Research Evaluation – Editorial Office

Do university-industry co-publication outputs correspond with university funding from firms?

Alfredo Yegros-Yegros · Joaquín M. Azagra-Caro · Mayte López-Ferrer · Robert J.W. Tijssen♣

Abstract Analysts of university-industry interaction sometimes measure it through numbers of university-industry co-publications (UICs), because of their relative availability and international comparability. However, we do not know whether UICs correspond to another measure of interaction: university funding from firms. We propose a conceptual model on four types of relationships between UICs and university funding from firms, emphasising the interactive nature of their relation, e.g. not only funding can lead to UICs, but also UICs can signal competences that motivate funding. We test the model with UIC and income data from the Polytechnic University of Valencia at individual level: around 6-7% of researchers participating in projects with firms were authors of UICs published in 2008-2011; and around 27% of those UIC authors were participating in projects with firms during that period. Overall, we do not find evidence of any significant positive correlation between UIC output and university funding from the business sector in general. The one exception is a minority of authors who participate in business-funded projects, where we find a positive association of current UICs and business funding.

Keywords University-industry interaction · Co-publication · Business sector funding

JEL code O390 Technological Change: Other

1. Introduction

Interactions and the transfer of knowledge between universities and companies conduct to a variety of potential benefits, including the potential contribution to the economic growth, not absent of costs. During the last decades this topic has attracted the attention of academics and increasingly also of policy makers, trying to understand the

♣ A. Yegros-Yegros
Centre for Science and Technology Studies (CWTS), Leiden University, PO Box 905, 2300 AX Leiden The Netherlands
• R.J.W. Tijssen, CWTS, Leiden University, The Netherlands; DST-NRF Center of Excellence in Scientometrics and Science, Technology and Innovation Policy, Stellenbosch University, South Africa.

J.M. Azagra-Caro (✉) • M. López-Ferrer
INGENIO (CSIC-UPV), Universitat Politècnica de València, Camino de Vera s/n, E-46022 Valencia, Spain
e-mail: jazagra@ingenio.upv.es

conditions under which university-industry (U-I) relationships lead to beneficial results, in order to promote and boost this type of interactions.

U-I interactions are considered a multi-faceted phenomenon with several 'channels', 'mechanisms' or more generically 'linkages', acting as informational or social pathways through which information, knowledge and other resources are exchanged or co-produced across universities and industry (Perkmann and Kathryn, 2007). Scott et al. (2001) classified these linkages into four main categories through which university and industry interact: 1) Codification/artefacts (e.g. publication or patents); 2) Cooperation (e.g. joint ventures or exchange of personnel); 3) Contacts (e.g. meetings or informal contacts) and 4) Contracts (e.g. licenses or contract research). Other authors also emphasize the wide range of possible linkages (e.g. D'Este and Patel 2007; Bekkers and Bodas-Freitas, 2008).

An essential analytical tool in the study of U-I interactions is the design of measures able to capture accurately different aspects of this complex process. The existence of a wide variety of linkages, suggest that in order to measure and analyse in a comprehensive way the two-way interactions between universities and industries it would be necessary the use of a wide range of metrics, some of which could be used as a proxy (an 'indicator') of a specific kind of interaction.

However, the measurement of some linkages is usually impossible, simply because of the lack of publicly accessible information (e.g. exchange of personnel, contracts or joint projects with industry, licenses) or others are most likely untraceable, such as the informal contacts.

One indicator based on scientific publications has been proposed to partially overcome these problems associated to the measurement of U-I interactions: and it refers to U-I joint scientific publications, those in which the author addresses include at least one university and one private sector organization: *university-industry co-publications* (hereinafter UICs). These UICs have been used in several studies under the assumption that these joint scientific publications capture to some extent U-I interactions (e.g. Calvert and Patel, 2003; Sun et al., 2007; Abramo et al., 2009; Klitkou et al., 2009; Tijssen et al., 2009, 2012; Giunta et al., 2014). However, despite this frequent use of UICs as a proxy of U-I interaction or collaboration, it still remains unclear what exactly represent these joint publications, which type of interactions led to these UICs as well as the level of accuracy in which these assumed interactions are captured. Indeed, only a few studies have tried to shed some light on this issue (e.g. Lundberg et al. 2006; Wong and Singh, 2013).

Following a similar vein, the objective of this study is to provide new insights on the validity of UICs as indicator of the interactions between universities and industry by analyzing the relationship between UICs and another indicator of these interactions: direct investment of private companies in university research. For this purpose, we collected financial data of one of the main Spanish technical universities (the *Polytechnic University of Valencia*). This is a unique dataset, containing confidential information from the internal system of the university. This information was then analysed together with joint scientific publications between the Polytechnic University of Valencia and business companies. We do not only consider UICs as a result of previous industry funding, but also that participation in UICs might shape later interactions between university researchers with the business sector. In this sense, our conceptual model encompasses several potential scenarios according to the time sequence between industry funding and UICs.

The paper is organized as follows. Section 2 we review the literature on UICs. In section 3 we present our conceptual model. Section 4 describes the data and section 5 our main findings. Finally, section 6 presents our discussion and conclusions.

2. Literature review

This section covers two different topics. Firstly, previous studies on the relationship between these U-I interactions and scientific publications, secondly, studies using UICs as a proxy of U-I collaboration, the advantages and limitations of this particular indicator.

2.1. Relationship between U-I interactions and scientific publications

The relationship between U-I interactions and scientific publications has been addressed in several studies and from different perspectives. Some studies focused on the effect that the participation in interactions with industry has in researchers' performance, which is often measured in terms of scientific publications.

Indeed, a number of studies aimed at analyzing the impact of the participation in projects funded by industry on the scientific productivity of academic researchers. The findings of these studies are not conclusive. Some empirical evidence reported suggests that collaborative activities with industry have a positive effect on the scientific performance of academic researchers. Gulbrandsen and Smeby (2005) found that Norwegian professors with industrial funding collaborated more with other researchers both in academia and in industry, and they reported more scientific publications as well as more frequent entrepreneurial results. Also Landry et al. (1996) found that collaboration, in general, increase researcher's productivity, while collaboration between researchers and industry in particular, far from being a detrimental factor, had significantly more impact on productivity than collaborations between researchers and their peers or researchers and other institutions like government agencies or local governments.

According to some other studies, U-I interactions might be beneficial to scientific productivity under specific circumstances and only up to certain limits. For instance, Manjarres-Henriquez et al. (2008) found a positive effect of U-I collaboration on scientific productivity of researchers only when the collaborative activities were based on the development of R&D contracts and when the industry funds did not exceed 15% of the researchers' budget. Banal-Estañol et al. (2013a) report similar findings, they found that collaboration with industry has a positive effect on the number of publications but it turns negative after certain point, suggesting an inverted U-shape relationship. Other studies do not suggest a positive relationship at any stage, e.g. academic research leading non-academic partners who funded the research to own patented results has none or negative impact on citations to scientific papers (Martínez et al., 2013).

On the other hand, some authors have focused on the relationships between specific U-I interactions and the publication in scientific journals of findings resulting from these interactions.

Perkmann and Kathryn (2009), based on 43 interviews to academics of the engineering faculty of a research-intensive UK university, investigated how different types of U-I projects impact on academic research, especially on scientific publications. They found that joint curiosity-driven projects with industry, whose main objective was the generation of new knowledge and focusing on stages far away from the market, were more likely to generate scientific publications. However, U-I interactions within the framework of other types of projects related to the testing of ideas, technology development or problem-solving, which are also closer to the market compared to curiosity-driven projects, were less likely to produce scientific publications due to a number of reasons, among others, data not collected sufficiently, projects affected by secrecy considerations or simply the results of the projects were not sufficiently interesting or novel to be published in a scientific journal.

Banal-Estañol et al. (2013b) analyzed projects funded by the Engineering and Physical Sciences Research Council in the U.K, both with at least one industrial partner and projects without participation of industry, to study the relationship with the quantity and quality of resulting scientific publications. Their findings suggest that publication outputs in joint projects depend not only on the past publication record of the academics, but also on the past research publication record of companies. Companies with low publication output decrease the number and quality of project outputs, while companies with high levels of publication output contribute to increase the number and quality of publications. However, the dataset used in this study consisted of projects indicating at least one research publication as part of the outputs of the project, so that those projects and collaborations with industry not leading to these publications are not considered in the study.

