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Fishing for Complementarities: Competitive Research Funding and Research Productivity

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Abstract

This paper empirically investigates complementarities between different sources of research funding with regard to academic publishing. We find for a sample of UK engineering academics that competitive funding is associated with an increase in ex-post publications but that industry funding decreases the marginal utility of public funding by lowering the publication and citation rate increases associated with public grants. However, when holding all other explanatory variables at their mean, the negative effect of the interaction does not translate into an effective decrease in publication and citation numbers. The paper also shows that the positive effect of public funding is driven by UK research council and charity grants and that EU funding has no significant effect on publication outcomes.

Keywords: Research Funding, University-Industry Collaboration, Scientific Productivity

JEL codes: L31; O3

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1 Introduction

In academic research, competitive funding is considered crucial for increasing research output (Stephan 1996, 2012). Public research grants have repeatedly been found to positively affect research productivity (Benavente et al., 2012; Chudnovsky et al., 2008; Hottenrott and Thorwarth, 2011; Jacob and Lefgren, 2011; Kelchtermans and Veugelers, 2011). It is important to note, however, that researchers receive grants from several sources. Recent research on the concurrence of different types of funding in selected countries shows that academic publications report an average of 2.4 to 3.3 funding agents per paper (Wang et al., 2012).

Multiple funding sources facilitate resource-intensive research, while creating the challenge to attribute research efforts and human resources to each project. Importantly, given the significant effects of industry grants on research outcomes (Hottenrott and Thorwarth, 2011; Banal-Estanol et al., 2013), it is of interest whether industry sponsorship accelerates or compromises the positive effect of public research funding. In other words, studying the effects of public funding on research output may require taking other funding channels into account.

Besides increasing use of competitive research grants from public funding authorities, research sponsorship from the private sector has grown in importance over the past decades in most OECD countries (OECD, 2010). Previous work has identified the various forms of interactions between industry and academia (e.g. Agrawal and Henderson, 2002; Cohen et al, 2002) and studied intensively the effect of such interactions on research outcomes (e.g. Blumenthal et al., 1996; Gulbrandsen and Smeby, 2005; Hottenrott and Thorwarth, 2011; Banal-Estanol et al., 2013). It has been claimed that industry partners may direct academics towards applied research and limit or delay the public dissemination of research results (Blumenthal et al., 1996; Cohen et al., 1998; Czarnitzki et al. 2011). These papers conclude that academics' general duties and research duties in particular may be compromised by an increase in time allocated to industry-sponsored research and development, consulting and commercialisation.

If industry partners determine research topics and demand secrecy then also public funding placed with such industry sponsored researchers may suffer from limitations and result in a decrease in research output (Cohen et al, 1998). This is particularly critical in light of shrinking institutional core budgets that induce researchers to increasingly look for other channels to fund their research. On the other hand, several studies have argued that industry can provide not only funds but also ideas for research (Mansfield, 1995; Lee, 2000; Siegel et al., 2003; Hottenrott and Lawson, 2013). Researchers may be able to benefit in their academic work from closer links with industry as insights into applied processes and problems in industry may provide the ideas for new ground-breaking research (Rosenberg 1998). If researchers obtain new ideas through links with industry then also the expected benefits from public funding placed with these researchers should increase as a result of positive complementarities (Mansfield, 1995; Zucker et al., 1996, 1998).

Thus, it is important to note that industry sponsorship cannot be evaluated without considering its impact on productivity effects from other types of funding, which could be positive or negative. This study aims to fill this gap by investigating the joint effect of funding from public and private sponsors on the research productivity of a sample of UK engineering academics. Using data on research income of 809 individual researchers at 15 UK universities we are able to investigate potential complementarities and substitution effects between different sources of private-sector and public-sector funding and how they affect publication and citation rates of the sponsored academics. Previous studies have shown a positive effect of competitive funding on publication output but that larger shares of research funding coming from industry are associated with publication rate decreases (Manjarres-Henriquez et al., 2008; Hottenrott and Thorwarth, 2011; Banal-Estanol et al., 2013). Our results add to these insights by showing firstly that competitive research grants are associated with higher research output. Looking at public sources of funding that include funding from the UK research councils, UK charities and EU funding, the paper also shows that only UK public funding increases publication and citation rates. Industry funding, however, decreases the marginal utility of public funding by decreasing the publication and citation rate increase associated with public grants. The negative effect of the interaction does not translate into an effective decrease in publication or citation numbers. Even for very high amounts of industry funding we still observe a positive effect of public funding on publications.

The remainder of the paper is organised as follows: Section 2 summarises the literature on research funding and productivity and section 3 introduces the empirical model and methodology. Section 4 describes the data and section 5 presents the results. In section 6 we conclude.

2 Background

2.1 Research funding and research productivity

In many countries in Europe where universities have primarily been financed through block grants, governments have introduced or increased the amount of funding distributed through competitive funding schemes (Stephan, 2012). Additionally, shrinking public research budgets meant that researchers are increasingly encouraged to look for funding elsewhere, e.g. source funding from industry and other sponsors. This resulted in a shift towards private sponsorship in most OECD countries (OECD, 2010). Competitive funding has been seen as a mechanism to reward and thus provide incentives for the most able researchers. It allows researchers to secure funding for equipment and research assistance, leading to more autonomy and flexibility. Competitive funding is thus usually accompanied by an increase in research productivity, regardless the sponsor (Stephan, 2012), and researchers that receive some external funding outperform their colleagues who do not acquire external grants (Kelchtermans and Veugelers, 2011; Banal-Estanol et al., 2013).

However, few papers have analysed the concurrence of different types of funding. Wang et al. (2012) analyse named sponsors on academic publications in 10 selected countries. They show for the UK that 43% of academic publications acknowledge external funding and report an average of 2.8 funding agents per paper. They also observe that the UK funding system is particularly diversified, with no one funding agent dominating. In our data we will see that more than 50% of researchers receive funding for at least one year. Of these, 47% receive public grants and industry funding simultaneously at least once. This points to the importance of analysing potential complementary or substitution effects between grants from different funding agents.

2.2 Industry funding and research productivity

Industry grants have been identified as a major source of funding for academic research in recent years. In the US the so called competitiveness crisis prompted a series of structural changes in the intellectual property regime accompanied by several incentive programs designed specifically to promote collaboration between universities and industry (Lee, 2000). In many subject areas, including engineering and material science, much of the research would not be possible without the input of industry partners. In a survey of 671 academic scientists and engineers, Lee (2000) reports securing of funds for equipment and research assistants as the principal reason for collaboration with industry, leading to more autonomy and flexibility for academic researchers. Further, Slaughter and Rhoades (2004) argue that university researchers may be motivated to interact with private companies for reasons other than access to additional research funding, for example finding potential co-authors and ideas for their research agenda. Also, Lee (2000) identified the acquisition of research ideas as one of the main motives for researchers to pursue joint research with industry. Mansfield (1995) reported that a substantial number of university research projects were initiated through consulting activities within firms. This did not only apply to industry-sponsored projects, also research projects sponsored by public agents were influenced by problems from industry. Thus, through the provision of additional grants and contact to real-world problems, industry sponsorship could also increase the marginal benefits associated with public grants.

