THE TWO SIDES OF ACADEMIC RESEARCH: DO BASIC AND APPLIED ACTIVITY COMPLEMENT EACH OTHER?

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1 INTRODUCTION

Academic institutions play a fundamental role in modern economies (Geuna and Muscio 2009), but their mission is one of the most controversial topics in the political debate over the organisation of modern innovation systems (Arnold et al. 2006). Several countries are reorganizing the management and funding of public research institutions in order to increase the production and diffusion of scientific research required for firm competitiveness and economic growth (Romer 1990). Since the early 1980s, European governments have intervened more directly in directing the research system. The different methods used have been driven by similar overall targets: developing a contract-oriented approach to university research funding, allowing indirect control of university research behaviour, by setting (quasi-market) financial incentive schemes (Geuna 1999). These policies were put in place primarily to improve the efficiency of research funding, but also to increase universities' accountability and put pressure on them to reduce their costs (Sörlin 2007). There is also additional pressure on universities to contribute actively to industrial innovation by raising research funding from industry. In fact, universities are facing an evolution characterized by greater involvement in economic and social development, more intense commercialisation of research results, increased patenting and licensing activities, institutionalisation of spin off activities and, among academics, managerial and attitudinal changes with respect to collaborative projects with industry (Van Looy et al. 2004).

The new funding rationale and the explicit external orientation of academia are feeding debate about the future of universities as economic and social institutions, at least with respect to two aspects. The pessimists believe that receipt of more industry funding for applied activity will result in the emergence of two types of problems. First, what the literature refers to as 'academic drift' (Elzinga 1985) or the 'skewing problem' (Florida and Cohen 1999). That is, academics will be forced to conduct more applied or problem-solving oriented research to the detriment of basic research, with evident negative effects on long term social benefits. The second problem is termed the 'secrecy problem', meaning that academic researchers will have an incentive to impose secrecy through strategies such as partial or delayed disclosure of research findings, which limit the socially beneficial free flow of information outwards. On the other hand, given the criticality of basic research for the production of any knowledge that eventually might be transferred to industry, there is no clear-cut evidence that performing basic research conflicts with or is complementary to performance of applied research and participation in knowledge transfer (D'Este et al. 2012).

Several scholars argue that the stronger connections between university and industry are challenging the culture of open science in academia and shifting attention from basic to applied research (Geuna and Muscio 2009). However, while the university goals of 'creating knowledge for its own sake' and 'disseminating knowledge' are the policy rationale for publicly funded (basic) research, shunning applied work and consulting activities (and their potentially successful commercial outcomes) may prevent university departments from finding solutions to practical scientific problems and transferring the results of their research (Feldman and Desrochers 2003). Perkmann and Walsh (2009) highlight that research-to-order contracts and consultancies are important, highly relational and informal knowledge transfer channels.

Building on these arguments, in this paper we investigate whether applied activities and basic research complement or substitute for each other. In particular, we assess this relationship empirically at the Italian university department level, by considering the amount of funding raised through research-to-order and consulting activities for external entities, and the public funding awarded via competitive selection processes for basic research projects of national interest.

The paper is organized as follows. Section 2 sets the theoretical background to the relationship between basic and applied research in academic institutions, and the interactions with industry. Section 3 presents the empirical results for the determinants of basic and applied research in universities. Descriptive statistics and regression models are used to analyse the data on universities. Section 4 discusses the results and their implications for policy.

2 THEORETICAL BACKGROUND

2.1 Basic and applied academic research

According to the Frascati Manual (OECD 2002, 30):[1]

[1] There was lengthy debate, which became particularly heated in the 1990s, over the categorization of R&D, aimed at assessing whether the categories of basic, applied and experimental developmental research were still representative of R&D activity. It is beyond the scope of this paper to reconstruct or discuss this debate. However, Gulbrandsen and Kyvik's (2010) discussion and conclusions are interesting; they suggest that the distinctions and categories of R&D included

Basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view. Applied research is also original investigation undertaken in order to acquire new knowledge. However, it is directed primarily towards a specific practical aim or objective.

Salter and Martin (2001) point out that publicly funded basic research includes much of the basic research conducted in universities, government research institutes and hospitals. Public research funding is provided to correct a market failure and to support scientific research that otherwise would not have been carried out because of its limited market-value. However, the boundary between public and applied research is not clear-cut since some public monies are allocated to research that is conducted through collaboration between universities and industry (Calvert 2004). There is not a straightforward relationship between basic and applied research and public and private sponsors, although there is some evidence of a significant relationship between industry funding and applied research (Gulbrandsen and Smeby 2005). Along the same lines, Hottenrott (2012) points to a complementarity between basic and applied research when professors in science and engineering try to attract research funding from industry. Also, there is often considerable mutual interaction between public and private research activities. As Calvert and Martin (2001) point out, scientists tend not to use the basic/applied terminology unless they are presenting themselves for assessment or seeking funding. Calvert and Martin draw on the findings from interviews with nearly 50 scientists and policy makers about the concept of basic research to show that scientists define their research as basic or

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in the OECD Frascati Manual are sensible and useful, although it is true that most university researchers characterise their activities as combining two or even all three of these types.

applied depending on the context. Research might be basic to the person performing it, but from the sponsor's viewpoint might be applied; thus, the distinction, in part, is a matter of perspective.

Basic research funding does not provide resources for the study and discovery of only new scientific issues. According to Callon (1994), government funding for basic research should be seen also as enabling the establishment of new networks. Funding promotes new combinations of relations between organisations and individuals, creating new forms of interaction. In contrast, market transactions exploit existing sources of variety, leading to convergence and irreversibility and locking society into particular technological options. Therefore, government actions should be aimed at breaking this cycle by providing the funding necessary to pursue new research options and countering market tendencies to exhaust existing stocks of ideas and relations. Government funding for basic research enables novel approaches to addressing and resolving technical problems by increasing the variety of scientific options that academic institutions can make available to firms.