2.2. The use of UICs as a proxy of U-I collaboration

Several studies have used UIC data as proxy of U-I collaborations. For instance, Calvert and Patel (2003) used these co-publications to gather systematic data on U-I collaborations in the UK during two decades. Sun et al. (2007) explored the trends and characteristics of the linkages between universities and industry in Japan measuring the level of co-authorship in scientific publications. Abramo et al. (2009) analysed not only collaborations between Italian universities and Italian industry, but also the relationship of these collaborations at the micro level of university researchers as well as gauging the degree of multidisciplinarity of such collaborations. Tijssen et al. (2009) conducted a large-scale benchmarking analysis for the world's largest research universities based on UIC data. Klitkou et al. (2009) studied the links between technical universities and industry based in part on joint publications between several technical universities in East European countries with industry. Giunta et al (2014) used UICs as a proxy of U-I relations in bio-pharmaceutical R&D, using these joint publications to estimate models for the occurrence and intensity of U-I interactions. Also these joint publications have also served as a tool to measure the strength of the linkages between universities and companies for different conceptual frameworks aimed at analysing innovation processes, like national innovation systems (Tijssen, 2012)

Authors employ several arguments to base their decision on using UICs in the analysis of collaborations. For instance, it is argued that the UICs can be seen as a result of successful scientific collaboration (Abramo et al., 2009). Similarly, Tijssen et al. (2009) argue that:

> "*These joint publications reflect effective and fruitful research that not only produced valuable results worth disseminating to a wider international public, but also inspired collaborating partners to invest time and money to jointly draft a high-quality research article for publication a peer-reviewed journal*" (p. 22).

Abramo et al. (2009) mention several advantages of the use of UICs to measure U-I collaborations, for instance, they argue that this indicator is quantifiable and invariant and also that the measurement is not invasive and inexpensive. On the other hand, these authors consider that the number of UICs might be relatively high which may ensure a level of significance hardly reachable with other approaches.

Tijssen (2011) also mentions that UICs are considered as one of the few information sources for developing aggregate-level proxy measures of the magnitude and intensity of U-I research cooperation and also have additional advantages given that to some extent ensures some degree of comparability.

All in all, these advantages of using UICs as a proxy in the specific context of U-I interactions or collaborations are more or less similar to the arguments discussed earlier on the use of co-authorship to analyze research collaboration in general (e.g. Katz and Martin, 1997).

On the other hand, UICs as any other type of co-authorship are far from being considered perfect measures of actual collaboration. Katz and Martin argued that not all collaborative activities lead to a co-authored scientific publication, nor do all co-authored publications reflect a real collaboration. These authors also highlight the fact that only some of the more tangible aspects of collaborative activities can be quantified while others like the relationships between quantifiable activities and intangible contributions are hardly quantifiable.

Other studies, focusing on U-I interactions also stress that UICs, like other quantitative measures

> *"… allow for powerful analysis, yet do not directly account for social relationships, organizational arrangements or motivations. For instance, research based on patent data risks missing forms of collaboration that do not result in patents or areas of industrial innovation where patents do not play a primary role"* (Perkmann and Kathryn, 2007: 261).

The same argument might be applied to scientific publications: if certain types of interactions do not lead to scientific co-publications, but still the question is what these UICs tell us about U-I interactions.

Moreover, some UICs might not refer to collaboration, notably, when researchers move from academia to industry or *vice versa*. In those instances authors usually indicate both institutional affiliations in their scientific publications for a limited period of time after their move (Abramo, 2009; Tijssen, 2011; Yegros and Tijssen, 2014).

Gulbrandsen and Nerdrum (2009) indicate that one of the main weaknesses of UICs is that they are applied in a knowledge production context with specific characteristics, such as more intellectual property restriction, proprietary knowledge, more applied research, and sometimes short-term interactions perhaps due to the pressing need for companies in obtaining results – which do not favor scientific publication.

Although limitations of UICs as a proxy measure of U-I interactions are usually acknowledged, only a few authors tried to analyze the validity of these UICs as an indicator of U-I interactions. Lundberg et al. (2006) compared companies funding research conducted in Karolinska Institute in Sweden with those co-publishing with this particular university. They found that one third of the companies that had provided funding to the university did not co-publish any scientific paper with the university, thus concluding that UICs provided incomplete results on the actual collaborations between university and industry.

The study by Wong and Singh (2013), analyzing data from the National University of Singapore, focused on the relationship between UICs and some U-I technology transfer channels related to generate and exploit intellectual property rights (IPR): patents, licensing and spin-off formation activities. Their results point to the existence of a positive relationship between UICs and all these three universities' technology commercialization indicators.

3. Conceptual approach

There are four conceptual models of how UICs may relate to university funding from business firms, each depending on the specified time-sequence. The most intuitive 'causal' model is that past university funding generates current UICs, i.e. business firms endowed academics with financial resources to perform research that will lead to co-publications today. We call this the 'industry financing' model (depicted in the upper left section of Fig. 1).

{Fig. 1 here}

However, academics that carry out projects with firms may be writing UICs at the same time, so this interaction may shape the form and contents of co-publications because of exchange of ideas in parallel. For instance, co-designing a current R&D project proposal with a firm may inform or inspire how an academic co-writes his present papers on previous project with that firm or other firms. We call this the 'industry pull' model (lower left of Fig. 1).

Another contemporaneous relation may take place: academics that write UICs may be simultaneously preparing projects or contracts with that firm. Their scientific publications may then influence how both partners design and codify the interaction. This is the 'science push' model (lower right of Fig. 1).

Current UICs may attract future business funding, e.g. through increased recognition of university authors, because of scientific prestige, having shown specific competences or prove of previous interaction with firms. The UICs then become then a channel to transfer or signal relevant information for firms. This is our 'science signalling' model (upper right of Fig. 1).

We will test whether actual data fits into any of these four models.

4. Data

In our study we will focus on the Technical University of Valencia (UPV) to analyse the extent to which the amount of their UICs correspond to the university funding coming from business firm.

UPV is a Spanish public university founded in 1971. It is among the top three national universities in terms of Spanish-issued patents and often Spain's top ranking university in the EPO- and PCT-patent rankings. It is also representative of other young European universities, characterized by their small size, technological research and less consolidated public funding, which made them more heavily dependent on industry funding. UPV is increasingly engaged in industry interaction, through a relatively well-endowed industrial liaison office and a pioneering program to support the creation of university spin-off companies. However, public funding has grown at a faster rate than private funding, because of internal UPV policies to maintain a certain standard of quality in academic research.

4.1. UIC data

UICs published by UPV in the 4-year time-period t=2008-2011 were extracted from the Thomson Reuters *Web of Science* database (WoS) licensed to CWTS (Leiden University). This set of publications includes articles, reviews and letters. In total, 165 WoS-indexed UICs were found, where a UPV-affiliated researcher and at least one business sector company were listed in the author addresses. As business sector we considered basically manufacturing companies; private universities or private hospitals were discarded in our delineation of the business sector domain, but public companies are also included.

We identified 255 distinct authors in the UICs (see Fig. 2 for a visualisation).

{Fig. 2. here}

4.2. Financial data

Data referred to external funding sources comes from UPV's Centre for Innovation, Research and Technology Transfer (CTT), the technology transfer office of the UPV. It covers the period 2000-2013 and includes project and contract funding ("project funding" hereafter): research, development, technical support, professional works, etc. The database contains bibliographical items on the geographic origin (domestic, foreign) and institutional source of funding (public administration, company, etc.).

Because of our target on business funding, we dropped projects without firms as partners. We also excluded projects with both firms and other institutions as partners, to avoid confounding effects (just 12% of all projects with firms, see Fig. 3). However, to match UIC data, we included publicly owned firms. In addition, we also incorporated projects funded through public calls for tenders, if led by a firm that subcontracted UPV, because for UPV this is equivalent to be funded by a company.

{Fig. 3. here}

Another CTT database item describes the role of participants in the project: principal investigators, researchers, grant holders, technicians, etc. Only the first two classes of participants had mostly complete information on department affiliation, age, gender, etc. The other classes were therefore discarded, which should not be a great limitation because the former constitute the majority of participants in projects (61%) and are the ones with tenured positions, i.e. with higher possibilities to interact with companies.