However, more than just providing an attractive source of additional research funding to supplement the department's core resources, external sponsorship involves contractual agreements and research guidance that may potentially affect academic research. Specifically, the objectives of different sponsors may influence the choice of research topics and the choice of dissemination channels (Slaughter and Leslie, 1997; Cohen et al., 1998; Benner and Sandström, 2000) and industry sponsors may have a particular interest in influencing research and dissemination channels to recover their investments. Accordingly, Blumenthal et al. (1996) argue that industry may direct researchers towards applied research and limit or delay the release of publications. Blumenthal et al. (2006) and Czarnitzki et al. (2011) find evidence of publication delay and secrecy associated with industry funding. Such evidence points towards a potential negative effect of industry involvement on publication rates which could further result in a negative effect on marginal benefits associated with simultaneously received public funding.

Empirical evidence on the topic is mixed. Manjarres-Henriquez et al. (2008) and Banal-Estanol et al. (2013) show a curvilinear effect of the share of industry funding on publication output which may be indicative of a complementary effect of public and private funding up to a certain threshold. Other recent studies instead show a consistent negative correlation between the share of industry grants and publication rates (Hottenrott and Thorwarth, 2011). In a recent paper, Hottenrott and Lawson (2013) find researchers that report industry as a source for research ideas to publish less than their peers that source research ideas from elsewhere. Their findings suggest that ideas coming from industry do not translate into more or better quality publications. Thus, the potential negative effect of industry funding might merely be off-set through public grants instead of creating true complementarities.

2.3 Different sources of public funding

While most papers only differentiate between public and private funding, it is important to note that not all public funding is alike. Researchers source funding from a variety of public sources and there is evidence that some public sponsors promote research more effectively than others. Azoulay et al. (2011) study the impact of funding from two different public sponsors with different grant design and agenda. They find that funding from the Howard Hughes Medical Institute's, a sponsor that allows for more scientific freedom perform significantly better than a group of similar researchers funded by the National Institutes of Health (NIH).

Just as US academic life scientists rely on NIH funding for their research, UK engineering academics rely on funding from the Engineering and Physical Science Research Council (EPSRC). With the increasing competitiveness of these grants more researchers are turning towards the European Commission Framework Programmes for research sponsorship. While both sponsors have specific research lines they promote, European Union (EU) grants are organised in funding periods and around research actions, often involving researchers from several countries. The main difference, however, lies in the administrative burden associated with EU grants (Grimpe, 2012). We could thus expect them to affect academic research output differently. Indeed, Grimpe (2012) found for a sample of German academics that while research council grants go to the most able academics, EU grants are not strongly correlated with prior research publications. Grimpe (2012) further analyses the effect of different types of funding on the receipt of EU grants and shows that they are not acquired complementary to any other research funding but perhaps only being pursued when other funding channels are not available. We could therefore expect that also in terms of their effect on publication outcomes industry grants may complement research council or EU grants differently. Further, we may expect potential substitution effects between research council and EU grants in terms of their effect on publications.[1]

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[1] Similarly, government grants that are not mediated by the research councils may have a different effect on research output. Such grants may be mission oriented and not awarded through peer review. Goldfarb (2008), for example, finds that researchers repeatedly funded by NASA experience a reduction of their research output. Grimpe (2012) finds that government grants are acquired complementary only to industry grants and are not correlated to research output variables.

3 Empirical Model

We base our model of research funding complementarity on the notion of utility maximisation of the academic. An academic exerts different research efforts aimed at producing measurable research outputs with the goal of maximising her utility. Although researchers in science have repeatedly been shown to possess a "taste" for science and derive satisfaction from "puzzle solving" (Stephan, 1996, 2012; Stern, 2004; Sauermann and Roach, 2013), the literature assumes that academics derive their utility primarily from publications in peer reviewed journals. Publications in peer-reviewed journals in turn provide substantial benefits in terms of career, salary and internal and external recognition (Dasgupta and David, 1994; Stephan, 1996, 2012).

We consider funding from at least two types of funding agents as inputs to the utility function. External resources are crucial for scientific production (Stephan, 1996, 2012) and the number of publications is increasing with funding received from external sponsors (Kelchtermans and Veugelers, 2011; Banal-Estanol et al., 2013). However, while publication numbers are assumed to be non-decreasing with research input, this does not rule out diminishing returns or trade-offs between different types of resources as shown by Manjarres-Henriquez et al. (2009) and Kelchtermans and Veugelers (2011).

Facing time-constraints academics have to choose how much time to devote to each sponsor to maximize their utility. In our set-up the different types of grants are not frictionless adjustable as they are subject to different adjustment costs and are accompanied by different expectations of the sponsors. Earlier research has found that funding from industry is less targeted at the production of scientific publications and basic research than unrestricted funding from public sponsors (Blumenthal et al., 1996). Funding from industry is thus considered restricted funding that may potentially adversely affect a researcher's publication behaviour (Cohen et al., 1998). The direct involvement of industry sponsors into the research process as well as the supervision of contract research and the exchange of results may limit the disclosure of research results or lead to publications that are of lower quality than research that receives funding from public sponsors. Moreover, researchers may encounter conflicting incentives and guidelines in their research when receiving funding from more than one agent. Public funding aimed at free dissemination may be contradicted with industry funding, resulting in a substitution between different grants. Alternatively, contacts with an industry sponsor may help generate new ideas for research (Lee, 2000) and the different grants could instead be complements in a researcher's production function.

The production function in its most general form is then given by:

$$P_{it}(\varphi) = f\left(F_{1\,it-1}, F_{2\,it-1}, X_{it} | \varphi\right), \quad (1)$$

where $F_{1\,it-1}$ and $F_{2\,it-1}$ denote two different types of funding allocated in t-1, where one could be considered public, science oriented funding and the other funding from industry. X_{it} are other explanatory factors like rank, patents or gender. We then include the notion of a positive increase from either type of funding with potential substitution or complementarity effects:

$$P_{it}(\varphi) = \varphi\left[F_{1\,it-1} + F_{2\,it-1} + F_{1\,it-1}F_{2\,it-1} + X_{it}\right] + \varepsilon_{it} \quad (2)$$

where φ is the vector of parameters to be estimated and ε is the error term given as $\varepsilon_{it}=u_{it}+v_i+\tau_t$, where v_i is the unobserved individual effect, and τ_t is the time fixed effect.

Thus, to estimate the existence and extent of any complementary or substitution effect between different types of funding we interact the two funding variables and estimate their joint effect.

We estimate count data models as the number of publications are by nature positive and the data is characterised by a large number of zeros. We assume the outcome variables to have a negative binomial distribution and use a model that accounts for the skewed nature of the data employing a specification of the form:

$$E(P_{it}) = exp\{\beta_1[F_{1\,it-1}] + \beta_2[F_{2\,it-1}] + \beta_{12}[F_{1\,it-1}F_{2\,it-1}] + \gamma X'_{it} + \varepsilon_{it}\} \quad (3)$$

In the case of continuous variables in non-linear models the interaction effect is the cross-derivative of the expected marginal change in publications. For example, the marginal effect of funding $F_{1\,it-1}$ on our dependent variable P_{it} is derived as the first derivative of (3):

$$\frac{\partial E(P)}{\partial F_1} = (\beta_1 + \beta_{12}F_2)E(P) \quad (4)$$

Then, derived from (4) the marginal change of funding $F_{1\,it-1}$ on the dependent variable P_{it} with respect to the interaction term $F_{2\,it-1}$ can be written as:

$$\frac{\partial E(P)}{\partial F_1 \partial F_2} = \beta_{12}E(P) + (\beta_1 + \beta_{12}F_2)(\beta_2 + \beta_{12}F_1)E(P) \quad (5)$$

Any two types of funding are classified as complements if the sign of the cross derivative is positive, i.e. if an increase in industry funding increases the marginal utility of public funding. If instead, an increase in industry funding decreases the utility of public funding they are considered as substitutes on the outcome variable P_{it}. If the cross-derivative is zero then we would observe a purely additive relationship between the two types of funding where one could replace the other without compromising its marginal utility.

