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THE GOLDEN OPPORTUNITY FOR HIGH-TECH COMPANIES

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iCite Working Paper 2018-30

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ACADEMIC SCIENTISTS: THE GOLDEN OPPORTUNITY FOR HIGH-TECH COMPANIES

Lauriane Dewulf[1,2], Michele Cincera[1]

Abstract

The objective of this paper is twofold. First, it provides further knowledge about profitability of industry scientific publications as it is not clear yet whether industry scientific publications are profitable to firms. Second, it considers the central role of academic partners in the profitability of firms' scientific publications as previous empirical studies do not consider such role. To investigate the subject, we perform several regressions with firms profits as dependent variable. The results provide evidence that the publication of scientific articles is not a profitable activity. Collaborations with academic institutions are the real basis of profitable results; the production of scientific publications is only one of the consequences of these collaborations. This study also shows that not all collaborations are profitable, only collaborations in high-tech sectors that lead to high-quality publications lead to larger profits. Indeed, in their quest for survival and profitability, companies competing in high-tech sectors often need the help of academic partners to exploit scientific knowledge. On average, a rise of about 8% in successful collaborations (leading to high-quality publications) raises the profit of high-tech firms by about 1%.

Key-words: Industry-academic collaborations, scientific publications, industrial science, firms' profit

JEL codes: G32, O31, O34

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1. Introduction

It is well known that Europe is lagging behind the US in terms of innovation (European Commission, 2016). Among the numerous reasons to explain such gap, a commonly accepted factor is the low representation of firms in high-tech sectors (Moncada-Paterno-Castello et al., 2010; Veugelers and Cincera, 2015). A second factor is the unexploited opportunities that academic institutions could offer to the industry (Veugelers et al., 2012; Veugelers, 2014a,b) in particular to its performance in terms of profitability. However, this last point is extremely complicated to study at large scale because of an important lack of available indicators of Industry-Academia (I-A) collaborations (Veugelers, 2014a). Furthermore, the empirical literature on the profitability of science does not consider the role of academic partners although another stream of literature, on I-A collaborations, shows that such role should be considered at the center of industry science. The latter literature provides in fact strong evidence that firms willing to exploit science need the help of academic partners and that these partnerships are highly profitable.

The empirical studies on the profitability of science also provide rather contradictory results. For instance, Simeth and Cincera (2015) and Pellens and Della Malva (2017) provide evidence in favor of scientific publications whereas Arora et al. (2017) found no benefit in industry scientific publications for the latest years of their sample (1998-2007).

A first objective of this paper is therefore to provide additional evidence on previous studies' conclusions considering the most recent period (2003-2014) and a wider range of industries and countries. Indeed, previous empirical studies on the subject were only studying the U.S. while this paper considers worldwide R&D companies. Furthermore, Arora et al. (2017) consider different sectors but do not differentiate these sectors whereas both Simeth and Cincera (2015) and Pellens and Della Malva (2017) consider high-tech sectors. By comparing high-tech sectors with other sectors, we show that previous studies do not contradict each other.

A second objective of this paper is to further analyze the subject by studying the role of academic partners in businesses profits. We test if it is (1) the partnerships with academic institutions - leading to the production of scientific publications - that benefit to firms; or (2) industry science in itself (measured by the number of publications) that is profitable to firms - as evidenced in previous studies on the profitability of industry science.

To investigate the subject, we perform several linear regression models considering the logarithm of the profit of top worldwide R&D active firms as the dependent variable. We also control for unobserved fixed effects and possible endogeneity of regressors and conducted several robustness tests.

This paper provides evidence that only high-quality I-A co-publications issued from firms in high-tech sectors are strongly positively correlated with firms' profits whereas all other publications are not correlated with firms' profits. This result, unlike previous studies on the subject, provides evidence that the publication of scientific articles is not a profitable activity in itself. Collaborations with academic institutions are the actual firms' behaviors that lead to profitable results; the production of publications being only a by-product of these collaborations. This paper also shows that not all collaborations are profitable, only successful collaborations (i.e. collaborations that lead to high-quality publications) in high-tech sectors lead to larger profits. This finding can be interpreted in the following way: in their quest for survival and profitability, companies competing in high-tech sectors often need the help of academic partners to exploit scientific knowledge (e.g. George et al., 2002).

