Second, in another versions, the distance is essentially linked to the different orientations and value systems governing academic and industrial research. According to this view, scientists are essentially motivated by the rules of “open science” (Dasgupta and David, 1994) and therefore appropriate incentives should be introduced for scientists to engage in research relevant to industry: higher reliance on industrial rather than standard government funding, encouragement to patent their research results, etc..

Third, a further interpretation basically reverses the traditional view expressed in the Arrow-Nelson model. Here, the main problem is identified in the observation that academic research is far from being a public good. Rather, it has a largely tacit nature and it has partly the property of “natural excludability”. Moreover, it is claimed that the traditional “linear model” is fundamentally flawed, since it fails to recognize the intrinsically interactive nature of learning processes and it is recognized that the processes through which the knowledge created within universities impacts on industrial development and technological innovation are far more intricate than it is usually assumed in most (theoretical and empirical) models[2]. As a consequence, the transfer of knowledge requires close interaction with firms and intermediary institutions should be developed with the task of diffusing knowledge and making it accessible to a wide set of agents.

Fourth, it is sometimes claimed that scientific research has become increasingly multidisciplinary and involves different types of institutions, techniques and methods (Gibbons et

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[2] The relevance of academic research and above all the mechanisms through which such knowledge is transmitted vary greatly across scientific disciplines, technologies and industries (Rosenberg and Nelson, 1994). Academic research contributes to the solution of technical problems of firms through a variety of channels, including the provision of instrumentation, of background knowledge (often industrial researchers are less interested in the content of publications than in the experience and tacit knowledge of the authors of those articles) and the participation in professional networks at the national and international level (Klevorick et al. 1995, Sequeira and Martin 1996, Pavitt 1996). Moreover, the effective acquisition of academic knowledge requires, on the firms’ side, at least three types of competencies: capabilities of absorbing the new knowledge created outside the industry (Cohen and Levinthal, 1989), capabilities of exploring an expanding set of opportunities (through closed links with the scientific community) and capabilities to integrate different new and old scientific disciplines (Henderson, 1994). Finally, knowledge flows from university to industry are often local and geographically bounded (Jaffe 1989), mainly because knowledge is often embodied in individual scientists and research teams. The access to such knowledge requires the development of social ties and personal contacts, but also and mainly deep involvement in the research process and bench-level scientific collaboration. Finally, knowledge flows largely occur through the mobility of people and teams across organizations and through the labour market (Zucker and Darby 1996, Lamoreaux and Solokoff, 1997. See for a provocative discussion of these issues Breschi and Lissoni, 2001).

al, 1994). Thus, universities are no longer the privileged institutions in scientific research, but one agent in a dense and ever changing web of relations with other agents. Once again, the implication is that closer and flexible interaction with firms should be promoted and that appropriate institutions to facilitate these exchanges should be created.

However, this approach has proved to be only partially successful. Despite all the efforts, it is still widely perceived that university-industry ties remain underdeveloped in Europe and especially in Italy. Similarly, although the share of business firms in the funding of academic research has been actually increasing over the past ten years in Italy (in most European countries), its share remains small and government funding remains largely predominant (Geuna, 1999, Pavitt, 2001). If anything, it is often observed that little change has taken place in the academic world, which continues to be dominated by bureaucratic, feudal and inertial structures.

2.2 Alternative views

Against this background, it becomes therefore legitimate and interesting to ask why has it has proved to be so difficult to "fill the gap" between industry and academia in Europe. Indeed, recently, several types of criticism have begun to be advanced against the conventional approach discussed so far. First, the appropriatedness of an excessive involvement of universities in industry-oriented and commercial activities has been criticized on several grounds[3]. But even without entering into this discussion, other pieces of empirical evidence start to indicate that the development of university-industry relations might well be influenced by factors quite different from incentives and the development of organizational structures for the transfer of technology.

2.2.1 The structure of Continental European Academic Systems

First, comparative history and sociology of academic systems offers interesting insights for an understanding of the difficulties that (mainly Continental European) universities face in linking with industry and suggests that far deeper changes might be needed in the structure and organisation of universities than bureaucratic simplification and the introduction of economic incentives.

First of all, it is often remarked that in Europe, university professors are public servants and their careers are fundamentally determined by bureaucratic and automatic rules, essentially based on seniority like in most others public jobs.

[3] See for example Mazzoleni and Nelson (1998), as university patenting is concerned; David, Mowery and Steinmueller (1992) and David, Foray and Steinmueller (1999) about the dangers that the insertion of incentives mechanisms created by industrial funding might bear on the traditional orientation to Open Science, that are typical of academia; Geuna (1999) about the perverse effects that an increasing dependence of academic research on forms of "formula" and contractual funding – in general of quasi-market allocative principles - might have on the behaviour and efficiency of the academic system).

Second, the organization of research and teaching in the USA has characteristics that facilitated both the production of high quality research and high degrees of mobility between academia and the commercial world (Ben-David 1976; Clarke 1984; Braun 1994). Specifically, in the USA (and in Great Britain) departments have long been the main organizational entities as opposed to the European institutes, dominated by a single professor, far less interdisciplinary in nature and with feudal-like career paths. As a consequence, for example, American universities have been and typically are particularly rapid and flexible in developing and building into their structure new scientific but especially new engineering disciplines that were formed to support new technologies when they arose (Mowery and Rosenberg, 1998).

Moreover, in the USA high degrees of integration between teaching and learning have been achieved through the sharp separation between undergraduate and post-graduate levels. The creation of research-oriented post-graduate studies entailed, in fact, a number of important consequences. In particular, post-graduate students are typically exposed and trained to the practice of scientific research within research teams composed by students and professors within departmental organizations. This arrangement does not only tend to free resources for scientific research, but provides also a fundamental experience in participating to and managing relatively complex organizations. In other words, it constitutes an essential source for the development of organizational capabilities. Moreover, the career of young research scientists after graduate studies has – under various perspectives - entrepreneurial characteristics. For instance, post-docs have to raise funds for their own research in a highly competitive environment, where performance is judged on the basis of a track record and the ability to set an independent research agenda (Gittelman, 2000). Finally, graduate students joining the industrial world after the completion of their studies constitute an essential source of skilled demand for academic research.