We estimate pooled models which have the advantage that they relax the strict exogeneity assumption of a fixed effects model. However, they do not control for unobserved individual heterogeneity (v_i). In our case such unobserved effects could be specific skills of each researcher that are positively correlated with the right hand side variables such as external funding and a potential endogeneity problem arises. For example, the literature suggests that more able researchers have many more opportunities to receive funding as grant awarding bodies screen researchers for their ability and sponsor the most productive. If unobserved individual heterogeneity is present, the estimated coefficient of the funding variables would be upwards biased. We can cope with this challenge if pre-sample information of the dependent variable is available. Specifically, Blundell et al. (1995, 2002) suggest a solution which controls for individual heterogeneity by specifying the average productivity of the academic before she enters the sample. The pre-sample mean of the dependent variable is a consistent estimator of the unobserved individual effect if it mainly corresponds to the intrinsic ability of an academic and her motivation, both factors that are not directly observable but may affect scientific productivity. Following Blundell et al. (1995, 2002) we can therefore account for unobserved individual heterogeneity by using pre-sample information of publications and citations. We include the log of the average number of publications published in a pre-sample period (in the period 1999 to 2001). In cases where the pre-sample value is zero, we include a dummy to capture the "quasi-missing" value.

Theory further suggests that research activity is subject to dynamic feedback (Dasgupta and David, 1994) as each researcher's performance is driven by cumulative unobserved factors (u_{it}), e.g. learning, which are not controlled for through fixed effects. Blundell et al. (1995) therefore argue that it is important to consider continuous, sample-period dynamics when modelling research outcomes. To proxy for dynamic feedback within the sample period we calculate the stock of publications (and citations) published during the observation period. We assume that knowledge does not depreciate during the short sample period considered here (5 years).

The pre-sample value and the stock variable are included in all estimations. This dual approach helps to address the problem of endogeneity that arises from correlated individual effects and through feedback from the dependent variable.

4 Data

This paper evaluates the possible joint effects of different types of external sponsorship on publication output, using data on competitive research grants for UK engineering academics. Competitive grants represent research funding that an academic receives in addition to the university's core funding.

To gain access to grant information for academic researchers, we contacted 40 UK universities with engineering departments[2]. 15 of these universities sent detailed records containing information on private and public research grants received by their engineering staff during the period 2001 to 2006[3] (see Table A1 in Appendix A for a list of universities). The funding information was manually matched with name and rank information for all academic staff employed at engineering departments in the UK, as well as their publication records[4]. We supplemented this data with PhD year and subject information for all 885 researchers that worked at the 15 universities during the whole period 2001 to 2006, whether they received funding or not. After exclusion of incomplete records the final data set contains 809 engineering academics. Of these researchers, 58% received some external funding at least once during the six year observation period. The descriptive statistics for the regression sample are reported in Table 1, correlations between the variables are reported in Table 2.

4.1 Data collection and descriptive statistics

Research Output

The main variables of interest are research output and its quality, which are measured using researchers' publication records. Publications were obtained from the ISI Web of Science database. We collected publications from when the researcher first joined the database (and were employed by one of the institutions in the full 40 university sample) up to 2007. Names

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[2] The 40 universities were selected based on a list of universities, for which staff and publication data had been collected as part of the ESRC project described in Banal-Estanol et al. (2013).

[3] 6 more universities sent partial information, e.g. industry funding or researcher names were missing. For some of the 15 universities funding is available for earlier years, e.g. for 3 from 1990 onwards, for another 7 from 1996 onwards. Funding was available until 2007 but due to missing values in the patent measure, 2007 has been dropped from the analysis. The period 2001 to 2006 is the preferred period for this analysis as it covers a larger number of universities and represents the assessment period for the 2008 RAE. The research information can therefore be expected to be fairly standardised across the 15 institutions and adjusted to the requirements of the RAE.

[4] The original data was collected based on staff registers in academic calendars and the name entries used as basis for gathering publications, patents and research council funding information for engineering academics at 40 UK universities for the period 1985 to 2007 (Banal-Estanol et al., 2013).

were matched based on university address, last name and first initial. All database entries were cleaned manually to assure correct matching of publications to individual researchers.[5]

Funding could have a different impact on research quality than it has on research quantity. We measure research quality using the number of citations received before the end of 2012 by articles published in *t*. In other words, for publications published in 2002 we consider a citation window of ten years while for publications published in 2006 we consider a citation window of six year.[6]

To summarize, we measure publication output as the number of publications in *t* (*PUBLICATIONS*) and quality adjusted publication output as the total number of citations received by publications published in *t* as of 2012 (*CITATIONS*). The mean number of publications during the observation period is 2.18 per academic per year and the citation count for these publications is 32.14. Further, 10% of the scientists in our sample did not publish during the entire six year period and 25% published less than one paper per year.

For both measures we generate three-year pre-sample means (*Pub_Mean* and *Cit_Mean*) for the period 1999 to 2001 and a stock variable (*Pub_Stock* and *Cit_Stock*). These are included in all models to control for the ex-ante scientific quality of the scientist (time-invariant unobserved heterogeneity) and dynamic feedback (time-variant unobserved heterogeneity).

Research Funding

The competitive research income information obtained from the 15 universities includes the name of the principal investigator as well as data on funding source, award date, grant period and funding amount. We can attribute competitive income to five different sources: (1) industry and business, (2) UK research councils (mainly EPSRC), (3) UK charities, (4) UK government and (5) EU. All funding amounts were split across the award period to avoid focussing the entire amount at the start of the grant and to account for the length of the research project. In other words, if the grant lasted two years we split it equally across those two years, if it lasted over three or more years, the first and the last years (which are assumed

[5] Publications without address data had to be ignored. However, we expect this missing information to be random and to not affect the data systematically.

[6] Citation counts are inherently truncated because at any point in time when collecting the citation count per article we may naturally miss out citations to that publication in the future. However, Hall et al. (2005), stress for the case of patents that the bulk of citations usually occurs early in a patent life cycle, and more precisely in a three to ten-year window. Similar results are found for the development of publication citations (Glaenzel et al., 2003; Adams, 2005) Thus, even a six-year window should capture the peak in citations for each publication.

to not represent full calendar years) received half the share of an intermediate year. This was done in order to account for the on-going benefits and implications of a project.

Funding received in *t*-1 is used to capture the impact of financial resource on scientific productivity in *t*. We firstly look at the overall effect of competitive funding (*FUNDING*). Then, we differentiate between funding received from industry (*INDFUND*) and from public agents (*PUBFUND*) which includes UK research council and UK charity funding (*UKFUND)* and EU funding (*EUFUND*). Charity funding is highly competitive and follows a peer-review process similar to that of the research councils and is therefore considered the same in this analysis.[7]

After excluding some outliers [8] researchers receive on average £29,632 per year in competitive funding. Industry funding amounts to approximately £5,000 per academic per year, while public funding provides approximately £22,000 on average, with the majority being sourced from UK research councils and charities (circa £19,000). If we only consider researchers that receive some funding during the observation period, the average amount of competitive funding per year is £53,301 with approximately £9,000 coming from industry and £40,000 from public sponsors. The majority of researchers receive funding from more than one type of funding agent during the observation period. 42% of researchers, however, receive no external funding at all. Of those that receive external funding at least once, 60% are sponsored by industry (35% of the total sample). In terms of funding volume, UK research council and charity funding accounts for 65% of all external research income, funding from industry accounts for 17%, followed by EU with 11%.[9]

Looking at funding received during one period, we find that 30% of funded researchers receive UK research council and charity grants and industry funding simultaneously at least once, 14% receive EU and UK public grants, 7% EU and industry funding, and 10% receive all three types of grants in one period. Table 2 reports the correlation between different types

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[7] UK government funding (GOVFUND) is not included in public funding as it may not be subject to the same peer-review process. Instead, it could be closer in nature to industry funding due to its applied nature. This is checked by adding government grants to public grants and assessing their fit in Appendix B. The result shows that in the case of UK engineering government grants could be considered public funding.

