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The complex effects of academic engagement on research productivity: Evidence from Italy

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Abstract

The academic systems In several countries are having to adapt to a complete reorganization of research funding sources, and cope with the consequences of progressive cuts in public funds and increasing engagement in commercial contracts with both the private and public sector. Universities are promoting the so-called third mission and encouraging and regulating university-industry collaboration agreements, in an attempt to balance the benefits deriving from access to new sources of research funding, and spread the results of academic research to the community, with the risk that commercial activities may distract academics from teaching and research. In this paper we analyse the concurrence of different types of funding for academic research and investigate whether and how research funding, in particular funding from research contracts and consultancies, influences research performance, in terms of both publication and citation numbers. We also analyse the impact of internal university regulation of knowledge transfer activities on university research performance. The empirical evidence is based on original longitudinal data for the period 2006-12 on scientific productivity and research funding for 60 Italian public universities and 275 groups of

departments classified by OECD scientific area.

Jelcodes:O38,O30

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Abstract

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JEL classification: I23, L31, O32, O33.

Keywords: university funding, knowledge transfer, scientific productivity, research performance, publications, academic regulation**.**

1 Introduction

The increasing scale of the costs associated with current university research and the growing reliance on knowledge in production processes have shed light on the magnitude of the phenomenon of university-industry collaboration and created strong incentives for more efficient ways to transfer scientific discoveries from academia to business (Butera 2000; Muscio 2010). Many universities are engaging in "third mission" activities through increased interaction with the private sector, and technology transfer (Etzkowitz et al. 2000; Florida and Cohen 1999; Gulbrandsen and Slipersæter 2007). The increased attention being devoted to university-industry interactions and to the commercialization of academic research results in general, has not been without controversy. Few studies take the perspective that collaboration is good for science since it can enable researchers to actively seek ideas from industry and shape their research agendas accordingly (Lee, 2000). However, fears that increasing commercialization of academic science might restrict the free circulation of ideas within academia are widespread (Breschi et al., 2007).

Collaborating with industry constitutes a discretionary activity for academics, and is characterized by complex patterns of knowledge exchange (Meyer-Krahmer and Schmoch, 1998). For numerous reasons, researchers may decide to engage (or not) in technology transfer activities (Tartari and Breschi, 2012) and their decisions will be shaped by institutional conditions, the incentive systems in place and individual perceptions of the potential benefits and costs of collaboration (Owen-Smith and Powell, 2001). However, as Perkmann et al. (2013) suggest, there is a lack of understanding about the consequences of academic engagement:

"Evidence on the impact of [...] collaborations on other university activities, such as research and teaching, is scarce so it cannot be assumed that engagement activities are always

beneficial and should therefore be promoted. […] A better grasp of the causal relationship between engagement and research performance is crucial for designing policy interventions. If engagement spurs research performance, it is obvious that engagement should be promoted if policy-makers wished to promote better research." (Perkmann et al., 2013: 432)

Despite the growing pressure on universities to engage in more commercially oriented and "entrepreneurial" research activities (Clark, 1998; Geuna and Muscio, 2009), driven by policy concern to improve the contribution of science to society, studies investigating the determinants of research performance are gradually receiving more attention, both at the level of the individual researcher and at more aggregate levels (Hottenrott and Lawson, 2013; Kelchtermans and Veugelers, 2011). This increased attention stems from the observation that while public funding remains the predominant source of funding for university research, the share of direct government funding is decreasing over time, compensated by dramatic increases in the share of competitive and industrial funding (Muscio et al., 2013; OECD, 2010). Despite this increase in academic research sponsorship from the private sector, empirical evidence on the effects that this shift in academic activities from being government-funded to being business-funded is having on research performance, is still scarce. Also, to our knowledge, there is no discussion in the literature of the effects that the widespread changes in university governance which are taking place to accommodate academic involvement in third mission activities, are having on research performance.

Taking stock of the literature leads to the conclusion that the arguments in favour of and against the increasing weight of academic engagement in university account are balanced (Auranen and Nieminen, 2010), and some scholars are arguing that funding shifts should not have a huge effect on actual research practices and publication behaviour (Behrens and Gray, 2001; Van Looy et al., 2004). Building on these arguments, this study investigates two research hypotheses:

- We first analyse the concurrence of different types of funding for academic research and investigate whether and how research funding, in particular, funding from research contracts and consultancies, influences research performance, in terms of both publications and citations;
- While there is emerging evidence on the impact of university policies on the intensity of academic engagement (Caldera and Debande, 2010; Muscio et al., 2014), we know little about the impact of university commitment to academic engagement on research performance; therefore, we analyse the impact of universities' internal regulation of knowledge transfer activities on university research performance.

Based on extensive data on research performance, university funding and regulation policy, we investigate how different sources of funding and internal governance and regulation influence research intensity in the Italian academic system. The Italian university system constitutes a perfect case to test our hypotheses. For many years, the Italian academic system has relied on a fully public and highly centralized governance structure with low levels of university autonomy and a key role played by the state (Capano, 2000). Initiatives to support knowledge transfer have been lacking, but political pressure to transfer the results of academic research has increased, with an emphasis on the development of university plans to support the "commercialization" of scientific research (Muscio et al., 2014). This has led many Italian academic institutions to enact a "regolamento contoterzi," which, in different ways and to different extents, regulates the several aspects of knowledge transfer activities, and establishes the rules related to research contracts and extramural consultancies. At the same time, there has been a gradual increase in research funding from private sources, whose effects on research productivity are still unknown.