Since our selection of UICs defines the period t=2008-2011, we split the project periods accordingly, to take stock of all the available years. Thus $t-\tau$=2000-2007 and $t+\varphi$=2012-2013. However, projects have a start year and end year, so this can create ambiguities if both are not contained in the given intervals. To deal with it, we calculated the mean value of start and end year, and allocated projects to periods according to this mean value. There were only 20% of these ambiguous cases, so it is a small distortion.

The agreements involve 1,224 UPV researchers in 2000-2007, 1,004 in 2008-2011 and 482 in 2012-2013.

4.3. Matching

We matched the 255 author names to the 1,546 participant names of projects. In the CTT database the typical participant name takes the form: “Surname 1, Surname 2, Given name”, e.g. “Corma Cano, Avelino”. Spanish names have two surnames, which are clearly differentiated in the CTT database. In the CWTS-WoS database, the typical author name takes the form: “Surname, Given name initial”. The field surname may contain either the first surname, e.g. “Corma, A”; or both surnames joined by a hyphen (a usual practice among Spanish authors), e.g. “Corma-Cano, A”, so we split surnames of the latter kind to create a new author name with the form “Surname 1, Surname 2, Given name initial”. Simply put, our matching algorithm stated that:

- if the two surnames and the given name initial of an individual coincided in both databases, there was a sure match, e.g. “Corma Cano, Avelino” and “Corma-Cano, A”;
- if the first surname and the given name initial of an individual coincided in both databases, but there was no information about the second surname in the author name, there was a probable match, e.g. “Corma Cano, Avelino” and “Corma, A”;
- in every other case, there was no match.

In the second case, i.e. the probable match, we performed a manual check to disambiguate it, taking resource to secondary information if needed. However, a few cases remained ambiguous, which we dropped from the analysis (3% for authors –see Fig. 2, and 1% for project participants –see Fig. 3).

5. Findings

5.1. Descriptive analysis

Fig. 4 shows the results of the matching process of UPV project participants and UIC authors. 6% of project participants in 2000-2007 authored at least one UIC in the following period (2008-2011), i.e. fitted into our ‘industry financing’ model. The figure rises to 7% if we move to project participants in 2008-2011, i.e. they engaged into these projects at the same time they were producing UICs (‘industry pull’ model). Both percentages already indicate that researchers involved in projects with firms are rarely authors of UICs, probably because UICs express a very sophisticated result of interaction that is beyond the objectives of many contracts with firms.

{Fig. 4 here}

The proportions are larger, though, when checked whether or not UIC authors participated in business projects. 28% of UPV authors in 2008-2001 were engaged in funding agreements with firms in the same period (‘science push’ model) and 17% one period after (‘science signalling’). However, they are still a minority of UIC authors, which suggests that most UICs are not (directly) linked to industry funding.

These are the results of the raw matching, but we are interested in the actual relation between numbers of UICs and the magnitude of business funding. As a proxy for the latter, we calculated the average funding level of business projects in which a researcher has participated. We deflated nominal values using the Spanish *National Statistics Institute* (INE)'s *Chain Volume Index*. Correlations between numbers of UICs and mean funding of business projects provide a first, crude approximation to the degree of correspondence between both variables. According to Table 1, there is none (coefficients are not significant).

{Table 1 here}

Another approximation is the comparison of average values of a single variable broken down by group of authors. In Fig. 5, we can see that mean business funding level has almost doubled from 2000-2007 to 2008-2011, but t-tests indicate that differences between the two groups (UIC authors versus non-authors) are not significant. Fig. 6 indicates that the number of UICs has remained stable from 2008-2011 to 2012-2013, but differences between groups (project participants versus non-project participants) are relatively large. T-tests show that they are significant in period 2008-2011, not in the later one, suggesting evidence in favour of a science push not a science signalling model.

{Fig. 5 here}

{Fig. 6 here}

To investigate these statistical relationships in more detail, we performed a regression analysis, including control variables listed in Table 2.

{Table 2 here}

5.2. Econometric models of industry financing and industry pull

We estimate whether the authorship of UICs is a function of university funding from business firms (i.e. we are testing the two models to the left of Fig. 4). To choose the best statistical model and econometric data-analysis technique, we have to consider that a zero number of UICs may mean two things:

- authors wanted to produce UIC and could not, e.g. for client confidentiality, IPR restrictions, lack of time or insufficient scientific novelty;
- or authors did not want to produce UICs, e.g. they used funding for other purposes or lack of a UIC-promoting R&D environment.

Hence, we may avoid sample selection bias due to unreported observations of authors who wanted to produce UIC and could not. One way to do it is by running a Heckman selection model with two steps (Heckman, 1976):

- Step 1: we model whether researchers produced at least one UIC as a function of university funding from business sources;
- Step 2: for researchers with at least one UIC, we model whether the number of UICs is a function of university funding from business sources.

Table 3 shows the regressions. The coefficients of the variable 'mean business funding' do not have a significant effect on number of UICs, either with lagged funding (2000-2007) or current funding (2008-2011), in any of the steps. This confirms the previous apparent lack of cause/effect relationships. Industry does not seem to play a role in fostering the production of UICs through increased financial resources, nor as a source of inspiration at the time of writing such research papers.

{Table 3 here}

5.3. Econometric models of university signalling and science push

Moving to the right of Fig. 4, we test the two models that express university funding from business firms as a function of the authorship of UICs. Again, we have to consider that a value equal to zero of business funding may be the outcome of two different distributional assumptions:

- researchers wanted business funding but did not manage to attain it, e.g. because they did not reach a threshold of minimum scientific visibility through their UIC production;
- or researchers did not aspire business funding, e.g. to preserve their academic freedom to choose research topics of no relevance to industry.

The correct verification of the impact of UIC authorship on business funding requires another two-step estimation:

- Step 1: we model whether having business funding, i.e. participating in at least one industrial project, is a function of the number of UICs;
- Step 2: for those researchers in at least one business project, we estimate if amount of university funding from business firms depends on number of UICs.

For the binary possibility of having business funding (step 1), the effect of UIC authorship is not significant (Table 4). For those having business funding (step 2), things change: there is a positive correlation between UIC and funding: highly significant in the case of the science push model and borderline significant in the case of the university signalling model. Hence, the evidence suggests that current production of UIC affects projects for companies with a scientific touch, and maybe (we cannot be conclusive because of the 10% significance) acts as an attractor of future business money.

{Table 4 here}

Note that in the case of the science push model (column 1), there is a sample selection bias, which means that individuals in step 2, namely researchers with business funding, are not representative of the whole population of UIC authors. This implies that fostering the production of UIC indiscriminately does not increase mean business funding, but only among selected researchers: those with higher number of previous publications and whose UICs include affiliations other than UPV and firms (see Table A4, column 1, step 1).

6. Discussion and conclusions

In this empirical case study we have investigated the possible causal relationship between U-I interactions and UICs. To analyse this relationship, we focussed on a frequently used indicator of interactions between universities and the business sector as a benchmark to compare the co-publications: university funding from business firms. A novel aspect of our research is that, unlike similar studies, our conceptual models considered these joint publications not only as an output of a previous co-participation in a research project with industry, but also as an element that could shape later participation on joint projects with industrial partners. Besides considering a certain time-lag between one and the other, our set of models also embraces the possibility that UICs and business funded projects occur close in time or even simultaneously.

The consideration of this comprehensive conceptualization allows us to expand the more traditional way of looking at UICs just as an output of a previous U-I interaction and provides a wider overview on the potential interdependencies between U-I interactions and UICs. Our results show that, in general, UICs can occur without business funding, and business funding without UICs. Hence, we did not find a straightforward causal relationship between UIC volumes and university funding from business firms. There is one exception to this rule in our findings: for a minority of authors (those who participate in business funded projects) there is a positive association of current UICs and business funding. This implies some evidence of a science push model, suggesting that academics who write publications with firms and are at the same time involved in early stages of a project with a firm, are able to imprint a stronger scientific nature in this project.