[8] Outliers were identified using average values of leverage and (normalized) residuals following a linear regression of funding on publication outputs and are excluded using DFFITS (Belsley et al., 1980). We follow Bollen and Jackman (1990) and exclude observations with DFFITS>1, meaning that the observation shifts the estimate by one standard deviation. We repeat the process for all funding variables and in total exclude 14 observation, most of which are EU funding outliers. Results for the full sample without exclusion of outliers are reported in Appendix B.

[9] The remaining 8% come from other government sources (see footnote7).

of funding and the outcome measures. We find a strong positive correlation between UK public and industry funding. EU funding correlates less strongly with other funding types. The correlation between the outcome and funding measures is positive and significant.

To measure complementarity and substitution between different types of grants we multiply the funding variables to estimate interaction effects. In other words, we multiply industry funding (*INDFUND*) and public funding (*PUBFUND*) to measure any additional effect of a simultaneous involvement in both types of funded research projects. Further, we split public funding into UK public funding (*UKFUND*) and EU funding (*EUFUND*) to see if they interact differently with industry sponsorship and to investigate potential complementary effects between different types of public research grants.

Control variables

We include patents as additional control to all regressions as it has been shown that publications and patent outputs are correlated (Agrawal and Henderson, 2002) and to account for alternative dissemination paths of researchers (*PATENT*). Patent data was obtained from the European Patent Office (EPO) database. We collected those patents that identify the aforementioned researchers as inventors and were filed while they were employed at one of the 15 institutions. Database construction required a manual search in the inventor database to identify those entries where the identity of the academic was certain. This was done by comparing addresses, titles and technology classes for all patents potentially attributable to each researcher. We did not only consider patents filed by the universities themselves, but also those assigned to third parties, e.g. industry or government agencies.[10] We recorded the filing date of the patent as this represents the closest date to invention. The number of patents filed in *t*-1 is used in the regressions. The average number of patents per year is 0.06 and 0.39 amongst those with at least one patent during the observation period. As the data were collected in 2008, only patents published by 2007, thus filed before 2006, are considered. Table 2 shows that as expected patents and publications are moderately correlated. Patents are only weakly correlated with funding but strongest with industry and EU funding.

We account for academic rank by including a dummy variable that takes the value one if the researcher was a professor in *t*-1 *(PROFESSOR).* Academic rank information was taken from university websites. Professors may have more resources available than lower ranked

[10] Lawson (2013b) showed that in UK engineering more than 50% of inventions are not owned by the university but by private firms, government or individuals.

academics and may thus benefit more in terms of publication output than junior researchers. The rank variable is lagged by one period to allow for publication delays and avoid simultaneity with our outcome measure. *PROFESSOR* is strongly correlated with publication numbers and to a lesser extent with publication quality. It further is moderately correlated with all our funding measures.

We control for gender (*FEMALE*) as previous literature has found a gender bias in both funding and academic productivity (Stephan, 2012). Women account for 7% of researchers in our sample. Table 2 shows that the gender dummy is not highly correlated to any of our main explanatory variables. We only find a negative significant sign for correlation with EU funding.

To account for other individual effects, we collected personal information of researchers based on PhD data. PhD information was taken from *Index to Theses*, an online database which lists theses accepted for higher degrees by the universities of the UK and Ireland. It provides information on PhD institution, year and subject area. For researchers not listed in the database we searched their websites and gathered PhD details from the library catalogues of the PhD awarding university[11]. Of the 809 researchers for which personal information could be collected, 56 do not hold a PhD. As for the remaining 753 researchers, they received their PhDs between 1958 and 2006, with a mean PhD award year of 1984. The degrees come from 58 UK universities and more than 30 different institutions in 16 countries outside the UK. Based on the PhD information we include the researcher's academic age (*PHD_AGE*) as the difference between the current year and the year of the PhD as a control to account for life-cycle effects. The correlation matrix shows that *PHD_AGE* is moderately correlated with our outcome variables but only weakly with the funding measures. We further include a dummy for those researchers that do not hold a PhD (*NO_PHD*), which represents 7% of the sample.

Subject specialisation is based on the subject of the PhD as department division is not consistent across the 15 universities. In our sample 22% of researchers graduated in electrical and electronic engineering (*ELECTRICAL*), 21% in civil engineering (*CIVIL*), 15% hold a PhD in chemical engineering (*CHEMICAL*), 15% in physics (*PHYSICS*) and 13% in mechanical engineering (*MECHANICAL*). Just 8% have a background in life sciences (*BIO*).

[11] This concerned some PhDs awarded in the UK that were not submitted to *Index to Theses* as well as PhDs awarded outside the UK and Ireland.

The correlation table shows some important differences by scientific field. Physics and chemical engineering are strongest correlated with our outcome measures. Physics is also positively correlated with funding, while civil engineering correlates negatively with all types of funding and the outcome measures.

Year and university dummies are included in all regressions to control for potential institution or time fixed effects. Due to the short panel window institution specific measures (e.g. size, income) are not included as they do not differ significantly across time and any differences should be captured by the university fixed effect.

4.2 Analysis of funding profiles

Table 3 reports descriptive statistics by type of funded researcher. Researchers are allowed to move between groups depending on their funding status in *t*-1. We differ between observations where a researcher receives (1) no public or private funding, (2) only private funding, (3) only public funding (UK and EU) and (4) both, private and public funding. The basic descriptive results show that all four groups are significantly different on most of our variables. They also show that researchers receiving funding produce more publications than those who do not. However, only for researchers with some public funding this difference is significant. Further, researchers receiving industry *and* public grants are most productive. This result also holds when looking at quality adjusted publication output. The descriptive results support our assumption of a positive production function and also point towards a complementary relationship between public and private sector grants.

In terms of funding amount, it becomes clear that researchers that source funding from more than one source raise significantly more funding than researchers that rely on just one source. This suggests that as public grants are distributed based on peer review and can be expected to benefit the most able researchers, industry may look at public grants to inform their own funding decision and to identify potential partners for research (Perkmann et al., 2013). This group of highly sponsored and diversified researchers is also the group producing the largest number of patents. This is in line with the literature on star scientists (Zucker et al., 1996, 2002) that suggests strong complementarities between high scientific ability, commercialisation and funding success.

In terms of control variables we make some interesting observations. Significantly fewer female researchers can be found amongst the group of researchers that receive funding from industry alone. Researchers without a PhD are significantly less represented in the groups of funded researchers, suggesting that they are less research but perhaps more teaching oriented. Age is significantly higher in the groups of researchers receiving public funding and highest amongst the top performing group. These also show the highest share of professors. We can further see that different scientific fields attract different types of funding. Researchers in bioscience are significantly more represented in the group that attracts funding from several sources, while researchers in physics are focussing on one agent at a time. Researches in mechanical engineering are more likely to be found amongst funded researchers, while researchers in chemical engineering are mostly found amongst those receiving no or only public funding. Electrical and electronic engineering faculty are less likely to only source funding from industry, while civil engineering researchers are more likely to be found amongst this group.