Finally, in contrast to much of the recent empirical literature in the area of academic research performance, our paper presents a fine-grained analysis of our research hypotheses which takes account of a large share of the population of academic institutions in a given research system at the level of the individual scientific areas identified in the Frascati manual (OECD, 2002).

2 Theoretical background

2.1 University funding and research productivity

Due to budgetary pressures and the perception that universities and public research institutions are central components of the national innovation system, political pressure to use university funding productively has increased in recent years (Geuna and Muscio, 2009). Shrinking national public research funding to academic institution has led researchers in many countries to search for other sources of funding. This has resulted in a shift towards private sponsorship in most OECD countries (OECD, 2010) and increasing competition for competitive research grants. However, there is little evidence on the impact of third-party funding on productivity (Bolli and Somogyi, 2011). The evidence that does exist is ambiguous and further research is required to formulate effective policy-measures.

Competitive funding increasingly is seen as a mechanism to reward and, thus, provide incentives for the most able researchers (Hottenrott, and Lawson, 2013). There is evidence that research grants awarded to individual researchers have a positive effect on individual productivity (Lee and Bozeman, 2005) although the intensity of these effects varies depending on the career stage (Arora and Gambardella, 2005) and the amount of funding (Godin, 2003). Defazio et al., (2009) find that competitive funding is important for research to the extent that it has a more significant direct influence on researcher productivity than collaboration within the networks promoted by research schemes such as the European Framework Programmes. These findings suggest that although the structure of collaboration changes in relation to the funding, it requires time to develop collaboration structures that are effective for enhancing researcher productivity.

The effect on research productivity depends also on the administrative constraints and the monitoring intensity of donors (Bolli and Somogyi, 2011). The amount of time the researcher devotes to administration can reduce scientific productivity, especially if the amount/frequency of commercial activity is high.

The literature concerning the impact of industry funding on research productivity is mixed. According to Perkmann et al. (2011), what is important is how faculty quality relates to industry involvement and, therefore, whether the universities with the most successful researchers are also those institutions that interact the most with industry.

Quaglione et al. (2015) investigate the relationship between commercially driven university activities and publicly funded basic research, measured by department-level funding. They find significant evidence of substitution effects between externally funded applied activities and public funding of basic research programmes of national interest. However, there are some differences between different scientific fields, with more evident substitution effects for life sciences academic departments. These findings are in line with those in Blumenthal et al. (1997), according to which faculty members who obtain industry funding for research are also more likely to take account of commercial considerations when choosing research topics, suggesting that industry involvement does influence academic research agendas (Larsen 2011). However, as noted in Lee (2000), in many scientific fields with higher proportions of more 'applied' science, much research would be impossible without the contributions provided by industry partners. For instance, in areas such as engineering, securing funds for equipment and research assistants is the principal reason for collaborating with industry, leading to more autonomy and flexibility for academic researchers.

Muscio and Vallanti (2014) found that for those academic departments that interact with industry, collaboration is a key source of funding for the department, and contributes to advancing research in an industry context and solving industry problems, thereby creating long-term relationships with business partners. The authors provide some support for Gulbrandsen and Smeby (2005), which stresses that collaboration with industry has positive effects on academic research and improves the performance of researchers without necessarily being detrimental to their careers. Along similar lines, some authors maintain that many university researchers are motivated to interact with the business sector for reasons other than access to additional research funding, for example, to find ideas for potential research (Agrawal and Henderson, 2002). This leads to the conclusion that the existence of industry collaboration complements academic research. Mansfield (1995) shows that a substantial number of university research projects grow out of consulting activities within firms. Thus, through the provision of additional grants and experience of real-world problems, industry sponsorship could increase the marginal benefits associated with public grants.

This empirical evidence supporting the hypothesis that industry funding is good for academic research is counterbalanced to an extent by work that highlights the potential negative effects deriving from the increasing engagement of academia with industry. Some studies show a consistent negative correlation between the share of industry grants and publication rates (Hottenrott and Thorwarth, 2011), and that researchers who report industry as a source of research ideas, publish less than their peers who obtain research ideas from other sources (Hottenrott and Lawson, 2013). Blumenthal et al. (2006) and Czarnitzki et al. (2015) find that industry may steer researchers towards applied research, and limit or delay publication. This could have a negative effect on the marginal benefits associated with public funding (Manjarres-Henriquez et al., 2009; Banal-Estanol et al., 2015), slowing the dissemination of preliminary results and endangering the practice of “open science” (Dasgupta and David, 1994). Geuna and Muscio (2009) point out that the question of whether stronger connections between university and industry are challenging the culture of open science in universities and shifting attention away from research to applied activity, deserves further study.