2.2 Industry funding, university strategies and prospects for universities role and financial sustainability

In several countries public funding for universities is decreasing, and larger portions of public research funding are being assigned through competitive contracts. At the same time, science–industry partnerships are attracting much attention, and academic institutions are being pressed to serve industry needs, carry out applied research projects and leverage their business funding. In fact, initiatives supporting university-industry interactions are common. Some authors suggest that the pendulum has swung too far to the side of policies encouraging commercialisation, to the point that this is endangering the open-science culture of universities and their reputation for good basic research (David 2004; Nelson 2004; Geuna and Nesta 2006). Several scholars provide evidence of the negative outcomes of this excessive focus in research policy on knowledge transfer and the related industry funding.

From a general perspective, Geuna (2001, 626) notes that problems can arise due: to 1) increased concentration of resources; 2) disproportionate incentives for short-term foreseeable research endeavours; 3) conflicting incentive structures; and 4) exacerbation of the impact of cumulating and self-reinforcing phenomena in the process of scientific production. Florida and Cohen (1999) suggest that there is a real danger of the value of research universities being undermined if they are regarded simply as sources of technology. Industry can affect the research directions of university-industry centres (Elzinga 1985), delay publication and influence research results (Blumenthal et al. 1997).

Some authors highlight that possible undesired outcomes can derive from excessive policy pressure on universities, uncritical implementation of new institutional academic strategies which involve the search for alternatives to government funding, and increased consulting and marketing activities. Strehl et al. (2007) show that university stakeholders claim that cuts in university funding will result in less basic R&D and lower quality research.

Possible conflicts between promoting university–industry partnerships in a situation where potentially successful pre-competitive university research is in danger of being not developed or commercialized by industry, and the diffusion of innovations financed by public funds is being constrained by private interests, are underlined by Geuna and Muscio (2009). Geuna and Nesta (2006) highlight the short and long term risks of substituting short-term funds and licences by structural funds. In the short run, it is likely that the net difference in academic financial resources will be negative for the majority of institutions, and it is unclear what will be the consequences for basic research and teaching. In the long run, the cumulative effects of reduced funding are likely to exacerbate differences among universities. Universities that reap little revenue from royalties will be penalized, and universities that enjoy large royalty payments will benefit from above-the-norm research budgets that allow them to implement large and challenging research projects. Supporting this view, Mowery (2002) underlines that commercially successful inventions completely dominate the income flows from academic licensing for two reasons. First, the distribution of inventions or patents by importance and/or potential profitability is skewed. Second, biomedical inventions appear to be among the most consistently profitable inventions in licensing transactions. Therefore, universities that do not have strong medical or biology research centres, rather than focusing on maximizing their income from licensing and technology transfer, will likely be more keen to pursue other objectives.

On the other hand, there is evidence also that collaboration with industry *per se* has no or no positive impact on academic activities. Several studies (Godin and Gingras 2000; Brooks and Randazzese 1999) find no evidence of industry influence on types of collaborative research (Perkman and Walsh 2008), while others (Gulbrandsen and Smeby 2005; Muscio 2008) find university-industry interactions have a positive effect on university researchers by improving research performance and academic career progress. This latter finding is supported by Siegel et al. (2003), which shows that knowledge transfer in university-industry interactions is bi-directional, and that university scientists report that interaction with industry enables better basic research, and provides a different perspective, which may be the inspiration for innovative research. We should consider also the development of technology transfer activities and the effect on professional fields, which can widen career perspectives for university employees and university students (Siegel et al. 2007). Finally, there is some evidence of a strong correlation between industry funding and high levels of research productivity, patenting and commercialisation of products, creation of spin-off companies, and involvement in consulting work (Gulbrandsen and Smeby 2005).

2.3 The effects on basic research of applied research contracts and knowledge transfer activities

Despite the large empirical literature on the new role of academic institutions in economic systems (Etzkowitz and Leydesdorff 2000; Gibbons et al. 1994), relatively few studies focus on the effect of university funding on the balance between basic and applied activities.[2]

There is substantial agreement that the type of university research funder (type of institution) and how the funding is channelled to academics have a major influence on the balance in the scientific activities carried out at academic institutions (Goldfarb 2008). However, whilst there is evidence that basic research complements applied research (Muscio et al. 2013; Bruno and Orsenigo 2003) whether industry funding for research has any effect on basic research activity remains unclear. Research contracts and consulting activity are notorious for being demand-driven processes, in which the sponsoring agency – whether a public or a private organisation – allocates money for research as a result of a

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[2] This issue is relevant also for firms making decisions about allocating the budget between basic and applied research. For instance, Cockburn et al. (1999) show that in science-based industries (pharmaceuticals in their case) firms investing in innovation are faced with a trade-off between allocating resources to basic research (typically characterised by returns over the long-term) and to applied research (directly commercialisable). They find that, in most cases, firms adopt incentive systems whereby the intensity of incentives to do applied research increases with the intensity of incentives provided by the organization to do basic research.

tender process, or via direct contact with a particular researcher or university research team (D'Este et al. 2012). These activities generally have well-specified goals, tend to be short or medium-term, and usually involve more applied than fundamental or basic research. Even when contract funding involves scientific production and the creation and transfer of knowledge, these activities will be based on the research sponsor's objectives, which may not involve scientific excellence or blue-sky research.