The paper is structured as follows. Section 2 reviews the literature on industry science and its benefits for firms. Section 3 presents the empirical framework. Section 4 discusses the empirical findings. The conclusions and a discussion are presented in Section 5.

2. The role of academic institutions and industry science's performance

The broad literature on industry science generally agrees that investment in science is beneficial to firms. Deng et al. (1999) find a positive relationship between the science intensity of patents (i.e. patents who cite scientific non-patent literature) and the market valuation of firms. In the same vein, Van Looy et al. (2003) provide evidence that the science intensity of patents positively impacts technological productivity. Koenig (1983) provides evidence that the drug output of large pharmaceutical companies is positively correlated to their publication output, especially when these articles are published in high-quality journals.

Among the previous studies on industry science, an emerging stream of the literature is analyzing if and how the publication of scientific articles influences the stock market value of companies. Three recent studies on this subject provide different results. Two of them provide evidence in favor of scientific publications (Simeth and Cincera, 2015; Pellens and Della Malva, 2017) whereas one study (Arora et al., 2017) found no benefit in industry scientific publications for the latest years of their sample (1998-2007).

Simeth and Cincera (2015) study a sample of large American firms from high-technology sectors during the period 1996-2003 and argue that publications have a positive impact on firm's Tobin Q and hence confirm that the benefits of open science outweigh the potential costs. The authors explain that publishing activities allow firms to become members of the scientific community which in turn provide them with access to state-of-the-art developments and research techniques. In line with these conclusions, Pellens and Della Malva (2017) who study semiconductor firms in the U.S. between 1980 and 2007, also find that publications of scientific articles have a positive impact on companies' valuation of intangibles. The authors go a step further considering the heterogeneity in the nature of firms' science. The latter find that only the publication of research with basic character influences the valuation of intangible. In addition, Pellens and Della Malva point to a special importance of basic publishing for design firms and the post-PC era of the 2000s, which generated new scientific challenges. The authors therefore conclude that basic science seems to be profitable when the sector faces new scientific challenges. In a contradictory study on large US corporations from 1980 to 2007, Arora et al. (2017) evidence that science and publications are being less attractive to firms as their impact on firm's market value has declined over time to a point to which publications do not influence market value.

These studies, providing contradicting results in appearance, provide useful information about the profitability of science. We may interpret their results in the following way. First, the publication of scientific articles does not seem to be a profitable activity to the industry in general (Arora et al., 2017). However, science seems to benefit to private companies if the latter come from high-tech sectors (Simeth and Cincera, 2015). Indeed, companies in these sectors are more prone to face new scientific challenges than companies in other sectors (Pellens and Della Malva, 2017). In addition, Pellens and Della Malva point to a special importance of basic publishing (versus applied publishing) for firms facing new scientific challenges.

The first objective of this paper is to provide additional evidence on these conclusions considering a wider range of industries and countries. Indeed, previous empirical studies on the subject were only studying the U.S. while we are studying worldwide R&D companies. Furthermore, Arora et al. (2017) consider different sectors but did not differentiate these sectors whereas both Pellens and Della Malva (2017) and Simeth and Cincera (2015) consider high-tech sectors. By comparing high-tech sectors with other sectors, we test if previous studies did or did not contradict each other.

The second objective of this paper is to further analyze the subject by considering the role of academic partners in the effects of science on firms' profits. This paper also investigates if the quality of collaborative science influences firms' performances. Indeed, Koenig (1983) provides evidence that the drug output of large pharmaceutical companies is positively correlated to their publication output, especially when these articles are published in high-quality journals. In addition, Simeth and Cincera (2015) find that particularly publications in top-journals generate a considerable premium.

Many reasons lead us to consider partnerships with academic institutions, rather than the production of science as the factor raising firms' profits.