There are signs that the pendulum has swung too far to the side of policies encouraging commercialization, to the point that the open-science culture of universities and their reputation for good basic research is being endangered (David 2004; Nelson 2004; Geuna and Nesta 2006). While there is some preliminary evidence that researchers who receive external funding outperform their colleagues who do not acquire external finance (Kelchtermans and Veugelers, 2011; Banal-Estanol et al., 2015) and, thus, that industry funding might be a good for the advancement of science, others are investigating whether industry sponsorship accelerates or compromises the positive effect of public research funding (Hottenrott and Thorwarth 2011; Banal-Estanol et al., 2015). This body of work concludes that, given the growing weight of industry grants on research budgets, studying the effects of public funding on research output may require that these types of funding channels are taken into account. While access to multiple funding sources facilitates resource-intensive research (Hottenrott and Lawson, 2013), there is some early evidence that larger shares of research funding from industry are associated with diminishing publication rates (Manjarres-Henriquez et al., 2009; Hottenrott and Thorwarth, 2011; Banal-Estanol et al., 2015). In other words, industry funding might decrease the marginal utility of public funding by decreasing the publication and citation rate increase associated with public grants (Hottenrott, and Lawson, 2013). Banal-Estañol et al. (2015) show that the effect of collaboration with industry on scientific productivity depends on the degree of collaboration. According to these authors, the number of publications increases both with the presence of government funding and with the fraction of government funded research carried out in collaboration with industry, but only up to a certain point. For levels of collaboration above 30%–40%, research output declines. These results confirm other empirical works (Manjarrés-Henríquez et al. 2009; Larsen, 2011) showing that complementarities with research productivity exist only for moderate levels of knowledge transfer engagement. Finally, Rentocchini et al. (2014) investigate the effects of consulting on the scientific productivity of academic scientists and find that its intensity depends on the scientific fields and the amount of engagement in consulting activities. The authors find that academic consulting is negatively correlated with number of publications in the fields of Natural and Exact Sciences and Engineering, but not Social Sciences and Humanities. Moreover, engaging in consulting activities is negatively correlated with scientific productivity only for high levels of involvement in consulting activities. Following these arguments, we argue that:

Hypothesis 1: academic involvement in research contracts and consultancies has a positive effect on research productivity. but this effect does not extend to all scientific areas.

2.2 University governance and research productivity

There are several papers that focus on the various forms of interaction between industry and academia (Agrawal and Henderson, 2002; Cohen et al., 2002: D'Este and Patel, 2007; Bekkers and Bodas Freitas, 2008; Muscio and Pozzali, 2013) and some study the effect of these interactions on research outcomes (Blumenthal et al., 1996; Gulbrandsen and Smeby, 2005; Hottenrott and Thorwarth, 2011; Banal-Estanol et al., 2015). Against the background of increased commitment of academic institutions to collaborate with industry, there is substantial agreement in the economic literature that governments need to introduce measures to foster and facilitate knowledge transfer (Muscio et al., 2014). Recent policies in several countries encourage universities to play an active role in the commercialization of academic knowledge (Siegel et al., 2007; Bercovitz and Feldman, 2006), but they raise questions about the compatibility between the 'disinterested' pursuit of science (Merton,

1973) and the industrial application of academic research. Moreover, industry involvement may require specific skills and organizational capabilities that differ from those required to excel in academia (Bercovitz and Feldman, 2008) and which may need to be supported by explicit policy intervention.

Universities responsibilities are being redefined and expanded (Etzkowitz et al., 2000), but the effects of the reorganization in university governance of traditional activities, such as teaching and research, to accommodate the increased commitment to third mission tasks, are not clear. Geuna and Muscio (2009) argue that university managers need to be aware of the conflict between promoting university–industry partnerships when potentially successful pre-competitive university research is in danger of not being developed or commercialized by industry, and ensuring that the dissemination of innovations financed by public funds is not being constrained by private interests.

Empirical evidence on the attention being paid at the institutional level to academic engagement is scarce (Muscio et al., 2014). A few studies investigate the importance of regulation and the adoption of a strategic institutional approach to the commercial valorization of university research (Siegel et al., 2007). The effectiveness and performance of knowledge transfer depends on the interplay among different elements at various levels (Muscio and Pozzali, 2013): the country- or regional-system level (Edquist, 2005); the institutional level, which explains differences among universities operating within the same system (Di Gregorio and Shane, 2003); and the individual level (Bercovitz and Feldman, 2008). The institutional level is especially relevant from a political viewpoint, since it involves strategic decisions and a governance design aimed at promoting and regulating knowledge transfer activity, and motivating faculty members to engage in interactions with non-academic organizations.

University policies and university governance aimed at fostering academic engagement range from establishing a knowledge transfer infrastructures to rewarding individual faculty members and managing conflicts of interest. However, it could be argued that there is a risk that institutional encouragement to engage in third mission activities might distract scientists from scientific production *per se*. Despite the complexity of the sets of rules being formulated by academic institutions to regulate and foster university-industry interaction, and their impact on knowledge transfer activity (Caldera and Debande, 2010; Muscio et al., 2014), the evidence on the effects of university governance on scientific productivity is limited. Although it would seem inevitable that university policies and norms regulating university-industry collaboration will have an impact on the intensity of the interactions between researchers and businesses, we lack evidence on the effect of universities' commitment to these activities on research productivity. We argue that:

Hypothesis 2: university policies and norms that regulate university-industry collaboration have a negative effect on academic research productivity.

3 Empirical analysis

3.1 Data and variables

The empirical analysis is based on three main sets of data:

1. Data made freely available by the Italian Ministry of University and Research (MIUR) which provides annual department-level information on the volume and sources of academic funding and the composition of research staff. The data are available in a standardized format for the period 2005–2011. The MIUR database includes 2406 academic departments and institutes in 64 public universities (including 4 polytechnic universities). We selected departments with financial data for at least three consecutive

years. Each academic institution's departments are grouped according to their main scientific research area, based on the six areas in the Frascati classification (OECD, 2002; 2007).