In Continental Europe, the integration of teaching with research has progressed far less than in the USA (and to some extent than in the UK). Clearly, enormous differences in education systems, especially on the higher education level, exist across Continental European countries and they certainly should not be overlooked[4]. Despite these enormous differences, however, the structure of the academic systems of many European countries shares some important common features, as compared to the Anglo-Saxon systems. Ph.Ds are a relatively recent innovation in

[4] For example, in France, universities have never been the main centre of both scientific research - which has been essentially conducted within the national laboratories and co-ordinated by the CNRS (National Center for Scientific Research) - and the education of the elites - monopolised by the system of the *grandes écoles*. In Germany, the "institute" – dominated by an individual professor – has been the main organisational unit co-ordinating teaching and research. Moreover, an extremely efficient intermediate level of teaching applied disciplines like engineering has been developed (the "Fachhochschulen"), which integrates teaching and practice, but largely overlooks fundamental research.

many Continental European countries (in Italy they were introduced first in 1983) and they remain far less professionally orientated than in the U.S.A. Departmental structures are also relatively new and in many cases institutes continue to be a very important organisational entity. In general, research has tended to be far more removed from teaching than in the USA. And in fact, in many Continental European countries, research has been to a large extent separated from universities and concentrated in specialised institutions. It is possible to speculate that this separation might have had negative effects on both the quality of research and on the ability of academic institutions to interact with industry, mainly through the severing of the main channel through which knowledge flows take place, i.e. teaching. Moreover, the separation between teaching and research and the permanence of institutional academic structures that attribute an enormous power to the individual chair-holders might also have contributed to the persistence of promotion mechanisms that favour much less scientific and teaching performance than the protection of influential "barons".

In this view, the development in Continental Europe of various types of specialised institutions for technology transfer, who act as intermediaries between research and industry, might be considered as an attempt at compensating this gap between teaching and research and of escaping from the feudal and bureaucratic academic rules. The presence of large scale intermediary institutions, however, might have paradoxically increased the distance between university and industry, introducing an additional layer in the relationship instead of favouring the required scientific, organisational and integrative capabilities directly within firms and within academic institutions.

2.2.2 Quality of academic research

A second possible explanation is to be found in the quantity and above all the quality of the research produced by universities. In this perspective, academic research influences industrial innovation mainly by opening up new opportunities of discovery and leads – rather than following – industrial demand. This interpretation seems to be at the basis of those interpretations of the American case that emphasize that the rise in university patenting – and more generally in the intensity of the relations between academia and the commercial world – is closely linked to the emergence and development of information technology and biotechnology (Mowery et al, 2001) and it pre-dates the introduction of incentives (mainly the Bayh-Dole Act) to university patenting. Supporting this view there is also evidence showing that innovative firms mostly use university research that is performed in high quality research universities, published in quality academic journals, funded publicly and cited frequently by academic themselves (Pavitt, 2001; Mansfield 1995; Narin et al, 1997; Hicks et al., 2000).

2.2.3 Industrial demand

A third set of factors is related to the pre-existence of a strong demand for academic research expressed by industry. There are different ways through which "demand" can be interpreted. It can mean that firms are already engaged in systematic innovative activities and possess the "absorptive capacities" that are needed to get access and fruitfully make use of academic research. It may also be considered as a manifestation of the role that universities play in favour of local industry through consultancy, solution of technical problems, etc.. For example, Rosenberg and Nelson (1994) have pointed out that in the USA universities a have long tradition of interaction with local industries in response to practical concerns , particularly in practically oriented disciplines – like engineering, medicine, agricultural sciences, etc.. In sum, the existence of long standing relations and above all of a strong demand by industry – especially at the local level – might be a critical factor on which new ties can be developed. In this case, one would expect that local demand – as distinct from demand coming from other geographical areas - is particularly relevant. Put it another way, the "conventional" doctrine - by emphasizing incentives and the creation of markets and transfer structures for facilitating the exchange of knowledge between industry and academia – implicitly assumes that both the "supply" and the "demand" of knowledge are already present and that the problem resides mainly in the market or organizational failures that prevent a smooth and efficient exchange. However, in some instances – as it have often proved to be the case in local areas mainly populated by small firms active in "traditional industries" and substantially lacking technological capabilities - it is mainly the weakness of local demand that prevents the establishment of stronger relations with local universities. Indeed, it is quite frequent to hear managers of local technology transfer offices complain that simply local firms are not interested in the research and services that universities are offering and that the marketing of such services should become the first priority in the activities of these centers.

Clearly, all these groups and sub-groups of variables are not necessarily mutually exclusive. On the contrary, it highly plausible that powerful dynamic relations exist among the, generating virtuous or vicious cycles. Thus, for instance, a strong industrial demand is likely to trigger actions by universities to build appropriate structure facilitating technology "transfer". Similarly, the quality of research might benefit from strong industrial funding, insofar as the latter provides financial resources for further support to research, increases the chance of having access to additional public funding, etc. (see Geuna 1999, for a discussion of some of these issues).

3. The empirical analysis: sources, data and methodology

Our econometric analysis is just a first attempt at exploring quantitatively industry-university relations. In fact, it focuses on just one aspect of these relations, namely industrial funding to academic research. Second, our analysis is severely constrained by the availability of data. Similarly, we are unable to examine in depth the dynamic interrelations between the relevant variables. In this perspective, our analysis is to be understood mainly as a preliminary descriptive exercise, aiming at establishing some major correlations among the variables, rather than a complete investigation of the complex causal relations among them, let alone a test of alternative theories.

Within this broad framework, we basically ask the following questions:

First, how is industrial funding to academic research influenced by the main categories of variables discussed in the preceding section? In particular, we try to assess the role played respectively by:

i) the quality and quantity of research - as an indicator of new innovative opportunities generated by universities that can possibly be picked up by industry.

ii) The existence of a local industry that expresses a demand for the research services and/or the more applied research that universities can provide to local firms.

iii) Other organizational characteristics of departments and universities, like size, prestige, age, etc; existence of dedicated organizational structures

A second related question refers to the relationships between teaching and the ability/willingness to interact with industry. Is there complementarity or substitution between teaching, research and the intensity of the linkages with industry? Does teaching – especially at the undergraduate level – absorb resources that might be used for research and support to firms? Or is this interaction linked and complementary to the teaching of skills and techniques to students?

Third, what are the similarities and the differences between the revealed allocative principles governing public and industrial funding to academic research?

3.1 The Data

The data are provided by the Conference of Italian University Rectors (CRUI), on the basis of a questionnaire submitted for the academic years 1992-93, 1993-94 and 1994-95 to all Italian universities.