Thus, the nature of the relationship between private research funding for universities and basic research is interesting and implies diverse long-term consequences. The existence of a form of additionality between private and public funding for universities would imply that universities are able to act strategically to improve their fundraising capabilities and, simultaneously, to increase their opportunities to engage in curiosity-driven science. Although the main determinants of collaboration with industry include finance (e.g. resource-scarcity as highlighted in Landry et al. 2010) and increased personal income (D'Este and Patel 2007; Muscio 2008; Perkman and Walsh 2008), there is no conclusive empirical evidence on whether academics' increasing reliance on industry funding is affecting their engagement in basic research, at least measured as access to competitive funding for basic research.

In particular, Ranga et al. (2003), in their case study of the Belgian Katholieke Universiteit of Leuven, find no clear evidence of a shift towards applied research determined by involvement in university-industry linkages. Their results suggest that the academic research groups examined had developed a publications base of applied research which had not affected their basic research published output. Confirming this, Jensen and Thursby's (2004) principal-agent model applied to academic research analyses concerns over university patent licensing as detrimental to the traditional mission of US research universities. Their model does not provide clear evidence that that licensing damages basic research and education. Bozeman and Gaughan (2007) studied the impact of industry grants on academic researchers' industry involvement and underline that there is little need for concern over the possible negative consequences of industry grants on basic research, given that many disciplines traditionally associated with basic research show low rates of interaction with industry. Tuzi (2005) analyses the research productivity of the National Research Council (CNR) institutes in Italy, testing whether they are affected more by performance of basic scientific activities than development of research activities responding to firms' innovation needs. Tuzi finds that collaboration with other public or private institutions and market-oriented activity, do not affect the innovation intensity of CNR institutes.

Conversely, there is some theoretical and empirical support for a positive relationship between industry funding and basic research. Academic scientists who collaborate with industry and, thus, contribute more to knowledge transfer, may benefit from increased reputation and visibility or a sort of 'reverse Matthew effect' (Merton 1968). Tuzi (2005) finds a positive correlation between scientific activity, measured by bibliometric analysis, and technological production. Breschi et al. (2007) highlight that the production of industry relevant research might provide access to external resources that allow academics to pursue their real scientific interests and follow innovative basic research paths (the so called 'resource effect').

On the other hand, Coccia and Rolfo (2008) investigate the relationship between production of basic research and applied activity, and the effect on strategic change in CNR institutes. They find evidence of a crowding-out effect of basic research by applied activity. They show that research units tend to increase production of applied activity and reduce their basic research efforts. Similarly, Hottenrott and Thorwarth (2011) find that professors with high levels of industry funding are less productive in terms of publications, confirming the existence of a skewing problem. If these arguments hold, even in the case of universities, then governments should reduce the emphasis on applied research and knowledge transfer activities, which, although they increase the production of applied knowledge and the ability of universities to support business, might divert academic research from pure science objectives.

We contribute to the literature by investigating the composition of university funding streams. We argue that funding for applied research and consulting does not complement basic research funding and, therefore, limits the opportunities related to future pure science knowledge production.

3 EMPIRICAL ANALYSIS

3.1 Data description

The empirical analysis is based on financial data from the whole population of university departments in Italy engaged in research in all nine Scientific Areas (SA) of the Engineering and Physical Sciences (EPS).[3] The data were provided by the Italian Ministry of University and Research (MIUR). We obtained financial data for the period 2006-2011, for 1,043 EPS departments[4] from 60 public universities (including 4 polytechnic universities) located across 48 municipalities. The main database provides information on volume and sources of university funding, staff composition, and existence at the

[3] The National University Council (CUN) classification of SA is similar to the OECD Frascati Manual classifications (OECD 2002). The SA considered here correspond to the Frascati Manual categories of Natural Sciences, Engineering and Technology, Medical Sciences, and Agricultural Sciences.

[4] The list of Italian departments is available at: www.cineca.it.

institution of an office to manage European patents. These data were matched to data on research ratings published by MIUR in 2007 based on an evaluation of departmental research output conducted in 2001-2003.[5]

Table 1 reports the distribution of departments across the nine EPS SA. Life sciences accounts for the biggest number of departments (590 units), and represents 57% of total EPS departments. Engineering and technology units account for 25% with the remaining 18% of the sample, basic science departments.

Financial data for the period 2006-2011 and the sources of funding (private vs public) are reported in Table 2. The largest share of income for university departments comes from public sources (either national or international government organisations). Over the sample period, public funding accounted for almost 57% of total resources. The main sources of public funding are internal transfers from the university (24% of public funds), MIUR (23%), other government bodies (23%) and EU (21%). Internal transfers and government funding constitute the core funding allocation at the institutional level, typically for basic research and not competitive. MIUR funding and EU funding are project-related and awarded to researchers who apply for grants.[6] In 2006-2011, Italian departments suffered significant cuts to their core funding for research (-8%), driven mainly by reductions in university internal transfers (-36%) and MIUR grants (-30%). This forced researchers to increase their efforts to collaborate with firms and external

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[5] This composite indicator takes into account peer review evaluations of research activity in academic institutions (patents, journal impact factors, etc.). Details on the construction of the indicator are available at http://vtr2006.cineca.it/documenti/linee_guida.pdf

[6] MIUR funding and EU funding are competitive and awarded in the form of grants to successful research proposals. Domestic public funding from MIUR is aimed mostly at basic research projects; EU research grants fund a mix of basic and applied research (Arnold and Giarracca 2012).

institutions to obtain funding. The data show that between 2006 and 2011, research contracts and consultancy activity increased by almost 9%, resulting in an overall increment in revenue from private sources of around 17%.[7]

Figure 1 reports the dynamics of the three sources of revenue - MIUR, EU and research contracts - allocated to departments, based on certain criteria. Over the period considered, the decrease in competitive research funding from MIUR was accompanied by increased effort by departments to obtain funding from other external sources, particularly the EU and research contracts. Despite the cut in domestic public funding, which affected all areas of scientific research, the trade-off between publicly available resources and research contracts was particularly important in the case of engineering and technology departments which are characterized by greater commercialisation of research output and stronger links with the productive sectors.