2. Data from the Thomson Reuters Web of Science database. We collected all journal publications listed in this database at the university level in each year. Each publication source, that is, the journal, is associated in the Thomson database to one or more scientific areas. First, we grouped the Thomson scientific areas in macro reference areas based on the Frascati classification (OECD, 2002, 2007), and then associated each journal publication to one or more Frascati areas. If a publication was associated with two or more Frascati areas, we weighted each publication equally across areas. This allowed us to build a dataset of publications by university scientific area *i* at time *t*. We used the above procedure to associate citations to scientific areas,; However, data extraction provided us with the total number of citations for each publication at the date of the download (January 2015), representing the situation at 31.12.2014. This required us to estimate the annual (average) number of citations received by each publication up to 31.12.2014.[1] The citations refer to a scientific area in a given year and our calculation was based on the sum of the annual average citations for each publications belonging to that particular scientific area, published in that year.

3. We obtained data from a questionnaire survey addressed to the central administrations of all Italian public universities. From the 64 questionnaires administered we received 61 completed questionnaires. The survey was conducted between end 2012 and early 2013 and asked for information on current university knowledge transfer policies as described in the "regolamento conto-terzi", and the year of their adoption. These strategic

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[1] E.g. the total number of citations for items published in 2007 was divided by 7, the total number of citations for items published in 2008 was divided by 6, and so on up to the items published in 2013 which were divided by 1.

documents describe academic engagement activities and set specific rules of conduct related to various aspects including incentives for academic staff, conflicts of interests, withholding of revenue from the central administration, etc. The formats used by universities are relatively similar.

We matched the data obtained from these three sources and excluded universities without three consecutive years of data, in order to create an original longitudinal dataset of 60 Italian public universities[2] and 275 groups of university departments classified by scientific area. To test our research hypotheses we rely on two dependent variables to proxy for scientific productivity: number of publications of university scientific area *i* at time *t*, and number of citations of university scientific area *i* at time *t*. The main set of independent variables refers to research funding. We distinguish between two main sources of funding: public funding and finance from academic engagement. Other controls include information on research (p_research, p_young_sh) and administrative staff (p_staff). We control for the innovativeness of the region in which the university is located by including a provincial (NUTS III) level variable, measuring the number of European Patent Office - EPO patent applications per inhabitants (pat_inhab). Table 1 provides a description of the variables.

Table 1 Data source and definitions.

<TABLE 1 HERE>

[2] Italy currently has 71 state universities and 15 private universities. There are another 11 universities that offer primarily online courses.

Table 2 reports the distribution of university groups of departments across Frascati scientific areas. Most are in the social and natural sciences - 20% and 19% respectively of the total population. Engineering and technology, Medical and health sciences and Humanities each account for about 16%, while Agricultural sciences is the smallest area, with 31 cases representing 11% of the population.

Table 2 Sample composition filed by scientific area.

<TABLE 2 HERE>

3.2 Recent changes in research funding in Italy

Figure 1 depicts trends in per capita research funding in Italy during the period 2005-11. It takes account of the four major sources of academic funding for research in Italy. Three of these are public sources (see Table 1), and the fourth includes funding earned from competitive research contracts and consultancies with public and private organizations. Figure 1 shows that in 2005 MIUR provided an important share of funding to university departments, amounting to almost 20% of the entire research budget. In 2009 this amount reduced by 26% to roughly 12.5% of the research budget. Funding from other public bodies and from the European Commission (EC) grew steadily over the period considered. In particular, EC funding via competitive programmes, such as the Framework Programmes, increased by 93% over the period considered. Finally, funding from research and consultancy contracts with the private and public sectors increased over the period 2005 to 2011 , although its growth came to a standstill after 2008, in the years of the world economic crisis. This growth in earnings from research contracts with the private sector is confirmed by Muscio and Vallanti (2014), who provide evidence of a relevant increase in the frequency of university–industry research collaborations over the period 2004-2007. It is worth noting that over the six-year period considered, while the number of research staff remained fairly stable, the number of junior researchers (PhD and Post-doc) increased substantially.

Figure 1 University funding, 2005–2011 (Euros, mean values).

<FIGURE 1 HERE>

3.3 Econometric specification

We investigate the following empirical specification:

$$\text{SciProd}_{it} = \beta_1 \text{Funding}_{it-1} + \beta_2 \text{Controls}_{it-1} + \beta_3 \text{Regulation}_{it-1} + \tau_t + \alpha_i + \varepsilon_{it}$$

Following the usual approach in the literature, the independent variables are lagged once, allowing some time for the received funding to be exploited in published output (Muscio et al., 2014). Given that MIUR data are available for the period 2005-2011, we collected data on university research productivity for 2006 to 2012. Therefore, our analysis is conducted on a longitudinal dataset of all Italian public university departments from 2006 to 2012. Table 3 reports the descriptive statistics.

Table 3 Descriptive statistics.