The questions were answered by offices partly at the level of universities, partly at the level of individual Faculties and partly at the level of individual departments. As a result, the database contains information on several characteristics of Italian universities, although at different levels of aggregation. Globally, the dataset provides 4893 observations: 1218 in 1992-93; 1348 in 1993-94; 2327 in 1994-95

The rate and the accuracy of the responses varies greatly across respondents and over time. In some years, for example, entire universities did not answer, while providing very detailed information in another year. Similarly, there are serious doubts about the accuracy of the answers, especially as it concerns scientific production and funding. After 1995, CRUI discontinued the survey in its parts concerning disaggregated research output and funding and therefore more recent data concern only teaching activities and other administrative information[5].

Despite all these problems, the database is unique because it is the only available source that provides such detailed and disaggregated data. In particular, it is the only dataset that allows us to link data about scientific output (in terms of number of books, articles published in Italy and at the international level, conferences organized, etc.) and data concerning amounts and sources of funding to research at the level of individual departments.

It is worth noting that most of the literature dealing with I-U relations has not focused directly on the determinants of industrial funding, especially in Europe and even more so at the level of departments. Research has concentrated on the one hand on the determinants of research productivity of universities and individual scientists ; on the outcomes of industrial funding on the other, e.g. on the trend in patenting, on the rate of new firms formation, on (local) economic growth, etc.. Some evidence from the USA and the UK tends to show that industrial – but also public – funding tends to be highly concentrated in a small group of prestigious research universities (Mansfield, 1995), although in recent years a significant growth is observed in recent years of some smaller and less prestigious universities. In particular, it has been shown that the growth of university patenting following Bayh-Dole in the USA derives almost entirely on the increased activities of new, smaller and less prestigious institutions (Mowery et al. 2001).

3.2 Descriptive evidence

Let us begin by examining some basic descriptive evidence.

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[5] In the past few years, Italian universities have shown a remarkable dynamism in their attempts to link with industry and – more generally – to simplify bureaucratic regulations. To a large extent, this ferment is linked to the process of reforming Italian universities, mainly by conceding them autonomy from the central government, both financially and in terms of freedom of launching new degrees, internal regulations, etc.. Similarly, the criteria governing public funding have started to change. In particular, as it concerns research, stricter criteria have been introduced that – in principle – should favour scientific excellence (e.g. external refereeing of grants applications, ex-post peer evaluation of the scientific output, etc..) and tend to increase the role of contractual funding as compared to general funding. The effects of these initiatives is yet to be determined. Certainly, the time span considered in our data does not allow us to consider these changes, let alone to evaluate them. Thus, it is possible that the following analysis cannot be used straightforwardly to interpret the current situation of Italian academia.

Table 1 shows the share of private sources of funding to research by scientific discipline. The database distinguishes two main sources: “private funding” and “research contracts”. The former variable includes all sorts of funding that goes to academic research by private institutions (e.g. donations, general support to research projects, etc..). The latter variable includes funding coming by any kind of contractor for specific research contracts. Thus, these variables do not correspond strictly to industrial funding, which is only a subset of these funds. Yet, they give a broad indication of the funding that goes to academic research outside the conventional public sources.

// TABLE 1 ABOUT HERE //

The share of “industrial” funding is higher than it is usually assumed. The share of – respectively - research contracts and private funding on total funding to research is around 15% and 8% . Considering that only a fraction of this funding comes from industry proper, these figures are broadly consistent with OECD data that indicate in around 5 to 6% the industrial contribution to academic research in the late Nineties. However, these sums are ridiculously low in absolute terms (Table 2). Even in the most “industrial-intensive” discipline – industrial engineering – the average per head (sum of private funding plus contract research/number of researchers) is less than Euros 5.000 per year. This indicates – of course – that also public funding is very low in absolute terms.

// TABLE 2 ABOUT HERE //

Industrial funding is not surprisingly concentrated in few scientific disciplines: engineering, followed by medicine, agriculture and chemicals. The share of biology – if anything – is much lower than one might expect, given that biomedical research is perhaps the most dynamic scientific discipline in linking with industry all over the world.

The distribution of funding by university is not surprisingly highly concentrated in the largest, most prestigious universities, but public funding is less concentrated than industrial funding (Table 3). The first 6 universities get almost 50% of total revenues from research contracts (and Milan Polytechnic alone gets around 9%) but one third of total public funding. Moreover, the ranking is not the same. Milan Polytechnic does not appear among the largest fifteen recipients of public funds and other smaller universities figure prominently in the list.

// TABLES 3 AND 4 ABOUT HERE //

Similar results are obtained at the level of departments. The distribution of funding by department – especially industrial funding, but also public funding - is highly skewed (Figure 1), but much less concentrated. The Concentration Index, C4, ranges between 3% (public funding) and 6% (industrial funding) and the ranking of the recipients is highly unstable and variable over time. However, departments belonging to the Polytechnics of Milan frequently appear in the list of the biggest recipients of industrial funding (5 in the first twenty departments), whereas the ranking for public funds is much more variable and distributed among departments that do not necessarily belong to the largest universities. Interestingly, physics and chemistry departments appear consistently in the top positions of public funding, whereas engineering and medicine departments take the lion's share in industrial funds.

// INSERT FIGURE 1 ABOUT HERE //

Also the distribution of publications, domestic and above all, international is not surprisingly also highly skewed.

Despite this variability, data not reported here (see Bruno and Orsenigo, 2002, for an analysis of the transition probability matrices for industrial and public funding and for international and Italian publications) show a remarkable persistence is observed in the ability of departments to get funding.

In sum, the emerging picture suggests that university- industry links involve typically small contracts, that are widely distributed and highly variable over time and across departments, although the largest and more prestigious universities emerge as the biggest recipients of industrial and (less so) public funds. Moreover, the ability to get funding appears to be cumulative, at least in the sense that recipients of research funding are likely to continue to do so. "Barriers to entry" exist but they do not look insurmountable, but they are stronger for industrial funds.

3.3 Econometric Analysis

The unit of analysis of our exercise is the individual department or institute. In principle, one should focus on research teams as the ideal unit of investigation. However, data at this level of disaggregation are unavailable and the department/institute is the closest level one can get. Not all observations refer to departments, though. Some of them refer to Faculties within a specific university. While this is essentially dictated by sheer availability of data, it is also worth noting that prestigious universities may generate spillovers for individual departments and some of the organizational capabilities and infrastructures are organized at the university level (even though qualitative evidence shows that very often these functions have been either informal or delegated to individual departments).