3.2 Econometric specification

We model the basic-applied trade-off in academic research activity by linking competitive public research funding from MIUR (which sponsors basic scientific research) to research contracts and consulting activity. Our analysis is based on two main indicators. We use the amount of national public funding per researcher raised by a university department to proxy for the capacity/effort of research staff to engage in basic research, over the period

[7] According to the MIUR classification of university revenue, private funding to departments includes both generic funding and revenue from contract research and consultancies with non academic institutions. The generic funding includes donations, generic research sponsorships, PhD scholarships, etc.; other revenue includes funding from public and private contractors in return for specific studies, research contracts and consulting activity.

2006-11.[8] Our indicator of applied activity is the amount of funding raised by the university department from research-to-order (contracts and consultancies) commissioned by public and private non-academic organisations and subject to university regulations.[9]

Since for some of the years considered several departments in our sample report no public funding, we model the relationship between the production of basic research and the applied activity of the research department, to take account of the presence of a corner solution outcome. Department *i*'s public funding collected at time t is denoted y_{it}; the Tobit model with department unobserved effects is:

$$y_{it}^{*} = x_{it}'\beta + c_i + c_t + c_r + u_{it}, \quad i = 1,\dots,N, \quad t = 1,\dots,T$$
$$y_{it} = \max(0, y_{it}^{*})$$

where x_{it} is a set of department-specific characteristics, c_i is the (random) department-specific effects, c_t is year dummies, c_r is regional dummies and u_{it} is the error term. Year effects are included to account for 'cyclical' variations in public funding.

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[8] Estimation of the intensity of basic research activity is limited to MIUR funding; it does not include EU funding because it is not possible to approximate the nature of the research activity supported by this funding type. Although EU Framework Programme funding to academic institutions is mostly for basic research, Structural Funds can be awarded for other types of research activity (Arnold and Giarracca 2012).

[9] Our proxy for applied activity does not include business funding to departments which is not compensated by research results (e.g. private contributions for mounting conferences and other events, scholarships and prizes for excellent young researchers, etc.). These resources are considered a separate source of revenue (see Table 2 under 'Enterprises', and fn. 5) which, generally, is relatively small. Also, the variable research funding from contracts and consultancies does not account for funding from research programmes/contracts that do not allow income distribution to research staff.

The vector x_{it} includes per capita research contract and consulting activity, per capita research funding from the EC, and a set of covariates that might be correlated with the department's capability to do successful basic research, such as department size expressed as number of administrative and research staff, share of research staff, and quality/reputation of the department measured by the research rating index calculated by MIUR for research activity carried out in 2001-03. The regressions also include dummies for all SA.

In studying the relationship between basic research and applied activity the direction of causation is important. There is a large body of empirical evidence on the complementarities between the ability of academic departments to produce good (basic) research and the capacity to attract private funding from industry and other external sources (see among others Bruno and Orsenigo 2003; Muscio et al. 2013). The presence of reverse positive causality from basic to applied research may lead to a downward bias of the coefficient of the indicator of applied research activity (which captures the trade-off between basic and applied research). To address the issue of endogeneity we use a standard instrumental variables (IV) approach and identify a set of variables that capture the presence of administrative structures within the university aimed at promoting the technology transfer process, namely age of the Industry Liaison Office and presence of an office to manage European patents. The objective of both organisations is to facilitate relations with external entities and enterprises and their existence is likely to be positively correlated with the extent of applied activity in the research department, but unrelated to the department's capacity to collect public funding for basic research.

3.3 Results

Table 3 reports the descriptive statistics of the variables used in the econometric analysis. Table 4 reports the estimation results of the Tobit model. Table 4 Column (1) refers to a simple Tobit model which does not address the problem of endogeneity of the variable research funding from contracts and consultancies. In this case, the estimated coefficient of this variable is positive and significant, implying a positive relationship between the two forms of funding. However, this coefficient does not imply a casual relationship between applied research funding and basic research funding since these variables are determined simultaneously. Columns (2) to (4) address the issue of endogeneity using standard IV techniques.[10] Columns (2) and (3) refer to the coefficients of the pooled Tobit model, which ignores the unobserved random effects; Column (4) focuses on the unobserved effects Tobit model, which is our preferred specification.[11] The marginal effects at mean values are reported in Column (5).[12]

In both the estimated specifications (pooled Tobit and unobserved effects Tobit) we instrument the variable research funding from contracts and consultancies, with two

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[10] The results of the first stage regression are reported in Table 6.

[11] In the specification reported in Table 3 Column (3) and Table 5 Column (2), we include among the regressors a 1-year lag of the dependent variable research funding from MIUR, in order to account for persistence in the process of collecting public finance. However, estimation of a dynamic non-linear model with unobserved effects and endogenous regressors implies conceptual and implementation difficulties which have not been studied (Wooldridge 2000, 2005). Therefore, in the unobserved effect Tobit estimates reported in Columns (4) and (3) of Tables 4 and 5 respectively, the lagged dependent variable is dropped. Nevertheless, the results for the pooled Tobit model show that the estimated coefficients are qualitatively unaffected by the inclusion of the lagged dependent variable.

[12] All the specifications include year dummies which capture the trend in public funding. The estimated coefficients (negative and highly significant) confirm the results discussed in the descriptive analysis. At the aggregate level, over the period considered, competitive research funding from MIUR has consistently decreased.

variables for the presence of administrative structures within the university aimed at promoting relationships with industry. The IV estimate shows that higher involvement of department staff in applied activity implies a reduced effort to access additional funding for basic research, shown by the negative and significant coefficient of the indicator of applied activity. This result appears to confirm the presence of a substitution effect between basic research and applied activity within academic departments. Because, unlike the Tobit model, the IV estimate is negative this suggests that the true causality effect from applied research to basic research is severely underestimated if reverse causality is neglected. Finally, if we take account of the presence of random effects (Columns 4 and 5), the coefficient of the variable research funding from contracts and consultancies, is slightly smaller, but still negative and significant at the standard levels. To quantify this estimated effect, for every euro of funding received by a department for research contracts and consultancies, the effort/capability to collect public funding decreases by 0.21 euros.[13] Note that, unlike funding from contracts and consultancies, the amount of European grants is positively related to the amount of national funds for basic research. This seems to suggest the presence of complementarities among sources of financing aimed at supporting the production of basic research.