<TABLE 3 HERE>

In addition to explanatory variables for funding, staff and territorial innovativeness, the model includes the unobserved time-invariant individual effect (α_i), year dummies (τ_t), and an error term (ε_{it}). By including individual specific effects we are able to control for unobserved (time-invariant) factors which might be related to a university department's publishing capability , such as university size, location in a polytechnic university, presence of a medical school at the university, geographical location in Southern Italy or elsewhere. Given the nature of our dependent variables, which are count variables and are non-linearly distributed, we employ a panel Poisson fixed effects model. There are a number of reasons for this choice. Figure 1A shows clearly that in the university aggregate form the number of publications and citations is Poisson-distributed. Table 3 shows that our data is over dispersed. Despite this over dispersion, the results from Poisson panel estimators with clustered-robust standard errors are more reliable than the results obtained by employing a negative binomial, which is designed to account for over dispersion, but imposes a higher level of assumptions on the variables distribution (Cameron and Trivedi, 2009: 627). Also, in contrast to the negative binomial, the Poisson estimator, allows the inclusion of fixed effects without incurring the incidental parametral problem. Also, Poisson fixed effects models do not suffer from incidental parametral bias (Greene, 2007). Finally, the fixed effects model, as proposed by Hausman et al. (1984), when applied to a negative binomial is not a true fixed effect (Allison and Waterman, 2002).

3.4 Results

Table 4 presents the results of the relationship between the source of funding and the number of publications. In specification (1) the results are at the aggregate level of universities, while specifications (2) to (7) report the results for the six Frascati scientific areas. Following Banal-Estanol et al. (2015), we hypothesize a parabolic relationship between funding from academic engagement and scientific performance, therefore, we introduce in the model the quadratic term of the variable f_acadeng. At the aggregate level, we do not observe a significant relationship between funding from commercial sources, and the number of publications. However, we find a significant impact of public funding (f_public) and number of research staff. Disaggregating across the six Frascati areas, the results become more heterogeneous. First, while public funding is positive in some cases and negative in others, its effect on research productivity is never significant. This might be due to data limitations since, typically, public funding tends to have longer term effects that cannot be fully accounted for in our data.[3] Conversely, the effect of commercial funding emerges as playing either a positive or a negative role, depending on the scientific area. The effect of commercial funding shows a U-shaped relationship with number of publications in the fields of Medical and Health Sciences and Humanities, and an inverted U-shaped relationship for Engineering and Technology. In the specific cases of Medical and Health Sciences, and Humanities, it is worth noting that day-to-day, low cost commercial activities, such as lab testing, do not involve research tasks and are regulated by pre-agreed price lists, while more-generously funded activities normally involve research projects, which can increase scientific productivity. Finally, in the field of Natural Sciences the effect is negative and significant only for high levels of commercial funding.

The effect of regulation *per se* (reg_ct) is negative at the aggregate level and in the fields of Natural Sciences, Medical and Health Sciences, and Social Sciences. As suggested in Bolli and Somogyi (2011), in these scientific fields, the presence of a regulatory framework increases the administrative burden , which has a negative impact on the time and resources that can be allocated to research tasks. In our view, reducing the freedom to define the terms of commercial contracts, although beneficial to academic engagement, hampers productivity adding bureaucracy to the management of contracts, thereby reducing the time and effort that

[3] The structure of our data does not allow us to take account of more than a 1-year time lag without considerable loss in the number of cases in the sample.

can be dedicated to publishing. In particular, in the case of Natural Sciences and Medical and Health Sciences, research contracts and consultancies tend to involve intellectual property, which cannot be disclosed in publications without ad hoc arrangements with partners. At the same time, the adoption of rules regulating conflicts of interest between research and teaching duties and academic engagement, have a positive and significant impact on research productivity (reg_conflict) in the above-mentioned fields and in Humanities. The results show also that, at least at the aggregate level and in some areas such as Natural Sciences and Engineering and Technology, there are some scale effects deriving from university size (p_research) with larger research groups being more productive, and a positive impact of younger scholars (p_young_sh).

Table 4 **Impact of funding and regulation on research productivity.**

<TABLE 4 HERE>

Table 5 presents the results of the impact of funding and regulation on research quality, measured by the average annual number of citations. Table 5 shows that, at the aggregate level (specification 1), we observe no effect of different sources of funding on research quality. The only significant variable is number of research staff, which confirms the presence of scale effects in research performance. Disaggregating the analysis according to the six Frascati areas changes the picture. Engineering and Technology show an inverted U-shape for commercial funding, while for Natural Sciences we find a negative effect in the case of the quadratic form, indicating that at low levels of commercial funding there is no effect on publishing, while large amounts only of commercial funding have a negative effect on publication quality. Therefore, large commitments to commercial activity, at least in some areas, tend to have a tangible negative impact on research quality, lowering the impact of scientific papers published at academic institutions. In the case of Engineering and Technology, the positive effect of commercial funding is matched by the positive impact of public funding, while f_public has a negative and significant sign in the case of Social Sciences.

The adoption of a regulatory frameworks has a negative effect in the fields of Agriculture and Social Sciences. However, the adoption of conflict rules has a strong positive effect on research quality only in the field of Social Sciences. Therefore, even in terms of research quality, we can confirm that a regulatory framework increases the administrative burden, which has a negative impact on the time and resources that can be allocated to research tasks. This would seem to indicate that researchers have to shift some of their time from research activities to administrative activities. At the same time, we find evidence of a significant impact of the adoption of rules to regulate possible conflicts between academic duties and commercial activity only in the case of Humanities. In relation to the other variables of interest, number of staff is positively correlated with number of citations, in the fields of Natural Sciences and Engineering, while the share of young researchers plays an important role in Natural Sciences. Finally the degree of innovativeness of the local context is correlated with high quality of research in the scientific field of Natural Sciences and Engineering.