We develop our econometric analysis in different steps. First, we pool all observations; then we concentrate only on the more "industry – intensive" disciplines in two ways. In one set of regressions we simply eliminate the disciplines that get less industrial funding – mathematics, social sciences and humanities. In another set of regressions we focus only the engineering and the biomedical departments, who capture the bulk of the funding. Fourth, we identify a subset of "excellent" departments and universities – those having the highest levels of industrial funding, irrespective of the discipline. Finally, we develop a two stage estimation procedure, in order to start coping with problems of dynamic endogeneity between some endogenous and exogenous variables.

Given missing data and censoring problems inherent in the dataset, we use Random effect Tobit regressions and Standard Tobit for the regressions on the individual scientific fields.

3.4 The specification

In general terms, our specification tries to capture – in a highly stylized way – the influence that the different categories of variable discussed previously – "supply" and "demand variables, organizational and department/university- specific variables – might have on the flow of industrial funding to academic research. Moreover, we estimate also the effects that the same variables have on the flows of public funding, in order to compare the different "revealed allocative principles" that guide industrial and public funding.

The dataset however imposes severe limitations on the availability of measures and proxies of the potentially relevant variables. In particular, we have no variables capturing incentives (which however do not change over time and across universities) and structures for technology transfer. Thus, we cannot directly test for the role played by these institutions in promoting university-industry ties.

Dependent variables

The endogenous variables used in the following regressions are:

a) as far as it concerns "industrial funding", we concentrate attention on the absolute amount of funds accruing to individual departments that derive by research contracts (RESCON). This is by far the most relevant and the easier to interpret measure at our disposal. "Private funding" is not only much smaller in absolute terms, but it is a much more heterogeneous – and sometimes difficult to interpret measure. The database provides also another measure, namely the number of agreements and "framework contracts" between universities and other institutions. However, this variable does not specify the amount of funds involved and it is again a highly heterogeneous category[6].

b) as for public funding, we distinguish instead between two major sources: the so-called "40% Funds (40%) and the "60% Funds" (60%). Both categories are erogated by the Ministry of University and Scientific Research. However, the procedures governing their distribution are quite different.

60% Funds are in essence a non-targeted form of research funding. They are by and large distributed to each individual university basically as a function of the number of professors. Then each university re-allocates these funds to individual professors according to their own procedures. In practice, these funds are a form of general funding, where each professor gets a (usually quite small) amount of money for "subsistence", equal for everybody. Often – but not always - universities allocate these funds on a hierarchical principle: full professors get more than associate professors and the latter more than assistant professors. However, within each rank, each gets the same amount. These funds are typically used to pay for some travelling costs, purchase of books and software and the like.

40% Funds are instead "targeted" funds, distributed according to a competitive evaluation of research proposals presented by the various research teams – typically collaborations between different teams of different universities - to a national commission. Thus, in principle, these funds should be allocated on the basis of standard academic criteria like the scientific value of the project, the curricula of the participants, etc.. Quite obviously – and especially on the Italian scene – issues of academic power interfere in the process and criticism has been raised in several occasions that also this category of funding is excessively spread so to give something to everybody and too influenced by academic politics[7]. Yet, there is no question that these funds are allocated according to more "scientific-based" criteria than the previous ones.

Independent Variables

<u>a) Scientific production:</u>

A first group of variables is meant to capture the "opportunity" effects for industrial innovation generated by academic research. That is to say, firms would fund academic research as long as the latter creates "discoveries" – and more generally advancements in the understanding of particular phenomena - that contribute to firms' innovative activities. As mentioned previously,

[6] It might be worth noting, however, that regressions on this endogenous variable give essentially the same results obtained with the variable "contract research".

[7] Recently, the evaluation procedure has been changed, introducing co-funding and external, anonymous referees, both Italian and international experts.

earlier literature (Klevorick et al, 1995, for instance) has shown that in most cases firms do not usually rely on very recent scientific results. However, in some industries and scientific fields – like biomedical research and information technologies – state-of-the-art scientific knowledge is fundamentally relevant for industrial innovation. Typically, these industries are precisely those where linkages with academia are stronger. In a broader sense, firms might fund academic research in specific departments not necessarily because they produce "radical" discoveries, but simply because – or provided that - they produce high quality research. Put it another way, firms would have little interest in funding uninteresting academic research. In this sense, we would expect industrial funding to academic research to be positively correlated to the quality and the amount of research produced in – and to the scientific productivity of - any given department.

The CRUI database provides different possible proxies for the quality of research, each with its own limitations and drawbacks. We have chosen two main variables: the number of international publications (articles) (INTPUB) and the number of articles published in Italian (ITAPUB). The number of international articles is expected to reflect higher scientific quality as compared to domestic publications. As known, the sheer number of published articles is a very poor proxy of scientific excellence, since it does not consider the quality and reputation of the journals, the impact of the paper and so forth. Yet, absent any further information, scientific output measured this way remains the only and less unsatisfactory proxy of the quality of research[8]. In order to take into account the different rates of publications that typical to each scientific discipline, we actually use the difference between the actual number of publications and the median number of publications in that scientific discipline (although results change only marginally).

b) <u>"Demand" variables</u>

The second group of variables tries to capture what we defined as "demand effects". That is to say, university-industry interactions should be enhanced by the presence of a strong industrial base that generates demand for the research, services and contribution to the solution of specific problems that universities can perform for them. Absent such demand, academic research is much less likely to have an impact on industrial activities. Differently from the "opportunity" variables, the demand variables have a much stronger "local" and geographically-bounded nature. Not

[8] The CRUI database gives also information on the number of published books (Italian and international), the number of organized conferences and seminars and the presentations at national and international conferences. In some sets of regressions, we used also measures of the departments' scientific productivity by dividing the number of publication by the number of professors (full, associate and assistant professors) affiliated to the department itself. Results do not change.

necessarily firms in a given location look for the best research available, but turn to local universities for help in less sophisticated activities.

We use three variables to measure these effects. First, we use an indicator of specialization in manufacturing in the province where the department is located (MANEMP), defined as the number of employees in manufacturing. This variable should capture the role that the existence of a strong industrial base might have in generating interaction with universities. We use also the number of patent applications at the European Patent Office in the province (PAT), in order to distinguish – in principle – the role played by the demand of respectively innovative firms as distinct from a more generic industrial demand. Finally, we also use the total population of the province (POPPROV). This variable might capture the demand coming not from manufacturing firms as such, but by other companies active in different sectors, e.g. services. Moreover, it might well be that university-industry ties tend simply to concentrate in large metropolitan areas, where big (and probably also more prestigious) universities are located and that attract firms from other locations. We also include interaction terms between the specialization and patent variables on the one hand and the province population on the other. In particular, we include both the ratio between patents and employees in manufacturing over the province population (PATRES and MANEMPRES); and the product of the same variables(PATRES2 AND MANEMP2). The reason of this specification is to control for potentially different effects that innovative intensity and specialization in manufacturing may have on industrial (and public funding) according to the size of the province.

c) Department- and university-specific variables

A third group of variables includes different measures of department and university-specific variables.