First, several research scholars argue that I-A co-publications are representative of I-A collaborations based on the evidence that academic partners play a central role in industry science and that I-A co-publications might be only by-products of these collaborations. It is therefore easy to confound publications and collaborations with academic partners. The literature provides lot of evidence that I-A partnerships frequently lead to scientific publications. It is in fact widely accepted that academic researchers are eager to publish the results of their research as the academic incentive systems always favor disclosure (Stern, 2004; Lacetera, 2009; Sauermann and Stephan, 2013). In addition, academic partners demonstrate important bargaining power which allows them, in most cases, to impose greater openness to firms (Tijssen, 2004; Lacetera, 2009; Simeth and Raffo; 2013). Hence, firms who want to convince academic scientists to work together must usually accept the disclosure of research outcomes (Hicks, 1995; Cockburn and Henderson, 1998; Stern, 2004; Tijssen, 2004; Lacetera, 2009; Liu and Stuart, 2010; Simeth and Raffo, 2013). For instance, Simeth and Raffo (2013), in an empirical study on 2,355 French manufacturing firms provide evidence that firms who consider interactions with academic partners as important reveal higher degrees of openness than other firms. Another argument put forward is that if a firm wants to publish for different reasons cited above, academic institutions are good partners because they usually have the capabilities to publish (which requires experience) (Simeth and Lhuillery, 2015).

Second, partnerships with universities appear to be essential if firms want to exploit science. Science-based knowledge is hard to codify and needs close partnerships in order to be transferred from academia to industry (Veugelers, 2014a). Collaborations with universities enable firms to access and leverage valuable resources like state-of-the-art research and the best scientists; and for exploiting scientific knowledge and novel discoveries (Dasgupta and David, 1994; Liebeskind et al., 1996; Audretsch et al., 2012; Subramanian et al., 2013). Cockburn and Henderson (1998) argue that the ability to "do good science" in the private sector may not be supportable in the long run without a close partnership with the institutions of open science.

Third, it is largely acknowledged in the literature on I-A collaborations that these types of collaborations are beneficial to companies (George et al., 2002; Belderbos et al., 2004; Faems et al., 2005; Markman et al., 2008; Baba et al., 2009; Lavie and Drori, 2012; Subramanian et al., 2013). For example, George et al. (2002) provide evidence that biotechnology companies with university linkages have lower R&D expenses while having higher levels of innovative output. Cockburn and Henderson (1998) provide evidence that I-A collaborations lead to higher performance in drug discoveries. Belderbos et al. (2004) use a large sample of Dutch innovative firms and provide evidence that university cooperation has a significant impact on productivity growth.

Fourth, considering collaborations with academic institutions (and not firms' science as a whole) being a source of firms' profits generate important links between the literature on I-A collaborations and the literature on the profitability of science. The latter finds that science benefits to firms from high-tech sectors (Simeth and Cincera, 2015) and that science benefits to firms facing new scientific challenges (Pellens and Della Malva, 2017). The parallel is easily made with the literature on I-A collaboration which states that companies competing in high-tech industries collaborate with academic institutions to face major challenges in their quest for survival and profitability (George et al., 2002). One more parallel may be found considering the empirical study made by Pellens and Della Malva (2017) on the profitability of science as they provide evidence that the publication of basic research (versus applied research) is specifically profitable. The parallel is made with the I-A literature who states that collaborations with academic partners are profitable to firms. Indeed, I-A collaborations are strongly related to basic research since universities conduct mainly basic and exploratory research that is typically complementary to industry knowledge (Zucker et al., 1998; George et al., 2002). Wheelwright and Clark (1992) add that collaborations with universities are usually seen as explorative oriented. These collaborations are focused on the creation of know-how and know-why of new materials and technologies that can be translated into commercial development.

We may therefore make the following hypothesis: good science benefits to high-tech companies thanks to the help of academic partners; directly as firms will benefit from new knowledge and indirectly as firms' researchers may acquire new knowledge/skills from these collaborations. In other words, successful partnerships with academic institutions may be beneficial to private companies whereas the publication of the research output might simply be a consequence of the academic partner(s) willingness or capabilities to publish.