5 Results

5.1 Baseline results

We firstly estimate the effects of funding on publication outcomes without differing between funding types to look at the overall effect of competitive funding. Table 4 reports the results for publication and citation outcomes. Standard errors are robust and clustered at the individual level. The results show that competitive funding has a positive effect on publication outcomes, supporting our positive production function assumption.

The control variables are consistent across the two different specifications. Patents show a positive correlation with publication and citation numbers confirming prior research. Professors publish significantly more and of higher quality than junior researchers, perhaps due to better access to resources and experience. We do not find a significant difference between the publication rates of men and women. Researchers that do not hold a PhD also produce significantly fewer publications than their peers, indicating that they may focus primarily on teaching. Productivity and publication quality declines with age. Publication and citation numbers are lower in more applied fields of engineering and lowest in civil and mechanical engineering. University fixed effects and year effects are jointly significant. Our pre-sample mean and the dynamic feedback variables are both positive and significant pointing at the importance of controlling for individual unobserved effects.

[Tables 4 and 5 about here]

5.2 Interaction effects

We secondly estimate the effect of different types of funding and their interactions on publication outcomes. For a correct interpretation of the interaction variable we calculate the cross-derivative for the joint effect of public and industry income holding all variables at their mean (following eq. (5)) and report the results in Table 5. The cross-derivative of the interaction term is negative (-0.074), indicating that while public funding positively correlates with publication numbers, the joint effect of industry and public funding is negative and they can be considered substitutive.

We can illustrate the substitution effect by calculating the publication rate increase associated with public grants at different levels of industry funding. Let us consider a researcher receiving a mean value of £22,000 in public funding and a mean value of £5,000 of industry funding. For this researcher the marginal effect of public grants on the predicted value of publications is 0.077 (following eq. (4)). If instead the researcher receives the same amount of public grants but £10,000 in industry grants, then the marginal effect of public grants on the predicted publication rate would be 0.073. Thus, having a higher amount of industry grants reduces the benefit received from public grants. Figure 1 shows the marginal effects of public funding on publications for different levels of industry funding. As can be gathered from these results, industry funding reduces the benefits from public funding and may compromise the positive effect of public funding in the top percentiles. Figure 1 also shows the difference between public funding at the mean and high amounts of public funding in the 95 percentile (£105,000). The marginal benefits of higher amounts of public funding decrease as industry funding increases. Thus, industry funding decreases the marginal effect of public grants such that higher amounts of public funding do not translate into a proportionally higher number of publications. However, when holding all other explanatory variables at their mean, the negative effect of the cross-derivative does not translate into an effective decrease in publication numbers. Figure 2 represents the predicted number of publications for different levels of public funding. The number of publications increases but the rate of increase is smaller for higher amounts of industry funding as shown before. Still, the overall joint effect is positive.

[Figures 1 and 2 about here]

The results are similar for citation counts. Public funding shows a positive sign, but again, the interaction term with industry funding is negative (Table 5). For a researcher receiving an average amount of industry grants(£5,000), public grants of £22,000 increase the predicted number of citations by 1.811, while for a researcher receiving £10,000 from industry, public grants of £22,000 increase the predicted number of citations by only 1.666 (Figure 3). Figure 3 shows that the difference between marginal effects of public funding at the mean and public funding in the 95 percentile decreases as industry funding increases. Figure 4 further shows that while public funding has a positive effect on citation numbers, these are lower if higher amounts of industry funding are sought. Above £70,000 in public funding, a researcher fares better not to increase the amount sourced from industry as this leads to a real decrease in the benefits from public funding.

[Figures 3 and 4 about here]

Columns two and four of Table 5 consider funding received from UK public agents, EU, and industry and include their interactions. The results show that only UK public funding is associated with higher publication output and quality. The interactions between public and industry funding are negative but only significant for UK public funding. Table 5 shows the cross-derivatives which confirm the negative interaction effect. The cross-derivative of the interaction between UK and EU funding is insignificant. This indicates that an increase in EU funding does not affect the benefit received from UK public funding.

6 Conclusions

This paper investigated empirically the existence of complementarities between public and private funding on scientific publication performance. The question is particularly critical as public budgets are shrinking and researchers are increasingly looking at other channels for supporting their research. Industry sponsoring relationships can provide ideas and resources for research that may open up new research lines (Mansfield, 1995). If this is the case then also the expected benefits from public funding could increase based on positive complementarities. On the other hand, previous research also expressed concerns that industry partners may direct academics towards applied research and limit or delay the dissemination of research results (Blumenthal et al., 1986, 1996; Cohen et al., 1998, Czarnitzki et al. 2011). If sponsors induce a shift of research topic or require secrecy then also public funding placed with such industry sponsored researchers may suffer limitations and the marginal utility of public grants may decrease.

Using a sample of 809 researchers in engineering and controlling for unobserved heterogeneity, we find that industry funding decreases the marginal utility of public funding by decreasing the marginal effect of public grants on publication outcomes. This indicates that researchers are working at full capacity and increases in funding do not translate into comparative increases in research output when multiple sponsors are involved. This negative interaction effect was found for co-sponsorship from UK funders but was insignificant for EU grants. At the same time it is important to note that industry funding does not compromise the positive effect of public funding but only reduces the rate of publication increase associated with public grants. We further observed, that significant benefits in terms of publication output can only be observed for increases in UK public funding. The results show that EU funding does not independently increase publication rates but increases the marginal effect of the joint public funding variable. The results help to inform the debate on how industry and public funding jointly affect research productivity. In terms of policy implications we can conclude that it is important to maintain high levels of public funding to ensure the quality of the higher education research sector.

This study is a first step to unleash the interactions between different types of competitive funding. We concentrated on the engineering field that is traditionally associated with industry and therefore may provide a lower threshold. We therefore strongly encourage further research taking into account other disciplines as funding environments continue to shift. The evidence presented here shows that this shift may not be without consequences for the development of the science base, even in applied sciences like engineering. Ours can only be a first attempt and more research is clearly needed to pin down the mechanisms behind the effect of industry grants that could be due to non-disclosure clauses or research themes less relevant to science. Blumenthal et al. (2006) and Czarnitzki et al. (2011) show evidence of secrecy clauses for researchers with industry grants that may also affect the release of publications from public grants. Hottenrott and Lawson (2013) further suggested that ideas from industry may not always lead to better research performance perhaps by simply not being relevant to science (see Perkmann and Walsh, 2009). With the comparability of our results in mind, we suggest further research on the dynamics underlying the sponsoring-research outcome relationship in both qualitative and quantitative ways. In particular, the debate on research funding would benefit from investigating if and how funding relationships not only affect short-term scientific outcome, but also how they shape scientific careers. Researchers may specialize in certain types of grants and sponsors, and hence the type of research output they pursue.

Finally, it is important to stress that this study does not evaluate other benefits that may come from co-sponsorship. A more comprehensive assessment is therefore needed to establish if benefits for students, teaching or commercialisation of research as well as benefits for the sponsoring firms exist that contribute to the social returns from science and may therefore be of greater policy relevance than publications in scientific journals.