A first sub-group refers to the role of teaching. As discussed previously, it is a widespread opinion that a heavy teaching load might have detrimental effects on both research and interaction with industry. On the other hand, a high number of students is a proxy for the department size and large departments, with many students and many dissertations, may more easily attract industrial funding. Thus, we use the number of students (STUD) as an exogenous variable in our regressions. These variables do not pertain to the individual department though, but to the Faculty to which the department is affiliated. Moreover, a distinction between undergraduate and postgraduate studies might be relevant here. Indeed, an emphasis on postgraduate training may benefit interaction with industry both indirectly – through the positive effects on the research of the department – and directly – Ph.D.students find a job in industry and therefore induce a "taste for research" in the firm and constitute anyhow a source of absorptive capabilities within firms. Thus, in some regressions, we use also the number of Ph.D students (Ph.D) as a dependent variable. However, only few departments indicate the number of their postgraduate students and thus the number of observations is drastically reduced.

A second subgroup of variables basically controls directly for the size of the department. The variables used in the regressions are the number of professors (full, associate and assistant professors) affiliated to the department (PROF) and the number of technical and administrative employees of the department (ADTECH). This variable might be also loosely interpreted as a proxy for some organizational capabilities of the department. A high number of technical and administrative employees might indicate that the department is not simply big, but also well staffed and organized, both as the function of laboratories and administrative offices is concerned. Moreover, intensive relations with industry are likely to require (and also to create the resources for) a larger number of technicians and administrative people. However, this interpretation is far from being clear. A big number of non-teaching employees might simply reflect the academic power of the local baron or – even worse – sheer inefficiency in the use of resources. Thus, this variable is best interpreted as a control for size.

Finally, we include the year of foundation of the department (AGE).

Available data – either coming from the CRUI database or from other sources - do not allow us to develop measures for what we called "organizational variables", including both the incentives to engage in relations with industry and the "bridging" facilities for technology transfer. This is a major weakness of this exercise. However, as incentives are concerned, the rules and regulations governing them were invariant at the time across departments and universities, since they are set at the national level, and they did not change significantly over time. The absence of measures of "transfer capabilities" is more serious. It implies that we cannot test directly the relative importance of the various possible factors affecting university-industry ties, but only evaluate the role played the variables that have received less attention in the debate, i.e. scientific capabilities on the one hand and "demand" conditions on the other.

Dummy variables

Finally, our regressions include different sets of dummy variables.

First, we include dummies for the 57 universities to which departments are affiliated, in order to control for possible "spillovers" or university-specific-effects that may affect individual departments.

In sum, the "general regression" has the following form (dropping subscripts for simplicity):

$$Y^j = a + b_1\, INTERPUB + b_2\, ITAPUB + b_3\, PAT + b_4\, MANEMP + b_5\, PATRES + b_6\, MANEMPRES + b_7\, PATRES2 + b_8\, MANEMPRES2 + b_9\, POPPROV + b_{10}\, STUD + b_{11}\, PROF + b_{12}\, ADTECH + b_{13}\, AGE + DUMMIES\ UNIVERSITY$$

with $j = 1, 2, 3$ and Y^1 = RESCON, Y^2 = 60%, Y^3 = 40%,

4. The Results

4.1 The General Regressions

Results for the general regressions are reported in Table 5. The variable measuring the year of foundation of the department is never significant and it has then been omitted.

// TABLE 5 ABOUT HERE //

In the equation for industrial funding (contract research, CONRES), the coefficients of the variables measuring international scientific production (INTERPUB), number of professors and administrative and technical employees (PROF and ADTECH) are positive and significant. The number of students (STUD) has a negative and significant coefficient. Domestic scientific production is non significant. The effects of the demand variables are quite complex. The number of patents (PAT) has a negative and significant coefficient. However, both the interaction terms with the province population (PATRES and PATRES2) have a positive and significant sign. Conversely, the number of employees in manufacturing (MANEMP), the product interaction term (MANEMPRES2) and the province population coefficients are non significant, while the degree of specialization in manufacturing is positive and significant at the 10% level.

In sum, these results suggest that industrial funding tends to be positively linked to the ability of producing scientific research at the international level, to the size of the department in terms of teaching and non teaching staff, while the teaching load seems to have a negative effect. Funding goes to big, scientifically productive, well organized universities, irrespective of the size of the province. The effects of local innovative activities (as measured by patents) have something like a U shaped form in relation to the province population. They are positive in small, highly patent intensive areas and in the large, highly patent intensive provinces. The effect of the number of patents as such on the ability of departments to attract industrial research funding are however negative. A high degree of specialization in manufacturing activities enhances industrial funding.

Let us look now at the regressions for public funding. The results for the equation for 60% funds are largely to those for research contracts. The main differences are that here publications in Italian are significant with a negative sign and the variables measuring industrialization have an opposite behaviour as compared to industrial research contracts: specialization in manufacturing (MANEMPRES) and the product interaction term (MANEMPRES2) have a negative sign, but the number of employees in manufacturing (MANEMP) is positive. Moreover, the size of the province (POPPROV) is significant and positive.

As 40% funds are concerned, the results confirm the significant and positive coefficients of the variables measuring international scientific production (INTERPUB), number of professors and administrative and technical employees (PROF and ADTECH). Again, the number of students (STUD) has a negative and significant coefficient and domestic scientific production (ITAPUB) is non significant. Here, however, the effects of variables measuring local innovativeness are opposite as compared to the case of industrial funding. The number of patents (PAT) has a positive coefficient while both the interaction terms with the province population (PATRES and PATRES2) have a negative sign. Moreover, none of the variables measuring the strength of the local industrial base are significant.

In other words, there are remarkable similarities between the revealed allocative mechanisms governing industrial and public funding, but also important differences. Large, scientifically productive and well organized universities tend to attract higher levels of both industrial and public funding. However, public sources of research funds are more concentrated in large metropolitan areas and, above all, are less and differently influenced by the "demand" variables.