3. Empirical framework

To demonstrate such link, we built a unique dataset considering 4287 top worldwide R&D firms for the recent period 2004 to 2013. The core data refers to financial information and scientific publications of the top corporate R&D investors worldwide, which represents 4287 firms.

The first data source consists of the different editions of the EU Industrial R&D Investment Scoreboard released by the Joint Research Centre - Institute for Prospective Technological Studies (JRC-IPTS) of the European Commission. [3] The R&D Investment Scoreboard has been issued every year since 2004 and provides economic and financial data at firm level for the top R&D-active firms in the world. The R&D Investment Scoreboard gathers increasingly more firms through time. Considering all datasets from each year, it represents a total of 4287 firms from 2000 to 2013 in an unbalanced dataset. The world top-2500 firms represented in the R&D Investment Scoreboard of 2013 accounted for more than 90% of the total R&D performed in the private sector (BERD) worldwide.[4] The information available in the R&D scoreboards is consolidated at the group level and includes, among others, R&D investments, net sales, number of employees, capital expenditures, the country where the company has its registered headquarters and the main business sector, based on the Industry Classification Benchmark (ICB) at two and three digits' level.

The second data source is the Elsevier's SciVerse Scopus online database.[5] Scopus is the largest abstract and citation database containing peer-reviewed research literature. It offers access to more than 47 million articles. The information regarding the publications of each of the top R&D firms has been retrieved manually[6] from this database using the affiliation identifier that allows automatically identifying and matching an organization with its research output. The research output of a firm may comprise various types of documents (i.e. article, article in press, conference paper, editorial, letter, review…), but for the sake of the analysis, only articles published in scientific journals have been considered, as the latter tend to report original research results.[7] Although the Scopus' Affiliation Identifier is reliable, the dataset suffers from some limitations insofar as it does not cover all the affiliates and other subsidiaries of the 4287

[3] http://iri.jrc.ec.europa.eu/scoreboard.htm
[4] See the highlights of the 2014 EU R&D scoreboard: http://iri.jrc.ec.europa.eu/scoreboard14.html
[5] http://www.scopus.com/home.url
[6] Manual extraction is a time-consuming task as data export in Scopus is limited to a maximum of 2,000 records per extraction.
[7] Papers presented at conferences could also have been included. The reason why we do not include such proceedings is that their quality is complicated to estimate. For informational purpose, we checked some top-R&D firms. The firms in ICT sectors produce usually more conference proceeding than articles published in scientific journals. E.g. IBM published 653 articles in scientific journals and produced 1262 conference proceedings in 2013. In contrast, pharmaceutical firms do not have much conference proceedings. E.g. Pfizer published 955 articles in scientific journals and produced 87 conference proceedings in 2013.

parent companies. In fact, it would be extremely time consuming to find all subsidiaries of all the 4287 parent companies and manually retrieve the publications of all these firms' affiliates.[8]

The third data source is the Scimago Journal & Country Rank available online.[9] It contains information about the journals in which firms' articles are published. This database is particularly useful to approximate the quality of the journal through the SCImago journal rank (SJR) indicator. The SJR indicator divides 3 years' period citations to a journal by the number of articles of the journal, during a specific period. The main novelty of the SJR indicator – compared to the impact factor based on Web of Science data – is that it attributes different weights to citations depending on the prestige of the citing journal without the influence of journal self-citations (Falagas et Al. 2016). Prestige is estimated with an algorithm in the network of journals. The Scimago Journal & Country Rank also gathers the areas of research of the different journals.[10] The SJR is preferred to the number of citations to approximate the quality of a publication for two reasons. First, we could only have access to the number of forward citations (in Scopus) which is decreasing with time. A correction of that bias would be always imperfect because there is a different decrease (of the number of citations) depending on the period, the sector, the area of research and many other factors. In addition, the number of citations, when corrected for this bias, depends also on many other subjective factors than the quality of the publication itself, e.g. the popularity of the authors, self-citations, etc.