Next, we analyse whether the substitution effect is homogeneous across departments operating in different scientific fields. Following Coccia and Rolfo (2008), we classify our research departments into three scientific macro-areas: (1) Basic science (B), which defines research departments operating in the field of mathematics, physics and

[13] As a robustness check, we ran the same specification for a subsample of departments (136) for which we had information on number of scientific publications to proxy for basic research activity (BLINDED CITATION). The results are qualitatively the same, and show a significant trade off between basic and applied research. Results available from the authors.

chemistry; (2) Life Sciences (LF), which defines departments working in the fields of geology, medicine, biology and molecular biology; and (3) Engineering and technology (ENG), which defines departments operating in the fields of engineering, architecture and technology.

In our empirical model we include two new controls obtained by interacting the variable research funding from contracts and consultancies with a dummy that takes the value 1 if the department operates in LF, and a dummy that takes the value 1 if the department operates in ENG. The results reported in Table 5 show the absence of any effect between production of basic research and applied activity, for departments engaged in basic sciences, and a substitution effect for Life Sciences departments (-0.26 euros of public funding for each euro of revenue from contract research and consultancies) and, but to a lesser extent, departments operating in Engineering and Technology (-0.16 of basic research funding for every euro of revenue from applied research).[14]

The relevant statistics to test the validity (relevance and orthogonality) of the instruments, and the associated p-values, are given in the last rows of Tables 4 and 5; Table 6 presents the first stage regressions. The instruments satisfy the orthogonality conditions in both specifications, and the F statistic in Table 4 is close to the limit of 10. In the specification with multiple endogenous regressors (Table 5), the Anderson canonical correlation statistic rejects the null hypothesis of zero correlation between the endogenous regressors and the instruments at the 5% level, suggesting that the instruments we consider are adequate to identify the equation. Indeed, in the first-stage regressions, both industry

[14] Our results are in line with those in Coccia and Rolfo (2008). They focus on CNR research institutes in the period 2000-2003 and find evidence of a negative correlation between applied activity and basic research in those institutes operating in the LF and ENG fields, and no correlation for basic science organizations.

liaison office age and presence of an office to manage European patents, positively affect the amount of financing derived from private contracts, and are statistically significant in almost all the first stage regressions.[15]

Overall, these results suggest a strong negative causal effect of applied activity on basic research once the endogeneity issue is addressed. Since fund-raising is costly activity for researchers, in terms of both time and effort, the estimated trade-off confirms the difficulties involved when academic departments try to operate as market-oriented research units and simultaneously try to access funding from public sources.[16]

4 Concluding remarks

This paper has investigated the relationship between commercially-driven university activities, specifically research contracts and consultancies, and publicly funded basic research, measured by department level funding. We found significant evidence of the existence of a substitution effect between externally funded applied activities and public funding for basic research programmes of national interest. When we focused on the scientific fields covered by departments, we found a strong substitution effect for life sciences departments, but this was less for engineering and technology departments.

[15] As expected, the instruments appear to be correlated less with applied activity in departments operating in the basic sciences.

[16] Our findings do not necessarily contradict the complementarity result found in studies based on information on the research activities of individual scientists. It is possible that prominent researchers may be capable of engaging successfully in both private fund raising and the production of basic research, but this may not apply to the department level.

There seems to be evidence of a substitution effect for departments whose scientific activity revolves around basic science.

These results are in line with the findings 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). Our analysis confirms this, particularly for researchers in life sciences. We did not find a positive relationship between industry relevant academic research and publicly funded basic research, implying there is neither a 'Matthew' effect (Merton 1968) nor a 'resource' effect (Breschi et al. 2007) where increasing returns are generated by access to external financial and cognitive resources.

These results combined with results on the effects of public funding on university-industry collaboration (BLINDED CITATION), have some implications for policy. In (BLINDED CITATION) we show that increasing public funding for university research is an effective way to foster knowledge transfer from university to industry, especially through informal relational channels such as research contracts and consultancies. The present paper highlights the possibility of reverse causality, where excessive emphasis on commercially driven activities could reduce valuable basic research efforts within publicly funded research programmes of national interest. Thus, our findings do not support the idea that the incentives for academic applied and knowledge transfer activities should be increased in order to avoid counterproductive effects on publicly funded basic research carried out by university departments.

It should be noted that our interpretation of the empirical evidence is based on the amount of national public funding per researcher raised by a university department proxying for the capacity/effort of its research staff to engage in basic research. From this perspective, the substitution relationship between applied and basic research can be understood essentially as the effect of time and effort/capacity constraints. However, although investigation of the dynamics underlying the levels and orientation of academic research is beyond the scope of this paper, it is important to note possible alternative explanations. The evidence of a trade-off between applied and basic research, might be due to an ex-ante departmental research specialisation, to university policies aimed at fostering university involvement in collaborations with non academic organisations (Rothaermel et al., 2007), or to locally-specific "cultural" factors (Kenney and Goe, 2004). Thus, some of the most relevant university strategies and policies are related to the definition of an incentive framework (Jensen and Thursby, 2001) and the design of academic governance of university–industry interactions (Caldera and Debande, 2010).

Further work on these additional dimensions might be informative for academic funding strategies and might shed light on the effects on basic research implied by different sources of university funding.