4.2 Regressions for specific scientific disciplines

The general regressions discussed above consider departments active in all scientific disciplines, including those having very little interaction with industry. In order to focus attention only on those scientific disciplines where most of the action takes place, we ran two more series of regressions[9]. In the first series, we excluded mathematics, social sciences and humanities. Results of these regressions – not reported here – confirm the previous ones, although in general the level of significance of the coefficients is lower – probably as a consequence of the lower number of observations.

In the second series of regressions we considered only the most "industry-intensive" disciplines, namely biomedical sciences and engineering. Results are reported in Table 6.

// TABLE 6 ABOUT HERE //

As industrial research contracts are concerned, the positive and significant role of international publications (INTERPUB), teaching and non-teaching employees (PROF and

[9]We also ran regressions for each of the 14 scientific fields identified in the dataset, to check for systematic differences across disciplines. However, we obtain too often non-significant results as a consequence of lack of observations.

ADTECH) are confirmed. Yet, here the number of students has a positive sign. Moreover, differently from the general equation, neither the patent variables, the industrialization variables and the size of the province are significant.

Thus, industrial research contracts in these scientific disciplines appear to accrue mainly to scientifically productive and large departments – also in terms of students - irrespective of their location.

Public funding exhibits a somewhat different behaviour. International publications (INTERPUB), the number of professors (PROF) and of students (STUD) have again significant and positive coefficients, but now the variable for administrative and technical employees (ADTECH) is non significant. Moreover, interesting differences can be observed as it concerns the "demand" variables. In the equation for 60% funds, the number of patents (PAT) is negative and the two interaction terms (PATRES and PATRES2) are positive: i.e., the effects of local innovation has a U-shaped form in relation to the size of the province. Conversely, the number of employees in manufacturing (MANEMP) is positive but the two interaction terms (MANEMPRES and MANEMPRES2) are negative: the effect of a high number of employees in manufacturing decreases in the smaller and larger provinces. Finally, the size of the province (POPPROV) is positive.

In the case of 40% funds, patents (PAT) are significant at the 5% level and positive but the interaction terms are non significant. The measures of specialization in manufacturing are non significant, except for the share of employees on total population (MANEMPRES), which has a positive sign and is significant at the 5% level. Again, as in the case of 60% funds, the size of the province (POPPROV) is positive.

Thus, public funds tend to go large and scientifically productive universities, although the technical and administrative personnel does not matter as in the case of industrial funds. Moreover, again the "demand" variables have a different impact as compared to industrial funds. Finally, public funds accrue to departments located in large provinces.

4.3 Two stages estimation procedure

Many of the dependent and independent variables in our regressions are likely to be actually endogenously co-determined and influenced by their past values. For example, it might very well be that scientific production is influenced by past funding. In order to start addressing the problem of simultaneous co-determination between the variables, we have developed a two-stage procedure, that focuses on international and Italian publications as determinants of public and industrial funding.

In the first step, we construct dummy variables for respectively international and domestic publications, DINTERPUB and DITAPUB. They take a value = 1, if there is at least one publication, 0 otherwise. Then, we apply a logit model, where Pr { DINTERPUB, DITAPUB = 1} is a function of the following lagged variables: international publications, nr. of professors, non teaching employees, students. Moreover, we include the current values of the other variables employed in the previous regressions: patents, patents per capita in the province, the interaction between the number of patents and the province population, employees in manufacturing in the province, employees in manufacturing in the province divided by province population, employees in manufacturing in the province times province population, province population. Finally, we include as an additional instrument the number of Ph.D students (Ph.D). On the basis of the result of these regressions, we compute the probability of producing at least one international and Italian publications for each department.

In the second stage (Random effects Tobit model), we regress the amount of “industrial funding” (RESCON) on these probabilities of producing at least one international or Italian publication obtained in the first step plus the same remaining variables included in the “standard” specification used in the previous regressions.

In sum, we try to correct for the occurrence of a simultaneity bias between research and funding.

Table 7 reports the results for the first step, respectively for all departments and only for biomedical and engineering departments. In the general regression for international publications, the lagged values past international publications, number of professors (at the 10% level) administrative and technical employees have a significant and positive coefficient. Moreover, the second interaction term for patents times province population (PATRES2) is also positive and significant at the 5% level., while the degree of specialization in manufacturing (MANEMPRES) and province population are negative and significant. Finally – and interestingly – the number of PH.D students is positive and significant. Similar results are obtained for Italian publications. However, the number of professors is no longer significant, while the number of students becomes positive and significant at the 10% level. The behaviour of the patent and of the industrialization variables is also different. The total number of patents is negative and the ratio of patents to province population is positive; the number of employees in manufacturing is positive, but the share of manufacturing employees on total population as well as total province population are negative.

// TABLE 7 ABOUT HERE //

In the regressions that consider only engineering and biomedical scientific disciplines, only past publications and the number of Ph.D students are significant with a positive sign. In the case of

Italian publications, also the coefficient on the number of professors is negative and significant, but only at the 10% level.

The main interest of these regressions lies in predicting the probabilities of publishing, conditional on instruments validity. And this seems to be the case indeed, especially as lagged publications and Ph.D students are concerned.

On these grounds, we can turn to the second step (Table 8). Results are quite similar for the general regression and the regression for engineering and biomedical sciences. International publications and the number of students are strongly significant with a positive sign. The number of professors is positive only in engineering and biomedical departments, while it is negative but barely significant in the general regression. The patent variables have the already observed U-shaped impact: they are positive in small, highly patent intensive areas and in the large, highly patent intensive provinces. Conversely, the degree of industrialization has an inverted U-shaped impact: a high number of employees in manufacturing has a s positive effect on the ability to get industrial funding, but this effect decreases in larger and smaller “manufacturing- intensive” provinces. The size of the province itself is non significant.

// TABLE 8 ABOUT HERE //

In sum, these results broadly confirm and make our previous findings more precise. Industrial funding is attracted by departments that are large in terms of students and prolific in terms of international publications. The demand variables are important but have an opposite behaviour. Local innovative activities are important in the smallest and largest provinces. The presence of a strong manufacturing sector is less and less important in the smaller and larger areas.

5. Conclusion

In general, industrial funding goes to big, scientifically productive, well organized universities, in areas specialized in manufacturing, but irrespective of the size of the province. The effects of local innovative activities are positive in small, highly patent intensive areas and in the large, highly patent intensive provinces. However, by concentrating in the more “industry-intensive” scientific disciplines (engineering and biomedical research), some important differences emerge. The number of students has now a positive role and the demand variables play no role. These results are largely confirmed in the two-stage estimating procedure, the only differences being i) the role played by the industrialization variables - positive but decreasing in the smaller and larger areas and ii) the similarities observed here between the general regression and the regression for engineering and biomedical sciences.