Our final dataset used for the econometric analysis consists of 584,242 publications issued by 3080[11] firms out of the 4287 firms listed in the different versions of the EU industrial R&D Scoreboard.[12] Together the Scoreboard firms represent more than 90% of the total R&D performed in the private sector (BERD) worldwide and their publications represent 2.6% of all Scopus scientific articles published between 1996 and 2014 (22,534,697) in scientific journals. It covers 39 industrial sectors[13] and 50 industrialized countries over a period spanning 1996-2014[14] for the publications information and a period spanning 2000-2013 for firms' financial information.

To investigate the link between I-A co-publications and firms' profits, we run several linear models with the logarithm of firms' profit as dependent variables. In a first model (equations 1

[8] Cincera and Ravet (2014) carried out such an exercise for all EU companies listed in the 2008 edition of the EU Industrial R&D Scoreboard. They were able to retrieve about 44,000 subsidiaries for a subset of 837 EU companies.
[9] http://www.scimagojr.com/
[10] The areas of research are cited in table 27 (section 3.3.4.).
[11] It means that 1207 firms do not publish scientific articles.
[12] For the sake of coherence between publications, Scoreboard firms and patent data, some firms were aggregated, e.g Samsung Electronics, Samsung Display and Samsung Electro-Mechanics all became Samsung.
[13] See table A1 in the Appendix for the list of the sectors covered by the data set.
[14] 1996 was chosen as the first year because in 1996 Scopus started to use a different methodology to gather publications.

and 2), we differentiate publications issued from collaboration with academic partners from other publications. A second model (equations 3 and 4) also differentiates publications according to their quality (high- and low-quality publications).[15] The quality of publications represents, among others, the degree to which the research provides interesting output to science. Hence, high-quality I-A co-publications may represent innovative results of successful collaborations with academic partners. In addition, equations 2 and 4 include interaction terms representing high-tech sectors for the variables of interest.[16]

The control variables represent the common determinants of firms profit and market value found in previous literature (Kraft and Czarnitzki, 2004; Simeth and Cincera, 2015; Pellens and Della Malva, 2017), i.e. the R&D stock (in logarithm), the capital stock (in logarithm), the number of employees (in logarithm) and competition variables, i.e. the market share of the firms (firm_ms) and a herfindahl index representing the sector concentration (HHI_sector). Other control variables are the GDP per capita in current US$ of the different countries (gdp) of the different firms and its squared value. We also control for unobserved fixed effects and years dummies are also included in the model. Table A2 in the Appendix present descriptive statistics for all variables.

4. Empirical findings

4.1. Co-publications as indicator of technology transfer

The results of equation 1 in Table 1 suggest that only publications having at least one academic author are positively influencing firms' profits. Other types of industry publications do not significantly impact firms' profits. Equation 2 shows that this result is only validated for companies in high-tech sectors. Going to equations 3 and 4, we observe that only high-quality I-A co-publications made in high-tech sectors are positively and significantly correlated with firms' profits.

We consider a lag of two years for the variables linked to the R&D activities (i.e. public R&D expenditures, R&D stock, publications variables and the patent dummy) and a lag of one year for the other variables (i.e. GDP, taxes, Capital stock, number of employees and the competition variables).[17] Indeed, it appears more reasonable to consider larger lags between R&D activities and profit than other variables and profit. We found only one study, made by Ravenscraft and

[15] The quality of a publication is represented by the SJR indicator of the journal in which the article is published. High and low quality are defined using the median quality, i.e. Scimago Journal Ranking indicator (SJR) = 1.004.
[16] The sector classification is presented in table A1 in the Appendix.
[17] Testing different lags (1 year to 4 years) of explanatory variables does not significantly alter the results.