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Tables

Table 1: Sample composition by scientific area.

Code	Scientific area	Frequency	Percent
	Basic sciences		
1	Mathematics & Computer Science	73	6.9
2	Physics	45	4.3
3	Chemistry	72	6.9
	Life sciences		
4	Geology	33	3.2
5	Biology	105	10.1
6	Medicine	346	33.1
7	Agriculture & Veterinary	107	10.3
	Engineering and technology		
8	Civil Engineering & Architecture	124	11.9
9	Industrial Engineering	140	13.4
		1045	100.0

Source: Authors' calculations on MIUR data. The classification in macro research areas is from Coccia and Rolfo (2008)

Table 2: Department funding per researcher, 2006-11 (thousand of Euros, real values)

	2006	2007	2008	2009	2010	2011	mean	% tot. funding	Δ % 2006–2011
Public sources									
MIUR	4.80	4.04	3.17	2.80	2.59	3.36	3.46	13.34	-0.30
Domestic research inst.	0.74	0.95	0.70	1.03	1.06	0.81	0.88	3.40	0.10
Other public bodies	2.96	3.03	3.49	3.79	3.85	2.72	3.31	12.75	-0.08
European Commission	2.36	3.23	2.37	3.25	3.75	4.17	3.19	12.30	0.76
Foreign research inst.	0.19	0.32	0.21	0.24	0.21	0.25	0.24	0.91	0.28
University transfer	3.97	3.69	3.72	3.69	3.50	2.52	3.51	13.55	-0.36
Total public	*15.03*	*15.25*	*13.66*	*14.79*	*14.95*	*13.83*	*14.58*	*56.24*	-0.08
Private sources									
Research contracts and consultancies	7.45	6.97	7.56	8.20	7.92	8.12	7.70	29.71	0.09
Foreign private inst.	0.21	0.21	0.30	0.35	0.22	0.20	0.25	0.96	-0.04
Enterprises	1.07	1.02	1.13	1.14	1.01	1.08	1.07	4.14	0.01
Not-for-profit org.	0.86	1.09	1.19	1.22	1.74	1.97	1.34	5.18	1.28
Other sources	0.92	1.04	1.32	0.65	0.98	0.94	0.97	3.76	0.01
Total private	*10.52*	*10.34*	*11.49*	*11.57*	*11.87*	*12.30*	*11.35*	*43.76*	0.17
Total	**25.54**	**25.59**	**25.15**	**26.36**	**26.82**	**26.14**	**25.93**	**100.00**	**0.02**

Source: Authors' calculations on MIUR data. The monetary values are deflated using the CPI (Istat)

Table 3: Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Department Source of revenue					
Research funding from MIUR	5806	3.55	6.58	0	152.40
Research funding from contracts and consultancies	5806	8.29	13.30	0	299.18
Research funding from the EC	5806	3.41	11.14	0	252.16
Departments' characteristics					
Admin staff, research staff and PhD students	5806	90.29	60.28	3	642.0
Share of research staff	5806	82.08	9.04	50	100.0
Research rating	5806	0.79	0.08	0.4	1.0
Scientific areas					
SA Mathematics & Computer Science	5806	0.07	0.26	0	1
SA Physics	5806	0.04	0.21	0	1
SA Chemistry	5806	0.07	0.26	0	1
SA Geology	5806	0.03	0.18	0	1
SA Biology	5806	0.10	0.30	0	1
SA Medicine	5806	0.32	0.47	0	1
SA Agriculture & Veterinary	5806	0.10	0.30	0	1
SA Civil Engineering & Architecture	5806	0.12	0.32	0	1
SA Industrial Engineering	5806	0.14	0.34	0	1
University characteristics					
Presence of an office managing European patents	5806	0.84	0.37	0	1
Age of the ILO	5806	4.07	3.32	0	14

Table 4: Panel data tobit regressions

	Pooled tobit	Pooled IV tobit	Pooled - dynamic IV tobit	Unobserved effect IV tobit	
	(1)	(2)	(3)	(4)	(5)
	coef.	coef.	coef.	coef.	marginal effects
Research funding from contracts and consultancies	0.051	-0.602	-0.498	-0.517	-0,212
	(0.020)***	(0.239)**	(0.217)**	(0.227)**	(0.093)**
Research funding from MIUR (-1)			0.357		
			(0.026)***		
Research funding from the EC	0.107	0.242	0.179	0.186	0,008
	(0.027)***	(0.051)***	(0.043)***	(0.048)***	(0.001)***
Admin. staff, research staff and PhD students	0.016	0.017	0.014	0.018	0,030
	(0.002)***	(0.003)***	(0.002)***	(0.003)***	(0.009)***
Share of research staff	0.115	0.078	0.053	0.073	0,076
	(0.015)***	(0.023)***	(0.022)**	(0.022)***	(0.020)***
Research rating	0.107	0.242	0.179	0.186	4,614
	(0.027)***	(0.051)***	(0.043)***	(0.048)***	(1.210)***
SA Physics	5.735	10.944	8.347	11.267	0,053
	(1.733)***	(3.040)***	(2.794)***	(2.954)***	(0.403)
SA Chemistry	0.824	0.098	0.028	0.129	1,273
	(0.632)	(0.967)	(0.878)	(0.975)	(0.421)***
SA Geology	2.302	3.094	2.015	2.839	0,929
	(0.573)***	(0.859)***	(0.768)***	(0.862)***	(0.620)
SA Biology	0.327	2.607	1.996	2.108	1,267
	(0.675)	(1.318)**	(1.185)*	(1.313)	(0.418)***
SA Medicine	2.038	3.313	2.396	2.843	0,422
	(0.579)***	(0.883)***	(0.788)***	(0.866)***	(0.357)
SA Agriculture & Veterinary	0.134	1.648	1.060	1.017	2,245
	(0.601)	(0.874)*	(0.786)	(0.848)	(0.744)***
SA Civil Engineering & Architecture	2.049	5.312	4.104	4.766	1,422
	(0.669)***	(1.445)***	(1.301)***	(1.387)***	(0.920)
SA Industrial Engineering	-1.071	3.492	2.760	3.171	4,728
	(0.597)*	(1.834)*	(1.656)*	(1.882)*	(1.100)**
Constant	1.440	9.890	-9.591	9.057	
	(0.672)**	(3.176)***	(2.438)***	(3.114)***	
Regional dummies	yes	yes	yes	yes	
	yes	yes	yes	yes	
Observations	5806	5806	5667	5806	
No. of groups				1045	
Log-likelihood	-15400,28	-38752,5	-37161,843	-15200,9	
Overid. restr. test[a]			Chi2(1)=0.659	P-value = 0.642	
Test for joint significance of instr.[b]			F(2, 5767)=8.96	P-value = 0.002	