There are remarkable similarities between the revealed allocative mechanisms governing industrial and public funding, but also important differences. Large, scientifically productive and well organized universities tend to attract higher levels of both industrial and public funding. However, public sources of research funds are more concentrated in large metropolitan areas and, above all, are less and differently influenced by the "demand" variables. In the case of engineering and biomedical research, moreover, the technical and administrative personnel does not matter as in the case of industrial funds.

In essence, these results tell that the main determinants of both industrial and public funding are to be found in the size, organization and especially scientific performance of universities. In particular, the positive and significant effect of the number of international publication on both public and industrial funding is an extremely robust result, under different specifications, samples considered and estimation techniques. On the other hand, demand variables matter in the allocation of public funds, but much less in the case of industrial funding. Presumably, "excellent" universities develop ties and interactions with industry that spans beyond the local boundaries, especially in the case of the most industry-intensive disciplines.

These findings largely confirm results and perceptions obtained for other European countries and the USA. That is to say, university-industry interactions tend to be concentrated in few, large and prestigious universities and departments. While this observation does not obviously imply – by any means – that universities don not play any significant economic role at the local level, it suggests that the "conventional" understanding of and policy stance towards university-industry relations is likely to be seriously flawed. Put it bluntly, (the various versions of) the "European Paradox" doctrine appear to miss a fundamental issue, namely that very little interaction can develop absent excellent scientific performance. On the contrary, the ability to produce good research is the pre-condition for the development of a strong role of universities towards industry. In other words, rather than – or before - promoting the development of various kinds of incentives for a stronger involvement of academia in the industrial world and "technology transfer" institutions, policies should be directed towards the strengthening of the traditional mission of universities, the production of state-of-the-art scientific research.

This observation is partially strengthened by the results obtained for the variable number of students. While the impact of the teaching load is negative on both industrial and public funding in the general regression, it turns actually positive in the equations considering only biomedical research and engineering and in the two stage procedure. Moreover, it is worthwhile reminding the positive effect of the number of Ph.D students in the first stage of the two step procedure, i.e. as an explanatory variable of scientific output. This might suggest that – at least in engineering and biomedical departments – teaching is an important channel around which collaboration with industry is built and developed, while an emphasis on post-graduate teaching is complementary to good scientific research within the departments.

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Table 1: Private funding to academic research and revenues from research contracts as a % of total funding for academic research by scientific discipline. Academic year 1994-95

	Private funding	Research contracts
Mathematics	1.03	2.02
Physics	1.24	4.44
Chemistry	3.2	9.47
Geology and environmental sciences	3.04	8.45
Biology and biomedical sciences	4.93	6.69
Medicine	7.39	14.47
Agriculture	2.45	12.68
Civil engineering and architecture	2.23	14.87
Industrial Engineering	6.95	17.82
Information Technologies	3.22	10.38
Arts and Literature	3.55	2.92
History and Philosophy	0.99	2.87
Law, political and social sciences	0.37	2.59
Economics and statistics	5.56	5.28

Source: CRUI

Table 2: Private funding to academic research and revenues from research Contracts, per professor, by scientific discipline (ml Liras) (academic year 1994-95)

	Private Funding	Research contracts
Mathematics	0,1351	0,2642
Physics	0,3353	1,1997
Chemistry	1,0102	2,9871
Geology and environmental sciences	1,0071	2,7963
Biology and biomedical sciences	0,8331	1,13
Medicine	1,6627	3,258
Agriculture	0,9126	4,729
Civil engineering and architecture	0,6068	4,0373
Industrial Engineering	2,6036	6,6761
Information Technologies	1,3014	4,196
Arts and Literature	0,3547	0,2918
History and Philosophy	0,1022	0,297
Law, political and social sciences	0,0416	0,2888
Economics and statistics	0,9704	0,9213

Source: CRUI

TABLE 3	TOP 15 UNIVERSITIES IN TERMS OF RESEARCH CONTRACTS AND TOTAL FUNDING FOR RESEARCH (% OF THE TOTAL) YEAR 1995		
	Contract research		TOTAL FUNDING
Milano Politecnico	9,2	Padova	9,3
Napoli I	8,7	Roma I	8,2
Milano Statale	7,9	Bologna	6,4
Torino	7,2	Genova	5,3
Roma I	6,6	Milano	5,1
Bologna	6,1	Napoli I	4,5
Pavia	3,9	Firenze	4,3
Catania	3,7	Torino	3,8
Firenze	3,5	Catania	3,5
Genova	3,3	MilanoPolitecnico	2,8
Padova	3,3	Bari	2,7
Torino Politecnico	3,1	Pavia	2,7
Palermo	3	Torino Politecnico	2,6
Perugia	2,9	Cagliari	2,5
Cagliari	2,9	Palermo	2,5

Source: CRUI

Table 4 Top 10 Departments in terms of research contracts (% of the total). Academic year 1994-95

Production materials engineering	Naples 1	2.2
Electronics and information	Milan Polytechnic	2.1
Sciences and technology of animal productions	Catania	2.1
Structural engineering	Milan Polytechnic	1.6
Electronic and biophysical engineering	Genova	1.6
Legal medicine	Pavia	1.5

Table 5: Industrial and public funding of academic research: all departments

Random-effects tobit regression

	RESCON	40%	60%
ITAPUB	.1226854	-.1200683*	-.1596***
	(.18883)	(.0688)	(.0522)
INTERPUB	.7672087***	.518702***	.85462***
	(.2244)	(.0681)	(.0598)
PROF	1.705398***	2.513701***	2.8126***
	(.44809)	(.1226)	(.1042)
ADTECH	.6567993***	.156881**	.17311***
	(.2438)	(.0745)	(.0649)
STUD	-.0070056***	-.00126***	-.0014***
	(.0017)	(.0004)	(.0003)
PAT	-8.322178***	5.491348***	-7.067***
	(3.409)	(1.2542)	(1.083)
PATres	97.59456***	-44.44164***	134.42***
	(43.7559)	(16.1426)	(14.2103)
PATres2	.0874427***	-.0649485***	.0663***
	(.0409)	(.0150)	(.0129)
MANEMP	.0013019	-.0003044	.0057***
	(.0015)	(.0005)	(.0004)
MANEMPRES	.00004*	-8.09e-07	-.0010***
	(.0001)	(6.35e-06)	(5.88e-06)
MANEMPRES2	-.128032	-.0122336	-.1126***
	(.0225)	(.0088)	(.0076)
POPPROV	.00000702	-1.93e-06	.00004***
	(.00007)	(.00002)	(.00001)
CONSTANT	-595.6655***	22.9397	30.31007
	(198.68)	(28.7422)	(25.6309)
DUMMIES UNIVERSITIES	YES	YES	YES
Nr of observations:			
uncensored	1359	2166	2608
left-censored	1202	671	387
right-censored	0	0	0
Wald chi2(54) =	379.33	1347.36	3505.97
Log likelihood =	-9897.1929	-13023.872	-15040.098
Prob > chi2 =	0.0000	0.0000	0.0000