Scherer (1982), that explicitly study the lag structure between R&D expenditures and profits or sales. They use data on 42 U.S. firms and study the time lag between the beginning of the development and the introduction on the market of the resulting new product. 45% of the companies reported a lag of one to two years, 40% reported a lag of two to five years and 5% reported of a lag of more than five years. Their empirical results provide evidence of a mean lag of four to six years, although the first returns are realized in the next year after starting the project. Hence, a lag of at least two years between R&D variables and profit in addition to considering stocks of R&D variables instead of flows seem more reasonable. The robustness tests[18] provide evidence that different considerations in the lag structure do not significantly alter the results. These facts also support the choice of using stocks of publications instead of flows as explanatory variables. In addition, considering stocks and lags of two years are more efficient to avoid endogeneity. The panel data base also allows us, among others, to control for unobserved time invariant effects and consequently for possible endogeneity bias due some time invariant omitted variables.

Table 1. The effects of I-A co-publications on firms' profit

	(1)	(2)	(3)	(4)
VARIABLES	Profit	Profit	Profit	Profit
Ln_pub_stock_NA $_{t-2}$	0.0321	0.0276	--	--
	(0.0447)	(0.0447)		
Ln_pub_stock_A $_{t-2}$	**0.0967****	0.0188	--	--
	(0.0423)	(0.0480)		
Ln_pub_stock_A $_{t-2}$*HT	--	**0.143****	--	--
		(0.0578)		
Ln_lq_pub_stock_NA $_{t-2}$	--	--	0.0407	0.0415
			(0.0499)	(0.0495)
Ln_hq_pub_stock_NA $_{t-2}$	--	--	0.0168	0.00956
			(0.0590)	(0.0589)
Ln_lq_pub_stock_A $_{t-2}$	--	--	-0.0326	-0.0268
			(0.0499)	(0.0494)
Ln_hq_pub_stock_A $_{t-2}$	--	--	**0.127****	0.0504
			(0.0512)	(0.0556)
Ln_hq_pub_stock_A $_{t-2}$*HT	--	--	--	**0.128****
				(0.0614)
GDP $_{t-1}$	-9.31e-06	-9.27e-06	-9.05e-06	-9.36e-06
	(1.10e-05)	(1.10e-05)	(1.10e-05)	(1.10e-05)
GDP_sq $_{t-1}$	-6.20e-11	-6.18e-11	-6.53e-11	-6.28e-11
	(9.65e-11)	(9.69e-11)	(9.66e-11)	(9.68e-11)
Ln_rd_stock $_{t-2}$ [19]	-0.160**	-0.167**	-0.155**	-0.161**

[18] These results are available upon request.

[19] One may note the negative sign of the R&D stock. Once we consider only positive profits, this variable is not significant anymore. This value might be explained by the strong uncertainty beyond R&D investments. A firm may indeed end up bankrupted after important investments in a promising product that may end up being a failure.

	(0.0662)	(0.0662)	(0.0661)	(0.0661)
Ln_capex_stock $_{t-1}$	-0.0542	-0.0414	-0.0532	-0.0439
	(0.0934)	(0.0935)	(0.0932)	(0.0934)
Ln_empl $_{t-1}$	0.488***	0.475***	0.488***	0.479***
	(0.0663)	(0.0671)	(0.0666)	(0.0673)
HHI_sec$_{t-1}$	-2.647***	-2.487***	-2.674***	-2.532***
	(0.854)	(0.858)	(0.854)	(0.858)
Firm_ms $_{t-1}$	3.111***	3.097***	3.132***	3.116***
	(1.039)	(1.061)	(1.050)	(1.062)
Constant	1.395**	1.454**	1.399**	1.449**
	(0.690)	(0.691)	(0.690)	(0.691)
Observations	15,467	15,467	15,467	15,467
R^2	0.056	0.057	0.056	0.057
Number of firms	2,430	2,430	2,430	2,430

Notes: Significance levels are indicated with ***, **, *, respectively 1%, 5% and 10%, year dummies are included in the regression. "A" stands for "Academia", "NA" for "No Academia", "hq" for high-quality, "lq" for low quality and "HT" for "High-Tech".