Table 5 Impact of funding and regulation on citations.

<TABLE 5 HERE>

4 Concluding remarks

While the breadth and depth of academic engagement with industry is growing, the effect of collaboration on research productivity and research quality has received little attention in the academic literature, which is concerned primarily with academic patenting and spin-off creation as channels of university-interaction. A few authors have suggested that engagement activities may not always be beneficial for scientific progress. Evidence on the impact of industry collaborations could be fundamental for shaping future research policy and design. In this context, this study investigated whether and how research funding, and particularly funding from research contracts and consultancies, influences research performance in relation to number of publications and citations. We also analysed the impact of internal university regulation of knowledge transfer activities on university research performance.

In contrast to much of the recent empirical literature on academic research performance, we provide results for the impact of regulation and funding on research performance of a large number of academic institutions in Italy, a relatively well-established national research system To our knowledge, this is the first analysis at the level of the six scientific areas identified by the OECD.

The results presented in this paper lead to the conclusion that the complexity of the relationship between commercial and public funding, and the scientific productivity of universities has been greatly underestimated. While we find scant evidence of a significant impact of public funding on research productivity, which is to be expected given the long-term impact of this kind of funding on publication outcomes that cannot be measured with our data, our results shed light on the complexity of the impact of funding from academic engagement on publication performance and publication quality.

We find that the impact of funding from commercial sources varies across scientific areas. We show that Natural Sciences and Engineering and Technology are the only scientific areas where the impact of commercial funding is consistent - in terms of both research productivity and quality. In both areas we find evidence of an inverted U-shaped relationship with commercial funding, proving that academic engagement has beneficial effects up to a certain threshold of funding, after which the benefits of collaborating with industry and access to research funding fade and research performance decreases since it requires academics to allocate their time to contracts instead of writing papers. In contrast, in Medical and Health Sciences we find that research contracts have detrimental effects if the amounts of funding are small, but that larger amounts outweigh the administrative burden of research contracts and consultancies and increase research performance.

Overall, academic regulation of knowledge transfer activities has a wider impact on research productivity than on research quality. Many Italian academic institutions have introduced various rules on various scales to regulate the several aspects of knowledge transfer activities, research contracts and extramural consultancies. Our results show that the definition of a set of internal rules for knowledge transfer has a negative effect on productivity at the aggregate level and, in particular, in the fields of Natural Sciences, Medical and Health Sciences, and Social Sciences, which is evidence that, in some cases, protecting the university's interests in the knowledge transfer process, and guiding researchers on the their interaction with business partners can have opposite effects for the institution, at least in terms of researchers' productivity. There are some positive aspects to analysis of the impact of the rules regulating conflicts of interest between research and teaching duties and academic engagement. As expected, we find that forcing academics to comply with some minimum teaching and research responsibilities greatly increases productivity in four out of the six scientific areas investigated in this paper.

This work represents a first step in analyses of the heterogeneity in the relationship between sources of funding and scientific productivity, and how internal regulations influence this relationship. Inevitably, it has some limitations. First, a finer grained analysis that included the scientific productivity of individual members of the university departments would allow an investigation of the relationship between funding and research at the level of the university department. Our measure was at the aggregate level of Frascati scientific field, which, compared to previous work, is a quite disaggregated measure, but which aggregates various departments. Another limitation of our study is that it is impossible within the same university to identify the differences among several departments in the approach taken to traditional and commercial activity. More precisely, the predisposition of a research lab to engage in technology transfer activities might influence the department's behaviour (Bercovitz and Feldman 2008). Further in depth research is needed to capture more specific research laboratory dynamics. Finally, it should be noted that we analyse only the associations among the dependent and independent variables, but do not propose any causation effect. Thus, further research would extend this initial attempt to highlight the variations in the relationships between academic research and commercial engagement among scientific fields and might allow a better understanding of the determinants of this heterogeneity.

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Tables

Table 6 Data source and definitions.

Variable	Description	Source
publications	Number of publications for scientific area *i* at time *t*	Thomson WoS
citations	Average number of citations for publications of scientific area *i* at time *t*	Thomson WoS
f_acadeng	Volume of funding from research contracts and consultancies from public and private organisations raised in the last financial year (2005–2011)	MIUR
f_public	Research funding from the public sources: European Commission, MIUR and other national and regional governmental bodies (2005–2011)	MIUR
pat_inhab	Number of European patents granted in the administrative province (NUTS III) where the department/institute is located (2005–2011)	EUROSTAT
p_research	Number of research staff (full professors, associate professors, assistant professors, research officers) and PhD students (2005–2011)	MIUR
p_young_sh	Share of junior research staff (2005–2011)	MIUR
p_staff	Number of administrative and technical staff (2005-2011)	MIUR
reg_ct	Existence of a formal academic regulation of private contracts (yes/no)	Web survey
reg_conflict	Presence of rules regulating minimum teaching and research activity in the academic regulation (yes/no)	Web survey

Table 7 Sample composition filed by scientific area.

	Scientific areas	Number of groups	Percentage
1	Natural sciences	51	19%
2	Engineering and technology	48	17%
3	Medical and health sciences	43	16%
4	Agricultural sciences	31	11%
5	Social Sciences	56	20%
6	Humanities	46	17%

Figure 2 University research funding in Italy. Euros per research staff.