Pooled vs unobs. effects tobit[c]	Chi2(1)=420.59 P-value = 0.000

Note: * significant at 10%; ** significant at 5%; *** significant at 1%. Robust standard errors in parentheses.
a Test for over-identifying restrictions after IV Tobit estimators (Lee, 1992). The test is implemented using the Stata module overid (Baum et al., 1999).
b First stage test for the joint significance of the instruments.
c Likelihood-ratio test comparing the random effects model with the pooled (tobit) model. The instruments for the variable research funding from contracts and consultancies are: Presence of an office managing European patents and age of the ILO.

Table 6: Trade-off of basic research and applied activity by scientific areas

	Pooled IV tobit	Pooled - dynamic IV tobit	Unobserved effect IV tobit	
	(1)	(2)	(3)	(4)
	coef.	coef.	coef.	marginal effects
Research funding from contracts and consultancies	0.358	0.260	0.433	0,1772
	(0.461)	(0.446)	(0.433)	(0.177)
Research funding from contracts and consultancies*life sciences	-1.059	-0.917	-1.069	-0,4379
	(0.589)*	(0.559)*	(0.500)**	(0.205)**
Research funding from contracts and consultancies*engineering and technology	-0.800	-0.607	-0.826	-0,3382
	(0.468)*	(0.358)*	(0.435)*	(0.176)**
Research funding from MIUR (-1)		0.350		
		(0.028)***		
Research funding from the EC	0.220	0.170	0.169	0,0065
	(0.049)***	(0.043)***	(0.047)***	(0.001)***
Admin. staff, research staff and PhD students	0.016	0.013	0.016	0,0301
	(0.004)***	(0.004)***	(0.004)***	(0.009)***
Share of research staff	0.083	0.058	0.074	0,0692
	(0.022)***	(0.021)***	(0.021)***	(0.019)***
Research rating	8.173	0.170	8.960	3,6689
	(3.022)***	(0.043)***	(3.079)***	(1.260)***
SA Physics	0.572	6.256	0.478	0,1990
	(0.955)	(2.826)**	(0.982)	(0.415)
SA Chemistry	2.316	0.447	2.143	0,9394
	(0.892)***	(0.887)	(0.911)**	(0.426)**
SA Geology	-0.456	1.379	-0.914	-0,3626
	(1.787)	(0.832)*	(1.744)	(0.670)
SA Biology	8.167	-0.407	7.844	4,0410
	(3.189)**	(1.716)	(2.711)***	(1.704)**
SA Medicine	6.382	6.724	5.884	2,6130
	(3.199)**	(3.014)**	(2.711)**	(1.306)**
SA Agriculture & Veterinary	10.036	5.314	9.680	5,2371
	(3.848)***	(3.027)*	(3.283)***	(2.235)**
SA Civil Engineering & Architecture	5.984	8.529	5.695	2,7433
	(2.894)**	(3.617)**	(2.698)**	(1.507)*
SA Industrial Engineering	11.393	4.680	10.940	5,9857
	(4.059)***	(2.687)*	(3.820)***	(2.644)**
Constant	-14,979	-11.289	-10,763	

	(2.856)***	(2.692)***	(2.835)***
Regional dummies	yes	yes	yes
Year dummies	yes	yes	yes
Observations	5806	5663	5806
No. of groups			1045
Log-likelihood	-33354,5	-39234,5	-15200,9
Overid. restr. test[a]	Chi2(2)=6.891 P-value = 0.142		
Anderson corr. (IV relevance test)[b]	Chi2(4)=11.11 P-value = 0.022		
Pooled vs unobs. effects tobit[c]	Chi2(1)=417.04 P-value = 0.000		

Note: * significant at 10%; ** significant at 5%; *** significant at 1%. Robust standard errors in parentheses. The base group are departments belonging to the research field of basic sciences.

a: Test for over-identifying restrictions after IV Tobit estimators (Lee, 1992).

b: Likelihood-ratio test for significant *canonical* correlations between endogenous regressors and instruments for models with multiple endogenous regressors.

c: Likelihood-ratio test comparing the random effects model with the pooled (Tobit) model. The instruments for the variable research funding from contracts and consultancies (and its interactions) are: Presence of an office managing European patents, age of the ILO and their interactions with the dummies life sciences and engineering and technology.