We acknowledge that our study is based on a single Spanish technical university and for this reason perhaps more research would be needed to confirm that our results are similar in different countries and for different types of universities, in short to confirm that our results are generalizable.

Notwithstanding, our findings are in line with those reported by Lundberg et al. (2006) who found that not all the companies providing funding to the university did publish joint publications, as well as not all UICs were linked to projects funded by industry.

Indeed, there are several reasons for which companies funding university research do not co-publish the results with universities. Universities and companies are guided by quite different goals and incentives, while for companies the economic benefit is one of the most important objectives, and the not disclosure of new developments is a basic strategy to be better positioned than competitors. Academics in contrast seek the advancement of knowledge, and the publication of new findings in scientific journals is of utmost importance, thus making available information resulting from their research not only to communicate their findings to other peers but also for their career development. Therefore this search for secrecy by companies might hamper the publications of scientific papers by academics.

Other factor that might lead to a lower number of publications by researchers frequently engaged in collaborations with industry is the time constraint to pursue these two activities (Hottenrott and Thorwarth, 2010; Banal-Estañol, 2013). These authors argue that it may become more attractive to spend time doing research related to industry interests, which in turn would facilitate the access to additional financial resources, than other type of research which eventually could favor an increase in their publication rates.

On the other hand, even if companies have no objections to the publication of findings resulting from projects developed in collaboration with universities, it does not mean that the industrial partner is always among the co-authors of the publication given that the publication of scholarly articles is not seen as a priority for companies. This would suggest that some publications resulted from the close interaction between academics and companies while they are not considered as UICs due to the possible absence of one of the industrial party among the co-authors.

It is also important to take into consideration that our study relies on the WoS for the identification and collection of UICs, however we acknowledge that there might be joint scientific publications between universities and companies which are not covered in this database and therefore they have not been considered in this study. There might also be other types of joint publications like web reports, articles in industry journals which we did not consider because they are not joint articles published in scientific journals.

The above situations and arguments would reinforce the idea that UICs are a kind of 'tip of the iceberg' when representing U-I interactions.On the other hand, there are also several situations that could lead to joint publications between universities and companies without a previous participation in joint projects. For instance when the funding comes from third parties or when university researchers involved in start-up companies mention in their publications both the company as well as the academic affiliation (Lundberg et al., 2006; Yegros and Tijssen, 2014).

The fact that part of the UICs are generated without business funding also suggests that they result from U-I interactions of a different nature, in which funding is not necessarily the main element articulating the relationship. More research would be needed to explain which type of interactions might be producing these joint co-publications. Therefore, as noted by Lundberg and colleagues (2006) both, UICs and business funding, are partial and incomplete indicators of U-I interactions. This is not a surprising conclusion if we bear in mind the complexity and multiple forms through which interactions between universities and companies might take place, implying the existence of a wide variety of (tangible or intangible) inputs and outputs shaping the interaction between universities and companies. Private funding and joint scientific publications are just two of these many mechanisms enabling the interplay between universities and companies.

Acknowledgements

Alfredo Yegros-Yegros and Robert J.W. Tijssen received financial support from the CWTS-CHERPA research project (funded by the Netherlands Ministry for Education, Culture and Science). The authors are grateful to the UPV's CTT for opening access to the data, especially to Amparo Mateu Arce and José Juan Gil Ródenas for their support, and also to participants of the 19th Science and Technology Indicators (STI) Conference (2014) who gave feedback to the presentation of a previous version of the paper.

Appendix

Table A1 develops descriptive statistics of variables included in the industry funding and industry pull models. As said in the main text, 6-7% of project participants have co-authored at least one UIC and the mean budget of their projects rose from 30,000 to 70,000€ between the two periods considered. The average individual has participated in

3-4 projects and the typical project involves contract research or development, lasts around 18 months long and includes one firm (mostly national). A bit more than one third of the individuals are PIs, a bit less than one fourth are female, around 40 years old.

Project participants with at least one UIC have actually almost two UICs on average, and have published 16-17 papers within the five years prior to each UIC authorship having received one citation in the time window of four years each of these prior publications. The typical paper had 10 authors with around one half being international co-authors and one-half of their affiliations not being either UPV or industrial. Each UIC included around 26 backward citations and it was published in a journal with an impact factor of 2. More than one third belongs to the field of Maths, followed by Natural Sciences (over one fourth). Each UIC received a bit more than one forward citation.

{Table A1 here}

Table A2 develops regression results from Table 3. Regarding the industry funding model, the probability that a past project participant has co-authored at least one current UIC (step 1) increases the larger the project, the younger the researcher and the higher the amount of business funding of the researchers' entity.

Project participants with at least one UIC (step 2) see numbers of UICs increase in the number of collaborating firms involved in their projects. Numbers of UICs are also larger for researchers with higher publication record, with more co-authors, fewer share of international collaborators but higher share of third affiliations. UIC volume increases in Maths and Life Sciences.

Regarding the industry pull model, the probability that a current project participant has co-authored at least one current UIC (step 1) is larger for researchers involved in competitive and contract research, and lower for females.

Project participants with at least one UIC (step 2) see numbers of UICs decrease in the number of collaborating firms involved in their projects and of participation in business funded project of their entity. The later result suggests the presence of diseconomies of scale in the impact of industrial influence on UICs, i.e. too much involvement with companies is prejudicial for writing UIC at the same time. Other determinants are similar to those of the industry funding model.

{Table A2 here}

Table A3 develops descriptive statistics of variables included in the science push and university signalling models. As mentioned in the main text, the percentage of UIC authors who participate in business-funded projects decreased from 28 to 17 from one period to another. The number of UICs remained stable around 1.6. The characteristics of the average UIC author are similar to those of UIC authors with project participations (Table A1), except maybe for a higher presence of the scientific area of Natural Sciences in detriment of Maths.

The characteristics of project participations of UIC authors are similar to those of all project participants (Table A1), with some exceptions: UIC authors participate in projects more often as PIs (suggesting smaller team sizes), male are even more predominating, and tend to be slightly older. In the latter period, there is no competitive research led by firms.

{Table A3 here}

Table A4 develops regression results from Table 4. The probability of current UIC authors to participate in current projects funded by business firms (step 1) increases for repeated UIC authors, for papers with a third affiliation (not UPV, not industry), and in the area of Mathematics. It decreases if the knowledge base of the paper is large (proxied by backward citations).

For current UIC authors with current business funded projects (step 2), larger projects, fewer firms per project, lower shares of participations as PI and of third affiliations are associated to higher mean business funding per project.

Column 2 shows results related to the university signalling model. Current UIC authors will participate in future projects with industry (step 1) the larger their publication record is, the more cites per paper they received, the fewer citations to previous literature they included, the more recently they published, and the fewer they published in Natural Sciences.

For current UIC authors with future project participations (step 2), mean business funding is actually a positive function of share of contract research, project duration, age and number of authors. It is also and a negative function of share of participations as PI, involvement in business funding of the research entity, past citations per paper, publication year and forward citations.

{Table A4 here}

References

Abramo, G., D'Angelo, C.A.; Costa, F.D.; Solazzi, M. (2009). University-industry collaboration in Italy: a bibliometric examination. *Technovation*, 29(67): 498-507.

Banal-Estañol, A., Jofre-Bonet, M., Lawson, C. (2013a) The Double-Edged Sword of Industry Collaboration: Evidence from Engineering Academics in the UK (Report No. 13/03). London, UK: Department of Economics, City University London.

Banal-Estañol, A., Macho-Stadler, I., Pérez-Castrillo, D. (2013b) Research output from university-industry collaborative projects. Economic *Development Quarterly*, 27(1): 71-81.

Bekkers, R., Bodas-Freitas, I.M. (2008) Analysing knowledge transfer channels between universities and

industry: to what degree do sectors also matter? *Research Policy*, 37(10): 1837–1853.

Calvert J., Patel. P. (2003) University-industry research collaborations in the UK: bibliometric trends. *Science and Public Policy*, 30, 85-96.

D'Este, P; Patel, P. (2007) University–industry linkages in the UK: what are the factors underlying the variety of interactions with industry? *Research Policy*, 36(9): 1295–1313.

Giunta, A., Pericoli, F.M., Perucci, E. (2014) University-Industry collaboration in biopharmaceutical industry: the Italian case. 55th Italian Economic Association Conference. Trento, Italy, 23-25 October 2014.