Table 6: Industrial and public funding of academic research: biomedical and engineering departments

Random-effects tobit regression

	RESCON	40%	60%
ITAPUB	-.0441418	-.0879162	-.0991645**
	(.2358)	(.09008)	(.0499)
INTERPUB	1.046139***	.2557905***	.3818962***
	(.3661)	(.1145)	(.0774)
PROF	3.416635***	3.511103***	3.624748***
	(.9774)	(.2733)	(.1800)
ADTECH	2.012322**	.3236912	-.06938
	(.9390)	(.2583)	(.1680)
STUD	.012434***	.0028727***	.0013365**
	(.0033)	(.0009)	(.0006)
PAT	-5.98947	3.831608**	-4.606944***
	(5.2576)	(1.978)	(1.296)
PATres	64.87395	-21.16333	102.1559***
	(67.77185)	(25.7344)	(17.2019)
PATres2	.0519304	-.0388867	.04574***
	(.0634)	(.023819)	(.0155)
MANEMP	.0010622	-.0008265	.0041839***
	(.0020)	(.00074)	(.0005)
MANEMPRES	3.09e-06	.000021**	-.0000318***
	(.00003)	(.00001)	(7.22e-06)
MANEMPRES2	-.0041568	-.0008265	-.0951272***
	(.0344)	(.0007)	(.0095)
POPPROV	-.0000388	.0000869***	.0000816***
	(.00007)	(.00003)	(.00002)
CONSTANT	-130.9066	-166.8282***	-25.08835
	(184.245)	(57.339)	(40.3537)
DUMMIES UNIVERSITIES	YES	YES	YES
Nr of observations:			
uncensored	827	950	1215
left-censored	384	339	190
right-censored	0	0	0
Wald chi2(46) =	259.98	748.99	1914.48
Log likelihood =	-5939.6276	-5736.846	-6723.2869
Prob > chi2 =	0.0000	0.0000	0.0000

Table 7: Two step regressions. First step: International and Italian publications.

Random effects probit regressions

	All departments		*Engineering and biomedical*	
	INTERPUB	ITAPUB	INTERPUB	ITAPUB
IATAPUB-1		.0520143***		.0927395***
		(.0097802)		(.0226269)
INTERPUB-1	.048073***		.0900025**	
	(.0115844)		(.0338729)	
PROF-1	.0196165*	-.0093172	-.0137709	-.0397754*
	(.0107068)	(.0073453)	(.0336306)	(.0146009)
ADTECH-1	.0733328***	.0238032	.0948199	.0388331*
	(.0235093)	(.014775)	(.0613792)	(.0222776)
STUD	-.0000638	.0000439*	-.0000295	.0000495
	(.0000233)	(.0000228)	(.0000784)	(.0000396)
PAT	-.0611024	-.0953281**	-.0625075	-.0625075
	(.0310899)	(.0292342)	(.0918476)	(.0918476)
PATres	.3169842	.7583586**	-.7422853	-2.703586
	(.4903617)	(.2779931)	(1.719834)	(2.379852)
PATres2	.000888**	.0013075	.0011798	.000797
	(.0003911)	(.0003904)	(.0012017)	(.0011585)
MANEMP	.0000129	.0000277***	5.30e-07	-.0000218
	(9.41e-06)	(6.50e-06)	(.0000305)	(.0000213)
MANEMPRES	-2.18e-07**	-4.39e-07***	-3.81e-07	-2.72e-07
	(1.25e-07)	(1.11e-07)	(4.32e-07)	(3.84e-07)
MANEMPRES2	.000209		.0013022	.0026596
	(.000296)		(.0012476)	(.0017746)
POPPROV	-9.10e-07**	-9.09e-07**	-3.27e-06	-4.82e-06
	(5.44e-07)	(2.94e-07)	(2.32e-06)	(3.28e-06)
Ph.D	.0067008***	-.002054	.0053375	.0021518
	(.0022761)	(.0018133)	(.0071765)	(.0036403)
CONST	.7795642	1.974315***	4.333203*	4.657876*
	(.7186375)	(.516898)	(2.605921)	(2.825498)
Nr of observations:	771	1079	490	488
Wald chi2(12)=	50.07	46.15	10.13	25.88
Log likelihood =	-347.59335	-182.12053	-107.2557	-90.895703
Prob > chi2 =	0.0000	0.0000	0.6042	0.0112

Table 8: Two step regressions. Second step: Industrial funding. All departments

Random-effects tobit regressions

	All departments	***Engineering and biomedical***
	RESCON	RESCON
PREDINTBUB	1041.151***	1479.698***
	(118.6536)	(495.0128)
PREDITAPUB	93.30122	281.5095
	(208.6662)	(171.4219)
PROF	-1.376468*	5.671015***
	(.7835169)	(1.57543)
ADTECH	5.759218	1.938105
	(1.208127)	(1.9436)
STUD	.0096612***	.01673***
	(.0027373	(.0045707)
PAT	-9.838623***	-11.05003*
	(3.440803)	(5.006576)
PATres	102.1889 **	166.4104**
	(46.63674)	(67.04316)
PATres2	.1171386***	.1140949*
	(.0441413)	(.0642589)
MANEMP	.0037232***	.005128**
	(.0013943)	(.0020096)
MANEMPRES	-.0000502***	-.0000619***
	(.0000166)	(.0000233)
MANEMPRES2	-.0284397	-.0849876*
	(.0318209)	(.0466049)
POPPROV	-.0000567	-.0000208
	(.0000467)	(.0000657)
CONS	-1082.582***	-1784.536***
	(241.2517)	(523.7468)
Observations:		
uncensored:	511	312
left-censored:	411	125
right-censored:	0	0
Wald chi2(12) =	187.75	102.28
Log likelihood =	-3728.8616	-2270.4756
Prob > chi2 =	0.0000	0.0000