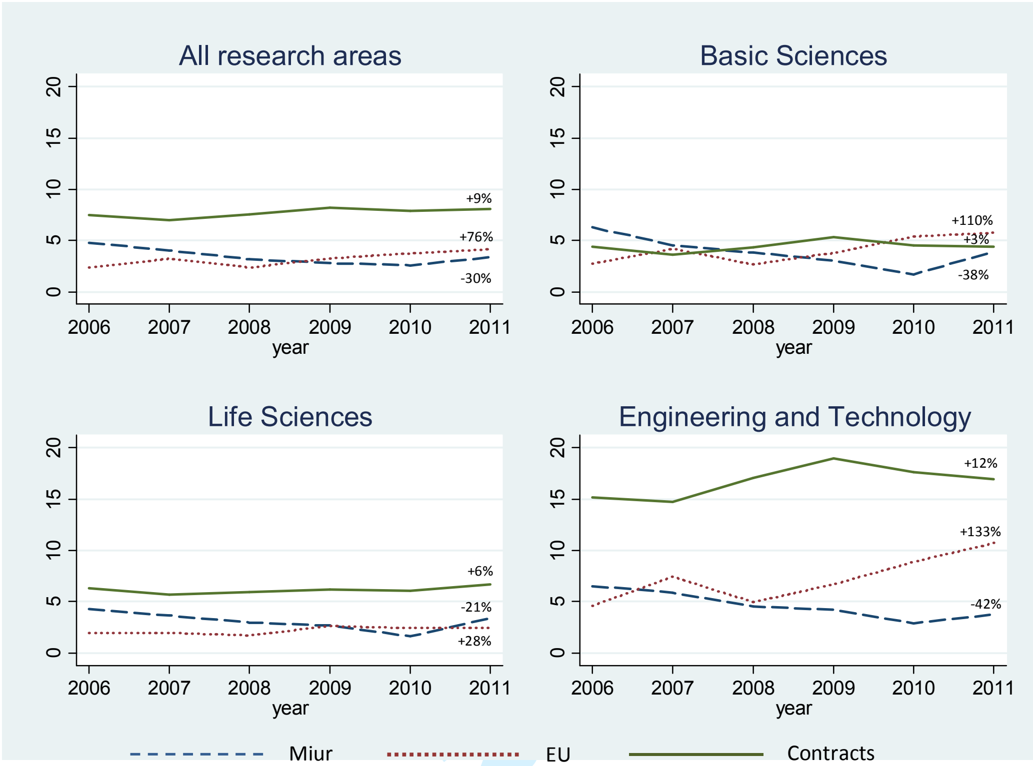
Table 7: First stage regressions IV Tobit

	IV Tobit - Table 5 -		IV Tobit -Table 6 -					
	(1)	(2)	(3)	(4)	(5)	(3)	(4)	(5)
Dependent variable:	Research funding from contracts and consultancies	Research funding from contracts and consultancies	Research funding from contracts and consultancies	Research funding from contracts and consultancies*life sciences	Research funding from contracts and consultancies*engineering and technology	Research funding from contracts and consultancies	Research funding from contracts and consultancies*life sciences	Research funding from contracts and consultancies*engineering and technology
Research funding from MIUR (-1)		0,073				0.073	0.044	0.014
		(0.025)***				(0.025)***	(0.019)**	(0.016)
Research funding from the EC	0.207	0.192	0.205	0.105	0.080	0.190	0.103	0.067
	(0.015)***	(0.015)***	(0.015)***	(0.011)***	(0.009)***	(0.015)***	(0.012)***	(0.009)***
Admin. staff, research staff and PhD students	0.004	0.004	0.002	0.006	0.009	0.002	-0.007	0.009
	(0.003)	(0.003)	(0.003)	(0.002)***	(0.002)***	(0.003)	(0.002)***	(0.002)***
Share of research staff	-0.046	-0.052	-0.060	-0.015	-0.046	-0.066	-0.020	-0.047
	(0.020)**	(0.021)**	(0.021)***	(0.016)	(0.013)***	(0.021)***	(0.016)	(0.013)***
Research rating	8.844	9.000	8.944	4.141	2,453	9.088	4.309	2.466
	(2.531)***	(2.572)***	(2.563)***	(1.929)**	(1.588)	(2.605)***	(1.970)**	(1.597)
Age of the ILO	0.214	0.218	0.079	-0.003	-0.018	0.082	0.003	-0.021
	(0.058)***	(0.058)***	(0.112)	(0.084)	(0.069)	(0.113)	(0.085)	(0.069)
Presence of an office managing European patents	0.349	0.299	1.373	-0.094	-0.299	1.183	-0.200	-0.319
	(0.211)*	(0.485)	(0.821)*	(0.816)	(0.672)	(1.098)	(0.830)	(0.673)
Age of the ILO*life			0.130	0.217	0.038	0.128	0.184	0.038

sciences								
			(0.129)	(0.102)**	(0.080)	(0.130)	(0.098)*	(0.080)
Presence of an office managing European patents*life sciences			-2.177	0.075	-0.373	-2.070	0.077	-0.337
			(1.249)*	(0.045)*	(0.774)	(1.270)	(0.960)	(0.779)
Age of the ILO*engineering and technology			0.256	-0.009	0.376	0.264	-0.025	0.401
			(0.152)*	(0.114)	(0.094)***	(0.154)*	(0.116)	(0.094)***
Presence of an office managing European patents*engineering and technology			-0.418	0.013	1.509	-0.180	0.219	1.457
			(1.424)	(1.072)	(0.883)*	(1.448)	(1.095)	(0.878)*
Constant	-1.557	-1.448	-0.748	-1.908	0.777	-0.455	-1.659	0.738
	(2.895)	(2.950)	(2.974)	(2.238)	(1.842)	(3.031)	(2.292)	(1.858)
Observations	5806	5667	5806	5806	5806	5667	5667	5667
R-squared	0.14	0.14	0.14	0.13	0.45	0.14	0.13	0.45

Note: * significant at 10%; ** significant at 5%; *** significant at 1%. All the first stage regressions contain regional, scientific area and year dummies.

Figure 1: Trends in revenue sources per researcher, 2006-2011 (thousands of Euros, real values)



Source: Authors' elaboration from MIUR database