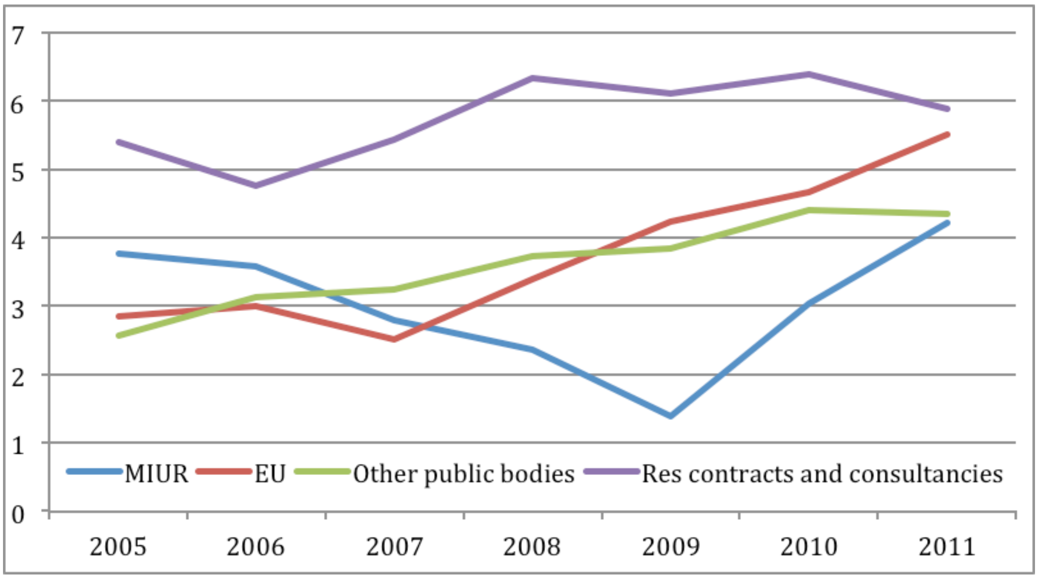


Table 8 Descriptive statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
publications	420	1174.029	1298.194	5	6778
citations	420	3521.716	4089.519	0.714	23399
f_acadeng	420	5.395	6.402	0.007	42.786
f_public	420	13.245	13.488	0.562	136.347
pat_inhab	420	73.524	65.833	0.434	332.814
p_research	420	956.798	834.563	58	4633
p_young_sh	420	0.858	0.673	0	5.207
p_staff	420	0.323	0.1568	0	1.4
reg_ct	420	0.776	0.417	0	1
reg_conflict	420	0.329	0.470	0	1

Table 9 **Impact of funding and regulation on research productivity.**

	(1) Univ Level	(2) NatSci	(3) Eng	(4) Med	(5) Agr	(6) SocSci	(7) Hum
f_public	0.00135**	-0.00251	0.00277	0.00199	-0.00477	-0.0109	-0.0149
	(0.000631)	(0.00368)	(0.00230)	(0.00269)	(0.0122)	(0.0204)	(0.0324)
f_acadeng	-0.00392	0.0239	0.0162***	-0.0255*	0.0360	0.0389	-0.338***
	(0.00891)	(0.0158)	(0.00574)	(0.0150)	(0.0943)	(0.0929)	(0.113)
f_acadeng^2	0.000201	-0.00439***	-0.000177**	0.00324**	-0.00675	0.00985	0.139***
	(0.000145)	(0.00155)	(8.95e-05)	(0.00134)	(0.0153)	(0.0290)	(0.0435)
pat_inhab	3.78e-05	-0.000271	0.000176	3.75e-05	0.000277	0.000331	-0.000591
	(0.000255)	(0.000321)	(0.000459)	(0.000226)	(0.000871)	(0.000390)	(0.000928)
p_research	0.000285***	0.000863***	0.000385	0.000379	0.000255	0.000202	0.000815
	(9.89e-05)	(0.000282)	(0.000355)	(0.000271)	(0.00126)	(0.000441)	(0.00138)
p_young_sh	0.0766*	0.0457	0.0641***	0.0211	-0.0976**	-0.0339	-0.0432
	(0.0391)	(0.0366)	(0.0209)	(0.0548)	(0.0497)	(0.0550)	(0.226)
p_staff	-0.0922	0.113	-0.320	-0.0945	-0.149	-0.460	-0.107
	(0.133)	(0.154)	(0.275)	(0.0726)	(0.217)	(0.364)	(0.537)
reg_ct	-0.0609**	-0.0505*	0.00728	-0.0735**	-0.0839	-0.0928*	-0.155

	(0.0262)	(0.0283)	(0.0339)	(0.0319)	(0.0563)	(0.0541)	(0.134)
reg_conflict	0.0691**	0.0716*	0.0436	0.0846**	-0.0328	0.173***	0.236**
	(0.0327)	(0.0380)	(0.0436)	(0.0353)	(0.0593)	(0.0550)	(0.109)
year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wald chi2	9782.21***	354.57***	860.23***	1189.36***	336.31***	2131.11***	951.96***
Observations	420	357	329	294	199	389	322
No. of groups	60	51	48	43	31	56	46

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 10 **Impact of funding and regulation on citations.**