Gulbrandsen, M., Smeby, JC. (2005) Industry funding and university professors' research performance. *Research Policy*, 34(6): 932–950.

Gulbrandsen, M; Nerdrum, L. (2009) University-Industry relations in Norway. Ed. Fagerberg, J; Mowery, D; Verspagen, B. *Innovation, Path Dependency, and Policy: The Norwegian Case*.

Heckman, J. (1976) The common structure of statistical models of truncation, sample selection and limited dependent variables and a simple estimator for such models. *Annals of Economic and Social Measurement* 5: 475–492.

Hottenrott, H., Thorwarth, S. (2010) Industry funding of university research and scientific productivity, ZEW Discussion Papers, No. 10-105

Katz, J.S., Martin, B.R. (1997) What is research collaboration? *Research Policy*, 26:1-18

Klitkou, K., Patel, P., Campos, A. (2009). Linkages between technical universities and industry measured by co-authorship and patent data. Third Conference on Micro Evidence on Innovation in Developing Economies – MEIDE, May 10-12 2009, Rio de Janeiro, Brazil.

Landry, R., Traore, N., Godin, B (1996) An econometric analysis of the effect of collaboration on academic research productivity. *Higher Education* 32(3): 283-301

Lundberg, J., Tomson, G., Lundkvist, I., Skar, J., Brommerls, M. (2006). Collaboration uncovered: Exploring the adequacy of measuring university–industry collaboration through co-authorship and funding. *Scientometrics*, 69(3), 575–589.

Manjarres-Henriquez, L., Gutierrez-Garcia, A., Vega-Jurado, J (2008) Coexistence of university-industry relations and academic research: barrier to or incentive for scientific productivity. *Scientometrics*, 76(3): 561-576.

Martínez, C, Azagra-Caro, J M, Maraut, S. (2013) Academic Inventors, Scientific Impact and the Institutionalisation of Pasteur's Quadrant in Spain. *Industry and Innovation*, 20(5): 438-455.

Perkmann, M, Kathryn, W (2007) University-industry relationships and open innovation: towards a research agenda. *International Journal of Management Reviews*, 9(4): 259-280.

Perkmann, M, Kathryn, W (2009) The two facets of collaboration: impacts of university-industry relations on public research. *Industrial and Corporate Change*, 18(6):1033-1065.

Scott, A., Steyn, G., Geuna, A, Brusoni, S., Steinmueller, E. (2001). The economic returns to basic research and the benefits of university-industry relationships: a literature review and update of findings. Science Policy Research Unit.

Sun, Y; Negishi, M., Nishizawa, M. (2007). Coauthorship linkages between universities and industry in Japan. *Research Evaluation*, 16(4): 299-309.

Tijssen, R.J.W., Van Leeuwen, T.N., van Wijk, E. (2009) Benchmarking university-industry research cooperation worldwide: performance measurements and indicators based on co-authorship data for the world's largest universities.' *Research Evaluation*, 18(1): 13-24.

Tijssen, R.J.W. (2011) Joint research publications: a performance indicator of university-industry collaboration. *Evaluation in Higher Education*, 5(2): 19-40.

Tijssen R.J.W. (2012) Co-authored research publications and strategic analysis of public-private collaboration. *Research Evaluation*, 21(3): 204-215.

Yegros, A.; Tijssen, R.J.W. (2014) University-Industry dual appointments: global trends and their role in the interaction with industry. 19th International Conference on Science and Technology Indicators. Leiden, The Netherlands, 3-5 September.

Wong, PK, Singh, A. (2013). Do co-publications with industry lead to higher levels of university technology commercialization activity? *Scientometrics*, 97, 245-265.

Figures

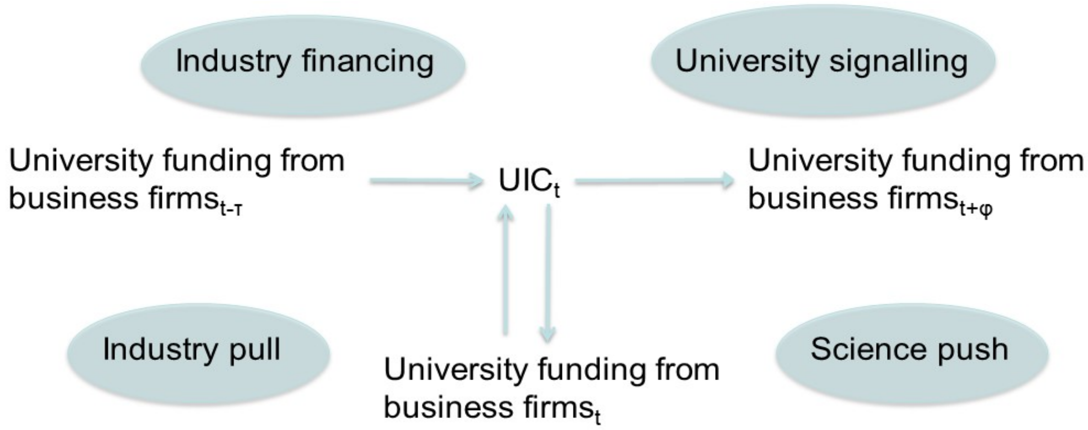

Fig. 1 Four types of theoretical relationships between funding and UIC – an interactive model

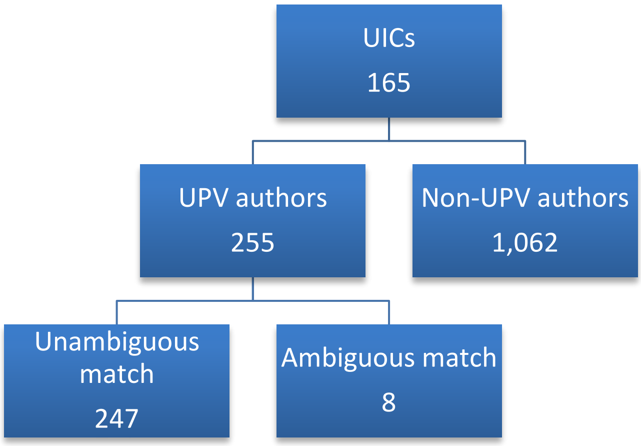

Fig. 2 UICs from UPV (2008-2011). Source: CWTS Web of Science database.

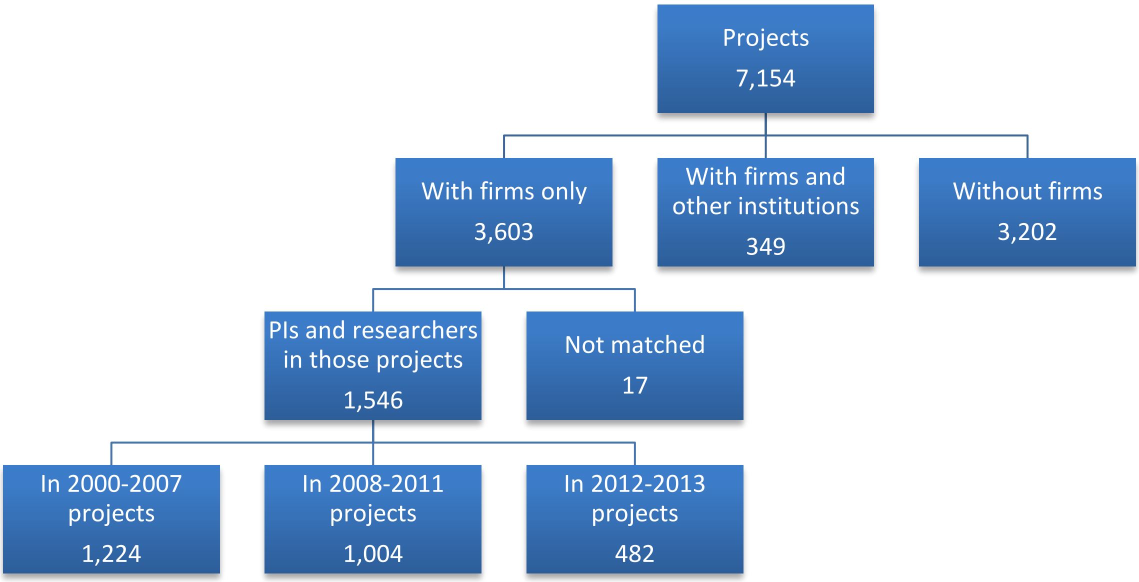

Fig. 3 Participants of business funded projects from UPV (2000-2013). Source: CTT (STEP 2)