Appendix A

See Table A1

Appendix B

Results including outliers

Outliers were identified using average values of leverage and (normalized) residuals following a linear regression of funding on publication outputs. We repeated the process for all funding variables and in total excluded 14 observations, most of which were EU funding outliers at the University of Cambridge. To check if these outliers affect the results we estimate our regression including the excluded observations and report the marginal effects in Table B1. The results are very similar to the results presented in Table 5. However, some of the interactions with EU funding are significant, indicating that complementarities between UK and EU funding are significant if outliers are included.

Results including government funding

In our main regressions UK government funding was included in public funding as it may not be subject to the same peer-review process. Instead, it could be closer in nature to industry funding due to its applied nature. For German researchers Grimpe (2012) finds that government grants are acquired complementary to industry grants and are not correlated to research output variables.

This is checked by adding government grants to public grants and assessing their fit. The results in Table B2 show that the marginal effects for all funding variables increase, indicating that government funding in the UK may be closer aligned to public funding than industry funding.

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Tables

Table 1: Descriptive statistics (4,031 observations)

	mean	sd	min	max
Productivity measures				
$PUBLICATIONS_{it}$ (Publication number)	2.18	3.12	0	32
$CITATIONS_{it}$ (Citation number)	32.14	79.12	0	1296
Funding measures(in 100,000 GBP)				
$FUNDING_{it-1}$	0.30	0.90	0	12.12
$PUBFUND_{it-1}$	0.22	0.79	0	11.15
$INDFUND_{it-1}$	0.05	0.21	0	3.35
$UKFUND_{it-1}$	0.19	0.76	0	11.15
$EUFUND_{it-1}$	0.03	0.14	0	2.29
Patent measure				
$PATENT_{it-1}$	0.06	0.32	0	8
Individual characteristics				
$PROFESSOR_{it-1}$	0.33	0.47	0	1
$FEMALE_i$	0.07	0.25	0	1
NO_PHD_i	0.07	0.25	0	1
PHD_AGE_i	18.18	10.41	0	48
BIO_i	0.08	0.26	0	1
$PHYSICS_i$	0.15	0.36	0	1
$MECHANICAL_i$	0.13	0.34	0	1
$ELECTRICAL_i$	0.22	0.41	0	1
$CHEMICAL_i$	0.15	0.36	0	1
$CIVIL_i$	0.21	0.41	0	1
Individual heterogeneity measure				
PUB_Mean_i	0.42	0.77	-0.69	3.26
CIT_Mean_i	1.46	1.38	-1.79	6.39
PUB_Stock_{it-1}	6.07	9.19	0	131
CIT_Stock_{it-1}	100.75	255.03	0	5975

Table 2: Correlation matrix (4,031 observations)

		1	2	3	4	5	6	7	8	9	10	11	12
1	$PUBLICATIONS_{it}$	1.000											
2	$CITATIONS_{it}$	0.740***	1.000										
3	$FUNDING_{it-1}$	0.190***	0.127***	1.000									
4	$PUBFUND_{it-1}$	0.175***	0.118***	0.956***	1.000								
5	$INDFUND_{it-1}$	0.108***	0.063***	0.492***	0.258***	1.000							
6	$UKFUND_{it-1}$	0.158***	0.103***	0.935***	0.984***	0.239***	1.000						
7	$EUFUND_{it-1}$	0.127***	0.102***	0.308***	0.295***	0.150***	0.118***	1.000					
8	$PATENT_{it-1}$	0.142***	0.151***	0.040**	0.027*	0.065***	0.015	0.069***	1.000				
9	$PROFESSOR_{it-1}$	0.295***	0.207***	0.242***	0.205***	0.182***	0.190***	0.127***	0.111***	1.000			
10	$FEMALE_i$	0.028*	0.018	-0.011	-0.014	0.015	-0.008	-0.032**	-0.010	-0.073***	1.000		
11	NO_PHD_i	-0.138***	-0.088***	-0.015	-0.020	-0.010	-0.012	-0.047***	-0.032**	-0.103***	-0.035**	1.000	
12	PHD_AGE_i	0.138***	0.102***	0.043***	0.030*	0.060***	0.022	0.046***	0.034**	0.454***	-0.117***	-0.078***	1.000
13	BIO_i	0.024	0.036**	-0.006	-0.006	0.010	-0.002	-0.022	-0.032**	-0.103***	-0.035**	-0.114***	0.122***
14	$PHYSICS_i$	0.136***	0.101***	0.080***	0.080***	0.039**	0.073***	0.053***	0.048***	0.035**	0.053***	-0.106***	0.201***
15	$MECHANICAL_i$	-0.037**	-0.050***	0.025	0.004	0.071***	0.002	0.012	0.008	0.087***	-0.058***	-0.144***	-0.029*
16	$ELECTRICAL_i$	-0.026*	-0.052***	-0.004	-0.000	-0.007	-0.009	0.047***	-0.033**	-0.026*	-0.003	-0.115***	0.043***
17	$CHEMICAL_i$	0.158***	0.161***	-0.035**	-0.019	-0.063***	-0.010	-0.053***	0.069***	0.029*	-0.060***	-0.140***	0.084***
18	$CIVIL_i$	-0.130***	-0.104***	-0.043***	-0.041***	-0.030*	-0.040**	-0.014	0.005	0.032**	0.107***	-0.078***	-0.050***

$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 3: Means by funding structure

Funding	No funding	Public=0; Industry>0	Public>0; Industry=0	Public>0; Industry>0	Anova F-Test
Observations	2487	284	850	410	Sig.
Researcher IDs	652	137	314	167	
Productivity measures					
$PUBLICATIONS_{it}$	1.73	1.91	2.68***	4.09***	***
$CITATIONS_{it}$	25.73	21.63	38.80***	64.49***	***
Funding measures (in 100,000 GBP)					
$FUNDING_{it-1}$	0.01	0.25***	0.62***	1.41***	***
$PUBFUND_{it-1}$	0.00	0.00	0.59***	0.98***	***
$INDFUND_{it-1}$	0.00	0.22***	0.00	0.34***	***
$UKFUND_{it-1}$	0.00	0.00	0.50***	0.86***	***
$EUFUND_{it-1}$	0.00	0.00	0.09***	0.12***	***
Patent measure					
$PATENT_{it-1}$	0.05	0.05	0.06	0.13***	***
Individual characteristics					
$PROFESSOR_{it-1}$	0.25	0.35***	0.43***	0.62***	***
$FEMALE_i$	0.07	0.03***	0.08	0.06	**
NO_PHD_i	0.09	0.06*	0.02***	0.03***	***
PHD_AGE_i	17.79	17.37	18.60**	20.17***	***
BIO_i	0.07	0.04**	0.08	0.11***	***
$PHYSICS_i$	0.14	0.18**	0.18***	0.15	***
$MECHANICAL_i$	0.12	0.18***	0.14**	0.17***	***
$ELECTRICAL_i$	0.22	0.17**	0.21	0.23	n.s.
$CHEMICAL_i$	0.16	0.10***	0.15	0.11***	***
$CIVIL_i$	0.20	0.27***	0.21	0.21	**

Mean comparison test compares observations with funding (columns 2-4) to observations with no funding (column 1).
Analysis of variance compares the four groups of researchers.
*** p<0.01, ** p<0.05, * p<0.1