	(1) Univ Level	(2) NatSci	(3) Eng	(4) Med	(5) Agr	(6) SocSci	(7) Hum
f_public	-0.000365	-0.00178	0.00645**	-0.00403	-0.00984	-0.0366**	-0.0176
	(0.001304)	(0.00696)	(0.00327)	(0.00315)	(0.0132)	(0.0183)	(0.0301)
f_acadeng	-0.00597	0.0449	0.0209***	-0.0194	0.0892	0.171	-0.304
	(0.00805)	(0.0284)	(0.00726)	(0.0286)	(0.131)	(0.148)	(0.259)
f_acadeng^2	0.000197	-0.00677***	-0.000166*	0.00301	-0.0157	-0.0450	0.114
	(0.000137)	(0.00252)	(9.28e-05)	(0.00259)	(0.0204)	(0.0459)	(0.0954)
pat_inhab	0.000714	0.000504	0.000188	0.000354	0.00116	0.00142**	-0.000610
	(0.000449)	(0.000729)	(0.000825)	(0.000317)	(0.00104)	(0.000625)	(0.00113)
p_research	0.000358**	0.000874*	-1.16e-06	0.000471	8.08e-05	0.000215	0.000855
	(0.000145)	(0.000475)	(0.000446)	(0.000313)	(0.000923)	(0.000589)	(0.00161)
p_young_sh	0.0295	0.0736	0.0138	-0.0113	-0.0705	-0.0210	0.0200
	(0.0672)	(0.0923)	(0.0239)	(0.0407)	(0.0543)	(0.0706)	(0.231)
p_staff	-0.443*	-0.268	-1.121**	-0.175**	0.233	-0.709**	-0.273
	(0.229)	(0.466)	(0.437)	(0.0729)	(0.174)	(0.326)	(1.216)
reg_ct	-0.0734	-0.0700	-0.0718	-0.0114	-0.288***	-0.166**	-0.133

	(0.0536)	(0.0720)	(0.0476)	(0.0475)	(0.106)	(0.0655)	(0.136)
reg_conflict	0.0567	0.0412	0.0565	0.0491	-0.0748	0.174***	0.118
	(0.0670)	(0.0882)	(0.0695)	(0.0554)	(0.116)	(0.0667)	(0.124)
year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wald chi2	2026.3***	837.17***	781324.76***	494.46***	157.03***	251.28***	1867.37***
Observations	420	357	328	293	198	389	321
No. of groups	60	51	48	43	31	56	46

Robust standard errors in parentheses

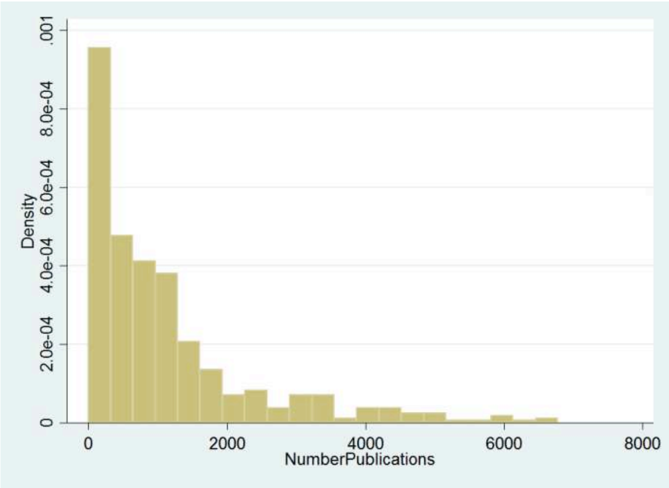
*** p<0.01, ** p<0.05, * p<0.1

Appendix

Table 11A Correlation matrix.

	publications	citations	f_acadeng	f_public	pat_inhab	p_research	p_young_sh	p_staff	reg_ct
citations	0.9774								
f_acadeng	0.7593	0.7197							
f_public	0.8172	0.7779	0.6984						
pat_inhab	0.3969	0.3935	0.3775	0.2986					
p_research	0.8693	0.8068	0.702	0.8212	0.2454				
p_young_sh	-0.0378	-0.0019	-0.0179	0.0011	0.1678	-0.1626			
p_staff	0.3869	0.3739	0.3598	0.3801	0.1138	0.4659	0.0257		
reg_ct	0.0931	0.1248	0.0799	0.0769	-0.0637	-0.0087	-0.0096	-0.1007	
reg_conflict	0.2029	0.2118	0.1375	0.1643	-0.0951	0.1694	-0.0508	-0.0253	0.4273

Figure 3A Dependent variables distributions.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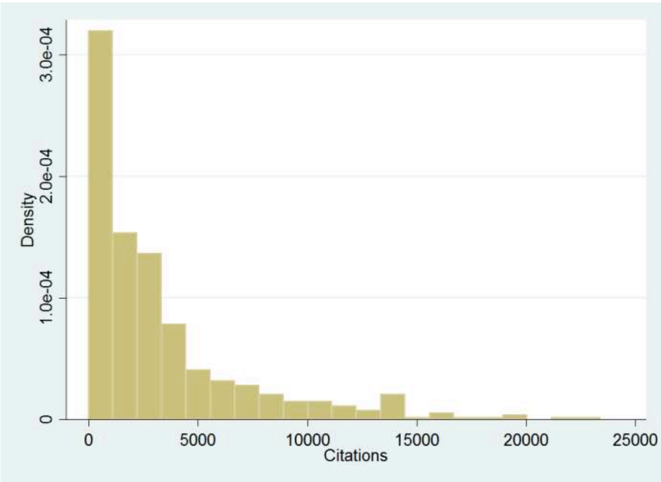
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