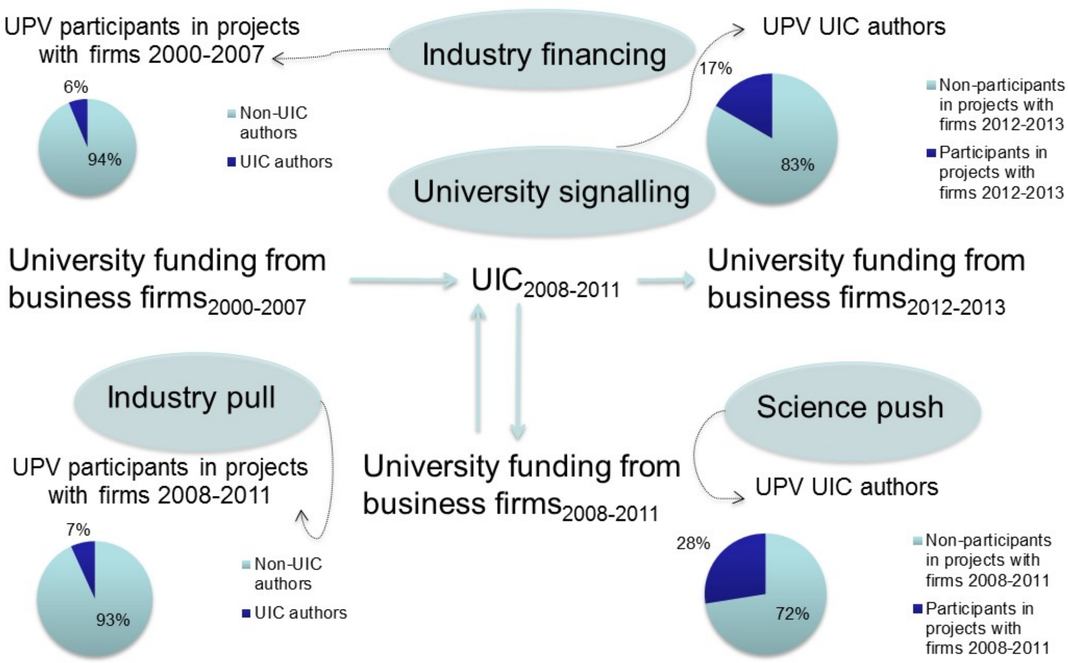

Fig. 4 Types of funding and UIC relationships at UPV

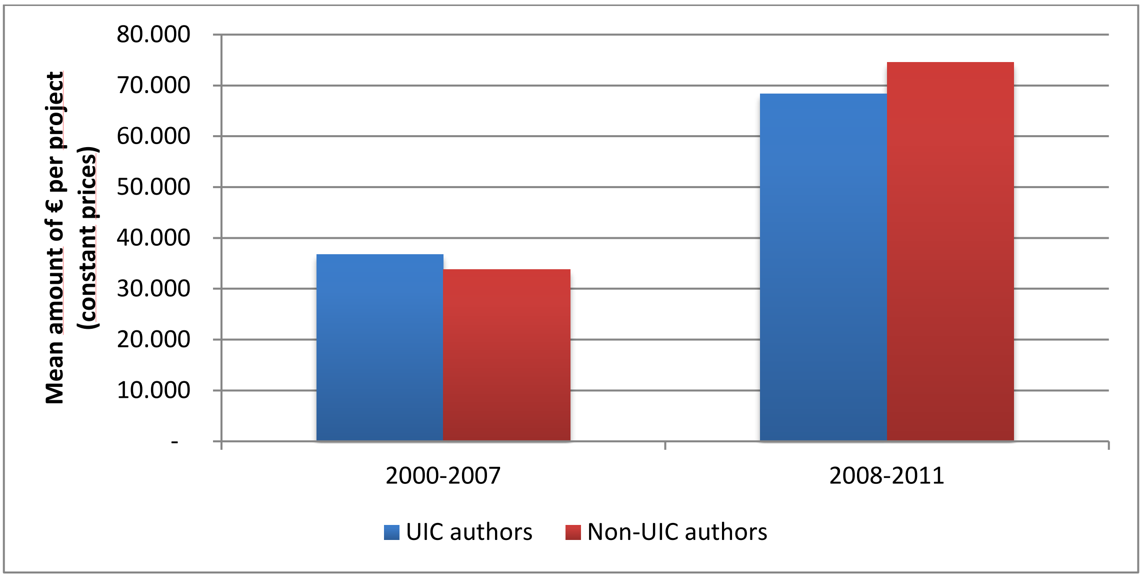

Fig. 5 Participation in projects with business firms at the UPV

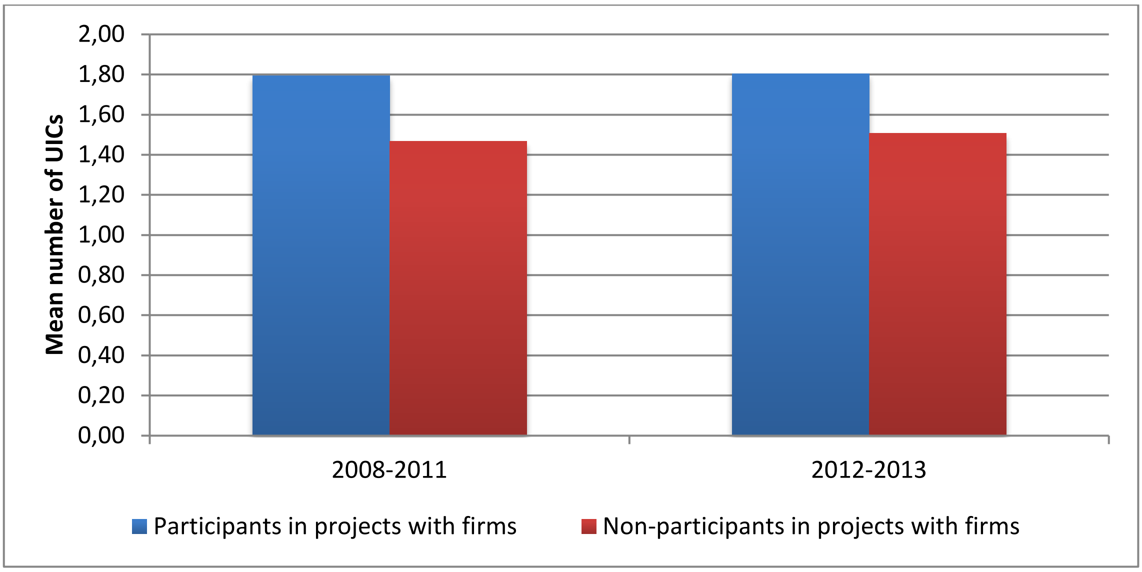

Fig. 6 Authorship of UICs at the UPV

Do university-industry co-publication outputs correspond with university funding from firms?