Table 4: Effects of competitive funding on publication outcomes

VARIABLES	(1) PUBLICATIONS$_{it}$ NBREG Coef.	SE	(2) CITATIONS$_{it}$ NBREG Coef.	SE
FUNDING$_{it-1}$	0.039**	(0.020)	0.070*	(0.037)
PATENT $_{it-1}$	0.140***	(0.048)	0.099*	(0.059)
PROFESSOR$_{it-1}$	0.401***	(0.051)	0.729***	(0.085)
FEMALE$_i$	0.033	(0.104)	0.022	(0.163)
NO_PHD$_i$	-0.751***	(0.156)	-1.056***	(0.244)
PHD_AGE$_{it}$	-0.018***	(0.003)	-0.028***	(0.005)
BIO$_i$	0.268***	(0.087)	0.622***	(0.162)
PHYSICS$_i$	0.356***	(0.075)	0.658***	(0.128)
MECHANICAL$_i$	0.117	(0.079)	0.076	(0.137)
ELECTRICAL$_i$	0.188***	(0.069)	0.337***	(0.124)
CHEMICAL$_i$	0.355***	(0.072)	0.610***	(0.120)
CIVIL$_i$ (Reference)				
ln[Pub_Mean]|ln[Cit_Mean]	0.273***	(0.040)	0.235***	(0.039)
[Pub_Mean=0]|[Cit_Mean=0]	-0.387***	(0.078)	-0.198	(0.129)
Pub_Stock|Cit_Stock	0.040***	(0.005)	0.002***	(0.000)
Constant	-0.456***	(0.151)	1.135***	(0.225)
Joint sign. of university dummies $\chi 2$ (14)	133.00***		126.63***	
Joint sign. of subject dummies $\chi 2$ (5)	34.07***		44.29***	
Joint sign. of year dummies $\chi 2$ (4)	10.53**		21.66***	
Log-likelihood	-6754.178		-13993.916	
Lnalpha	-0.960***		1.252***	
Cluster	809		809	
Observations	4031		4031	

Note: Coefficients are reported. Robust clustered standard errors in parentheses; clustered by individual researcher.
*** p<0.01, ** p<0.05, * p<0.1

Table 5: Marginal effects for funding values and their interactions

VARIABLES	(1) PUB$_{it}$ NBREG	(2) PUB$_{it}$ NBREG	(3) CIT$_{it}$ NBREG	(4) CIT$_{it}$ NBREG
PubFund$_{it-1}$	0 .074*		1.667**	
	(0.038)		(0.714)	
UKFund$_{it-1}$		0.054*		1.292**
		(0.032)		(0.657)
EUFund$_{it-1}$		0.210		6.900
		(0.209)		(4.377)
IndFund $_{it-1}$	0.186*	0.212*	1.392	1.083
	(0.111)	(0.123)	(2.216)	(2.450)
IndFund $_{it-1}$ *PubFund $_{it-1}$	-0.074**		-2.648 ***	
	(0.035)		(1.020)	
IndFund $_{it-1}$ *UKFund $_{it-1}$		-0.072**		-2.536**
		(0.031)		(1.012)
IndFund $_{it-1}$ *EUFund $_{it-1}$		-0.379		-2.843
		(0.313)		(5.694)
UKFund $_{it-1}$ *EUFund $_{it-1}$		0.135		1.023
		(0.097)		(2.009)

Note: Marginal effects are calculated following eq. (4) and eq. (5) at the sample mean. Standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table A1: List of Universities

University Name	Academics	Observations	Region
Brunel University	48	240	London
City University	23	112	London
Queen Mary University	31	153	London
University of Reading	22	110	South East
University of Cambridge	123	604	East
University of Essex	26	130	East
University of Leicester	29	144	East Midlands
Loughborough University	123	612	East Midlands
University of Durham	21	95	North East
Lancaster University	10	50	North West
University of Sheffield	100	491	Yorkshire
University of Edinburgh	54	266	Scotland
University of Glasgow	63	313	Scotland
University of Strathclyde	97	481	Scotland
University of Swansea	46	230	Wales
Total	**809***	**4031**	

*Academics can change university within the sample. Therefore numbers do not add up to 809.

Table B1: Marginal effects including outlier observations

VARIABLES	(1) PUB_{it} NBREG	(2) PUB_{it} NBREG	(3) CIT_{it} NBREG	(4) CIT_{it} NBREG
$PubFund_{it-1}$	0 .085**		1.829**	
	(0.041)		(0.767)	
$UKFund_{it-1}$		0.065*		1.365**
		(0.035)		(0.676)
$EUFund_{it-1}$		0.127		4.567
		(0.226)		(4.485)
$IndFund_{it-1}$	0.056	0.172	0.331	1.421
	(0.143)	(0.123)	(2.252)	(2.439)
$IndFund_{it-1}$ *$PubFund_{it-1}$	-0.097**		-2.390***	
	(0.041)		(0.903)	
$IndFund_{it-1}$ *$UKFund_{it-1}$		-0.093**		-2.454***
		(0.042)		(0.847)
$IndFund_{it-1}$ *$EUFund_{it-1}$		-0.583***		-7.843
		(0.157)		(7.469)
$UKFund_{it-1}$ *$EUFund_{it-1}$		0.114		2.168*
		(0.100)		(1.306)
Log-likelihood	-6820.239	-6817.360	-14121.763	-14120.854
Lnalpha	-0.939***	-0.944***	1.256***	1.255***
Cluster	809	809	809	809
Observations	4045	4045	4045	4045

Note: Marginal effects are calculated following eq. (4) and eq. (5) at the sample mean. Standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table B2: Marginal effects including government funding

VARIABLES	(1) PUB_{it} NBREG	(2) CIT_{it} NBREG
$PubFund_{it-1}$ (incl. $GovFund_{it-1}$)	0.078**	1.851**
	(0.038)	(0.767)
$IndFund_{it-1}$	0.203*	1.792
	(0.118)	(2.358)
$IndFund_{it-1}$ *$PubFund_{it-1}$	-0.080**	-2.735***
	(0.035)	(0.903)
Log-likelihood	-6752.346	-13991.327
Lnalpha	-0.960***	1.250***
Cluster	809	809
Observations	4031	4031

Note: Marginal effects are calculated following eq. (4) and eq. (5) at the sample mean. Standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Figures

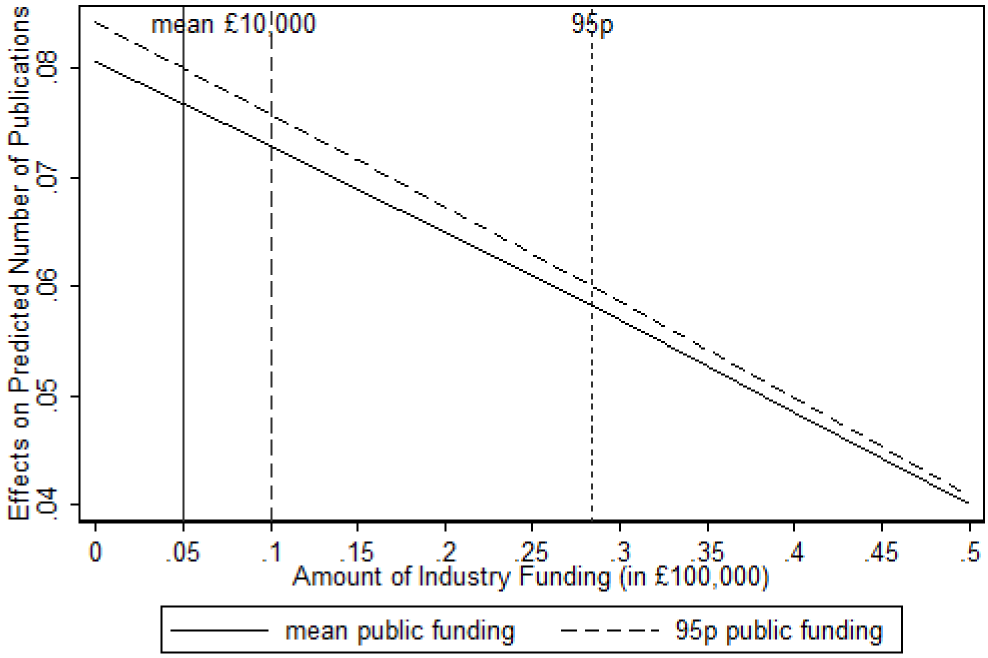

Figure 1: Effect of industry funding on the marginal effect of public funding on publication numbers

Note: All other variables are held at the sample mean

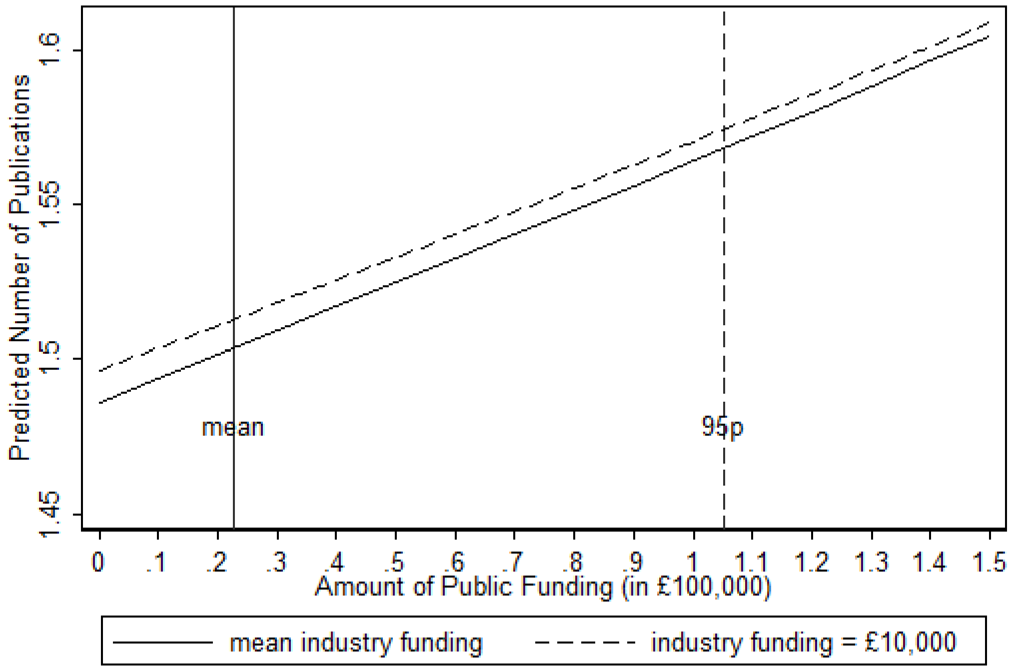

Figure 2: Predicted number of publications for different levels of public funding

Note: All other variables are held at the sample mean

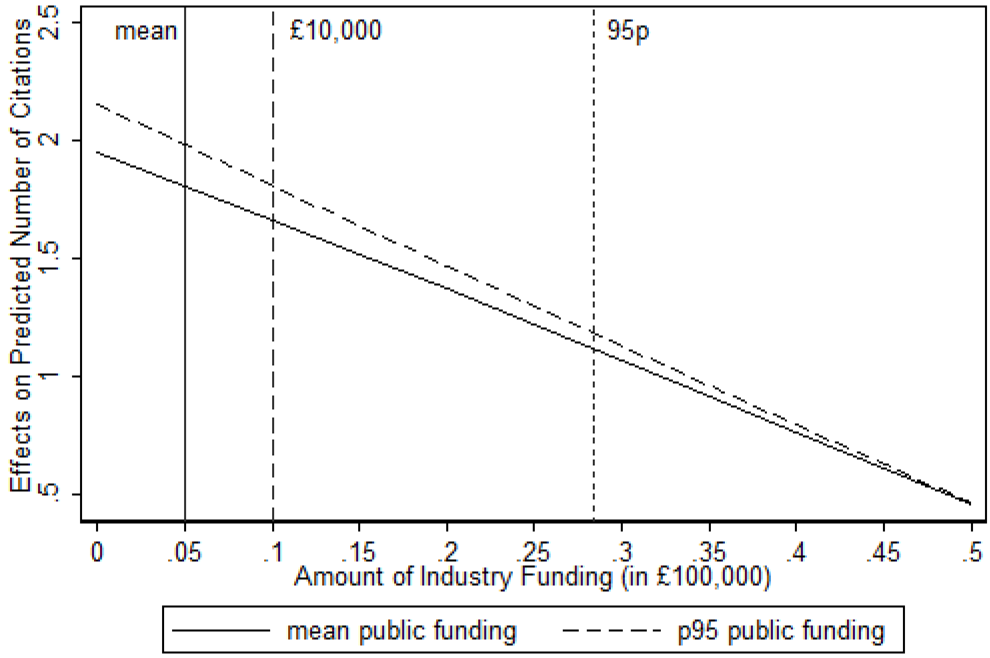

Figure 3: Effect of industry funding on the marginal effect of public funding on citation numbers

Note: All other variables are held at the sample mean

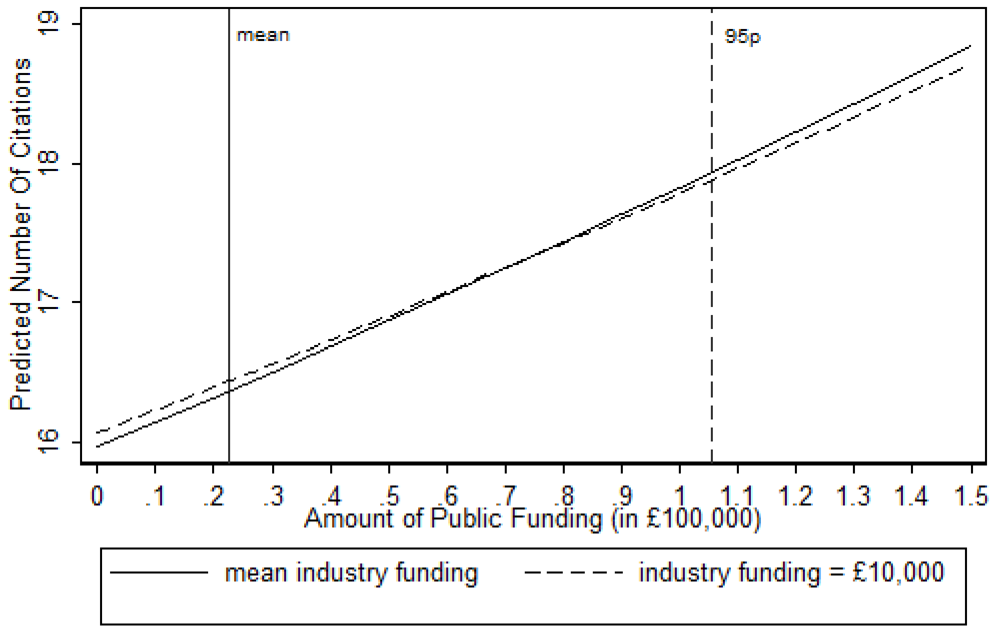

Figure 4: Predicted number of publications for different levels of public funding

Note: All other variables are held at the sample mean