Tables

Table 1 Pairwise Pearson correlation coefficients

	Mean business project funding (2000-2007)	Mean business project funding (2008-2011)	Mean business project funding (2012-2013)
# UICs 2008-2011 (industry funding and pull models)	R=0.01 (n=1,224)	R=-0.01 (n=1,004)	
# UICs 2008-2011 (science push and university signalling models)		R=-0.01 (n=247)	R=0.15 (n=247)

Table 2 Control variables

Name	Description
Project profile of UPV researchers (source: CTT database)	
Project characteristics	
# projects	Number of business funded projects in which the researchers has participated
% type of project (competitive research, contract research, development, others)	Percentage distribution of project types: • Competitive research: research projects, funded through public calls for tenders • Contract research: private research agreements • Development: technical support, professional projects, trials and essays, etc. • Others: support to transfer and diffusion, licenses, infrastructure, business chairs, etc.
Mean start year	Mean start year of business funded projects in which the researchers has participated
Mean duration	Mean duration of business funded project participations
Mean # of firms	Mean number of firms partnering business funded projects in which the researchers has participated
% type of firm (national, international)	Percentage distribution of firm types, according to their nationality: Spanish or foreign
Individual characteristics	
% role in projects (principal investigator, researcher)	Percentage distribution of role played in business funded projects in which the researchers has participated
Sex (male, female)	Sex of the researcher
Mean age	Mean difference between birth year of the researcher and year of project
Research entity (department/institute) characteristics	
# research entity projects	Number of business funded projects in which other researchers from the same department or institute have participated
Publication profile of UPV authors (source: CWTS Web of Science)	
Individual characteristics	
# past pubs	Number of past publications of the researcher five years prior to each UIC authorship
# cites per past pub	Mean normalized citation score per publication of past publications of five years before each UIC authorship
UIC characteristics	
Mean # authors	Mean number of authors per publication published by the researcher
% international collaborations	Percentage of publications published by the researcher including a foreign institution
% third affiliations (non-UPV, non-industry)	Percentage of UICs by the researcher including a third organisation, besides the UPV and a company
Mean # backward citations	Mean number of references in the UICs published by the researcher
Mean publication year	Mean year in which the UICs were published by the researcher
Mean journal impact factor	Mean value of the journal impact factor in which the UICs were published by the researcher
% scientific area (Maths, Natural Sciences, Life Sciences, other areas)	Percentage of a researcher's publications classified in each scientific area
Mean # forward citations	Mean normalized citation score of the researchers' UICs

Table 3 Heckman selection models of industry financing and pull at the UPV (selected results)

Step	Dependent variable	1 Coefficient of mean business funding (industry funding model, projects 2000-2007)	2 Coefficient of mean business funding (industry pull model, projects 2008-2011)
1	UIC (yes/no) 2008-2011	-0.94	-0.18
		(1.58)	(0.48)
2	# UICs 2008-2011	2.14	-2.01
		(4.24)	(1.25)
	Observations	1,224	1,004
	Censored	1,147	936

* p<0.1; ** p<0.05; *** p<0.01. Robust standard errors in parenthesis. No multicollinearity according to VIF. No sample selection bias according to Wald test. See Table A2 for full results.

Table 4 Heckman selection models of science push and university signalling at the UPV (selected results)

Step	Dependent variable	1 Coefficient of # UICs 2008-2011 (science push model, projects 2008-2011)	2 Coefficient of # UICs 2008-2011 (university signalling model, projects 2012-2013)
1	Business funding (yes/no)	-0.02	-0.05
		(0.09)	(0.11)
2	Mean business funding	0.01***	0.01*
		(0.00)	(0.01)
	Observations	247	247
	Censored	179	206

* p<0.1; ** p<0.05; *** p<0.01. Robust standard errors in parenthesis. No multicollinearity according to VIF. Sample selection bias in column 1, not in column 2 according to Wald test. See Table A4 for full results.

Table A1 Descriptive statistics of industry financing and pull models at the UPV

		Industry funding model (projects 2000-2007)					Industry pull model (projects 2008-2011)				
Step	Variable	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max
1	UIC (yes/no)	1224	0.06	0.24	0	1	1004	0.07	0.25	0	1
1&2	Mean business funding	1224	0.03	0.05	0	0.75	1004	0.07	0.14	0	1.41
	# projects	1224	3.77	4.18	1	49	1004	2.74	2.93	1	43
	% competitive research	1224	0.21	0.35	0	1	1004	0.22	0.36	0	1
	% contract research	1224	0.26	0.34	0	1	1004	0.41	0.42	0	1
	% development	1224	0.44	0.42	0	1	1004	0.35	0.42	0	1
	% other projects	1224	0.09	0.24	0	1	1004	0.02	0.11	0	1
	Mean start year	1224	2003.51	1.84	2000	2007	1004	2008.60	1.03	2003	2011
	Mean duration	1224	1.34	0.84	0.08	12.18	1004	1.60	1.36	0.08	12.86
	Mean # of firms	1224	1.05	0.19	1	4	1004	1.07	0.26	1	4
	% foreign firms	1224	0.01	0.06	0	1	1004	0.03	0.14	0	1
	% principal investigator	1224	0.34	0.41	0	1	1004	0.36	0.43	0	1
	Female	1224	0.23	0.42	0	1	1004	0.27	0.44	0	1
	Mean age	1224	39.24	8.59	24	84	1004	42.11	8.67	23	71
	# research entity projects	1224	458.62	452.88	2451	2451	1004	486.99	470.34	13	2451
2	# UICs	77	1.84	1.99	1	14	68	1.79	1.96	1	14
	# past pubs	77	16.19	29.89	0	239	68	17.17	31.43	0	239
	# cites per past pub	77	1.09	1.10	0	6.85	68	1.01	0.87	0	3.98
	Mean # authors	77	10	25.46	2.40	163.75	68	9.44	21.24	2.40	163.75
	% international collaborations	77	0.54	0.48	0	1	68	0.54	0.48	0	1
	% third affiliations	77	0.52	0.48	0	1	68	0.58	0.47	0	1
	Mean # backward citations	77	25.98	12.24	7	64	68	27.18	12.52	7	73
	Mean publication year	77	2009.69	0.92	2008	2011	68	2009.75	0.98	2008	2011
	Mean journal impact factor	77	1.81	1.09	0.14	4.57	68	1.89	1.11	0.14	4.57
	% Maths	77	0.34	0.46	0	1	68	0.35	0.47	0	1
	% Natural Sciences	77	0.27	0.43	0	1	68	0.23	0.41	0	1
	% Life Sciences	77	0.14	0.35	0	1	68	0.19	0.40	0	1
	% other areas	77	0.25	0.42	0	1	68	0.22	0.40	0	1
	Mean # forward citations	77	1.30	1.57	0	6.88	68	1.16	1.47	0	6.88

Table A2 Heckman selection models of industry financing and pull at the UPV (full results)

Step	Dependent variable	Independent variable	1 Industry funding model (projects 2000-2007)	2 Industry pull model (projects 2008-2011)
1	UIC (yes/no) 2008-2011	# projects	0.01	0.03
			(0.01)	(0.02)
		Mean business funding	-0.94	-0.18
			(1.58)	(0.48)
		% competitive research	-0.16	1.43*
			(0.27)	(0.86)
		% contract research	0.35	1.48*
			(0.27)	(0.84)
		% development	-0.10	1.03
			(0.24)	(0.85)
		Mean start year	-0.01	0.10
			(0.03)	(0.09)
		Mean duration	0.13**	0.06
			(0.06)	(0.06)
		Mean # of firms	0.26	-0.17
			(0.26)	(0.28)
		% foreign firms	-0.11	-0.09
			(0.66)	(0.39)
		% principal investigator	0.25	0.12
			(0.15)	(0.15)
		Female	-0.27	-0.33**
			(0.16)	(0.17)
		Mean age	-0.02**	0.00
			(0.01)	(0.01)
		# research entity projects	0.00**	0.00
			(0.00)	(0.00)
		Constant	11.10	-211.43
			(68.13)	(174.29)
2	# UICs 2008-2011	# projects	0.04	0.03
			(0.03)	(0.04)
		Mean business funding	2.14	-2.01
			(4.24)	(1.25)
		% competitive research	0.62	-0.22
			(0.84)	(1.86)
		% contract research	-0.29	-0.47
			(0.82)	(2.22)
		% development	0.05	0.52
			(0.83)	(2.03)
		Mean start year	-0.07	-0.15
			(0.08)	(0.19)
		Mean duration	-0.10	
			(0.22)	
		Mean # of firms	0.78***	-0.89*
			(0.27)	(0.50)
		% foreign firms	-1.72	-0.54
			(1.61)	(1.25)
		% principal investigator	-0.33	-0.33
			(0.35)	(0.48)
		Female	-0.02	
			(0.35)	
		Mean age	-0.01	-0.01
			(0.01)	(0.02)
		# research entity projects		-0.00**
				(0.00)

Step	Dependent variable	Independent variable	1 Industry funding model (projects 2000-2007)	2 Industry pull model (projects 2008-2011)
		# past pubs	0.06***	0.06***
			(0.00)	(0.01)
		# cites per past pub	0.00	0.01
			(0.09)	(0.28)
		Mean # authors	0.05***	0.04***
			(0.00)	(0.01)
		% international collaborations	-0.96***	0.09
			(0.29)	(0.27)
		% third affiliations	1.07***	
			(0.34)	
		Mean # backward citations	-0.01	-0.01
			(0.01)	(0.01)
		Mean publication year	0.14	0.18
			(0.11)	(0.12)
		Mean journal impact factor	-0.16	-0.00
			(0.10)	(0.13)
		% Maths	0.74***	0.81**
			(0.26)	(0.32)
		% Natural Sciences	-0.02	-0.11
			(0.37)	(0.45)
		% Life Sciences	0.52*	-0.50
			(0.27)	(0.32)
		Mean # forward citations	0.01	-0.09
			(0.06)	(0.10)
		Constant	-145.01	-53.07
			(290.90)	(405.33)
	Ath ρ	Constant	-0.17	-0.45
			(0.46)	(0.43)
	Ln σ	Constant	-0.27**	-0.06
			(0.11)	(0.22)
	Observations		1,224	1,004
	Censored		1,147	936
	Log likelihood		-359	-325
	χ^2 (model significance)		3,612.59	409.40
	p-value (model significance)		0.00	0.00
	χ^2 (sample selection)		0.14	1.12
	p-value (sample selection)		0.71	0.29

* p<0.1; ** p<0.05; *** p<0.01. Robust standard errors in parenthesis. No multicollinearity according to VIF.

Table A3 Descriptive statistics of science push and university signalling models at the UPV

		Science push model (projects 2008-2011)					University signalling model (projects 2012-2013)				
Step	Variable	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max
1	Business funding (yes/no)	247	0.28	0.45	0	1	247	0.17	0.37	0	1
1&2	# UICs	247	1.56	1.52	1	14	247	1.56	1.52	1	14
	# past pubs	247	10.70	21.02	0	239	247	10.70	21.02	0	239
	# cites per past pub	247	0.88	1.17	0	9.14	247	0.88	1.17	0	9.14
	Mean # authors	247	12.65	30.85	2	220	247	12.65	30.85	2	220
	% international collaborations	247	0.60	0.48	0	1	247	0.60	0.48	0	1
	% third affiliations	247	0.57	0.47	0	1	247	0.57	0.47	0	1
	Mean # backward citations	247	29.53	19.39	0	123	247	29.53	19.39	0	123
	Mean publication year	247	2009.66	1.06	2008	2011	247	2009.66	1.06	2008	2011
	Mean journal impact factor	247	2.10	1.59	0.14	9.61	247	2.10	1.59	0.14	9.61
	% Maths	247	0.25	0.42	0	1	247	0.25	0.42	0	1
	% Natural Sciences	247	0.33	0.46	0	1	247	0.33	0.46	0	1
	% Life Sciences	247	0.18	0.38	0	1	247	0.18	0.38	0	1
	% other areas	247	0.24	0.42	0	1	247	0.24	0.42	0	1
	Mean # forward citations	247	1.27	1.96	0	13.78	247	1.27	1.96	0	13.78
2	# projects	68	0.07	0.10	0.01	0.47	41	0.09	0.11	0.01	0.54
	Mean business funding	68	3.46	2.97	1	13	41	3.51	5.51	1	34
	% competitive research	68	0.23	0.35	0	1	41				
	% contract research	68	0.52	0.40	0	1	41	0.59	0.45	0	1
	% development	68	0.24	0.32	0	1	41	0.21	0.35	0	1
	% other projects	68	0.01	0.04	0	0.33	41	0.20	0.37	0	1
	Mean start year	68	2008.70	0.79	2007	2011	41	2011.91	0.67	2010	2013
	Mean duration	68	1.56	0.92	0.34	5.07	41	1.69	1.91	0.26	12.43
	Mean # of firms	68	1.05	0.15	1	2	41	1.06	0.19	1	2
	% foreign firms	68	0.03	0.10	0	0.50	41	0.16	0.35	0	1
	% principal investigator	68	0.40	0.40	0	1	41	0.48	0.46	0	1
	Female	68	0.16	0.37	0	1	41	0.10	0.30	0	1
	Mean age	68	42.42	8.60	27.25	62.50	41	45.35	9.24	29.50	67
	# research entity projects	68	561.81	538.52	83	2451	41	773.41	805.26	91	2451

Table A4 Heckman selection models of science push and university signalling models at the UPV (full results)

Step	Dependent variable	Independent variable	1 Science push model (projects 2008-2011)	2 University signalling model (projects 2012-2013)
1	Business funding (yes/no)	# UICs 2008-2011	-0.02	-0.05
			(0.10)	(0.11)
		# past pubs	0.02***	0.02**
			(0.01)	(0.01)
		# cites per past pub	0.13	0.25**
			(0.09)	(0.11)
		Mean # authors	-0.00	-0.00
			(0.00)	(0.00)
		% international collaborations	-0.34	0.16
			(0.21)	(0.26)
		% third affiliations	0.44**	0.44
			(0.22)	(0.27)
		Mean # backward citations	-0.01**	-0.01*
			(0.00)	(0.01)
		Mean publication year	0.11	0.18*
			(0.09)	(0.10)
		Mean journal impact factor	-0.01	-0.07
			(0.07)	(0.11)
		% Maths	0.46*	0.38
			(0.28)	(0.31)
		% Natural Sciences	-0.51	-1.10**
			(0.33)	(0.45)
		% Life Sciences	0.13	-0.13
			(0.30)	(0.35)
		Mean # forward citations	0.01	0.07
			(0.06)	(0.08)
		Constant	-230.16	-354.51*
			(180.91)	(203.06)
2	Mean business funding	# projects	0.00	0.00
			(0.00)	(0.00)
		% contract research	0.06***	0.09***
			(0.02)	(0.03)
		% development	0.05*	-0.09
			(0.03)	(0.06)
		Mean start year	0.01	0.04
			(0.01)	(0.03)
		Mean duration	0.09***	0.02**
			(0.01)	(0.01)
		Mean # of firms	-0.08***	0.04
			(0.03)	(0.06)
		% foreign firms	0.06	
			(0.06)	
		% principal investigator	-0.05***	-0.18***
			(0.01)	(0.04)
		Female	-0.02	0.10
			(0.01)	(0.08)
		Mean age	-0.00	0.00***
			(0.00)	(0.00)

Step	Dependent variable	Independent variable	1 Science push model (projects 2008-2011)	2 University signalling model (projects 2012-2013)
		# research entity projects	-0.00	-0.00***
			(0.00)	(0.00)
		# UICs 2008-2011	0.01***	0.01*
			(0.00)	(0.01)
		# past pubs		
		# cites per past pub	-0.01	-0.03**
			(0.01)	(0.01)
		Mean # authors	0.00	0.00**
			(0.00)	(0.00)
		% international collaborations	-0.01	0.04
			(0.02)	(0.04)
		% third affiliations	-0.04**	-0.03
			(0.02)	(0.03)
		Mean # backward citations	-0.00	-0.00
			(0.00)	(0.00)
		Mean publication year	-0.00	-0.03**
			(0.01)	(0.01)
		Mean journal impact factor	0.01	-0.00
			(0.01)	(0.01)
		% Maths	0.01	-0.03
			(0.02)	(0.03)
		% Natural Sciences	-0.01	-0.04
			(0.02)	(0.07)
		% Life Sciences	-0.01	-0.00
			(0.02)	(0.04)
		Mean # forward citations	-0.00	-0.02**
			(0.01)	(0.01)
		Constant	-12.40	-17.64
			(26.89)	(67.99)
	Ath ρ	Constant	-0.42**	0.25
			(0.21)	(0.60)
	Ln σ	Constant	-3.11***	-2.81***
			(0.15)	(0.23)
	Observations		247	247
	Censored		179	206
	Log likelihood		-11	-32
	χ^2 (model significance)		287.48	378.18
	p-value (model significance)		0.00	0.00
	χ^2 (sample selection)		4.08	0.17
	p-value (sample selection)		0.04	0.68

* p<0.1; ** p<0.05; *** p<0.01. Robust standard errors in parenthesis. No multicollinearity according to VIF.