Whereas literature on firms' publications cannot agree on the benefits of industry publications, the above results are in line with the literature on I-A partnerships. This literature shows indeed that I-A collaborations are beneficial to industry, especially in high-tech sectors. Moreover, it makes sense that high-quality I-A co-publications are the only publications correlated with higher profits as publication quality is an indicator of the quality of the output of I-A collaborations.

What we learn from these results is that I-A co-publications are a sufficiently strong indicator of I-A collaborations to be significantly correlated with higher profits. Moreover, it appears that I-A collaborations are rather highly profitable to firms. The coefficient of the interaction term in equation 4 shows indeed that a rise of about 8 % in successful collaborations in high-tech sectors (leading to high-quality publications) raises the profit of firms of about 1%.

However, one must note all I-A collaborative researches do not lead to publications. It can arise that firms impose secrecy to their academic partners such that the publication of the research results may not occur (Blumenthal et al. 1986, 1996a, 1996b, 1997, 2006; Campbell et al. 2002; Czarnitzki et al., 2015). This point underlines one weakness of this study. We unfortunately do not have an estimation of the percentage of collaborative research that does not lead to a publication. Nevertheless, such lack of information does not considerably affect the conclusions of this study. It just implies that the number of I-A co-publications represent a certain percentage of I-A collaborations, although this percentage is sufficient to show an important impact of I-A co-publications on firms' profits.

To conclude this section, I-A co-publications appear to be a strong but also imperfect indicator of I-A collaborations and should therefore be used as a complementary tool of other imperfect indicators such as survey data. Using publications as a measure of I-A collaborations presents nevertheless many advantages. First, the latter are much less expensive and cumbersome to acquire and to process than survey data, especially for aggregated data. Secondly, publications quality is a good measure of the quality of the output of such collaborations whereas such variable is difficult to evaluate otherwise.

5. Conclusion and discussion

The first objective of this analysis is to provide further evidence to the existing empirical studies on the profitability of industry publications/science. Previous studies on the profitability of science seem indeed to contradict each other. Whereas two studies provide evidence in favor of the profitability of scientific publications (Simeth and Cincera, 2015; Pellens and Della Malva, 2017), one study (Arora et al., 2017) found no benefit in industry scientific publications for the latest years of their sample (1998-2007). However, these studies gather different types of firms. Arora et al. (2017) study different sectors but do not differentiate these sectors. Both Pellens and Della Malva (2017) and Simeth and Cincera (2015) consider high-tech sectors. We therefore compare high-tech sectors with other sectors.

The second objective of this study is to go further by considering the role of collaborations with academic partners in the profitability of science. We test two different possibilities. Is it (1) the partnerships with academic institutions - leading to the production of science – that benefit to firms or (2) as evidenced in previous studies on the profitability of science, science in itself that is profitable to firms?

Regarding previous literature, the first possibility make sense. As shown in chapter 3 and chapter 4, it is indeed easy to confound science and collaborations with academic institutions because academic partners play a central role in industry scientific publications. In addition, this first possibility would generate a link between the literature on the profitability of science/publications and the literature on I-A collaborations. The first stream of literature provides evidence that science/publications are profitable to firms (depending on the period, the sector and the nature of the science) whereas the second one provides evidence that I-A collaborations are profitable to firms. Both streams of literature also provide evidence that science (for the literature on the profitability of science) or partnerships with academic institutions (for the literature on I-A collaborations) are more profitable to firms facing more R&D challenges.

To investigate the subject, we run several linear models on a multi-sectoral and world-wide database covering the latest period (2003-2013). The dependent variables are the logarithm of top R&D firms' profit. We also control for unobserved fixed effects.

The results provide evidences that publications, when considered as a whole, do not show significant effects on firms' profits. This is coherent with Arora (2017) who evidences that publishing activities are not valuable to firms in general (for the period 1998-2007). However, we observe that publications issued from high-tech sectors show a positive impact on firms' profit. These results are consistent with both Simeth and Cincera (2015) and Pellens and Della Malva (2017) who provided evidence of the profitability of science for companies in high-tech sectors (or for firms facing more R&D challenges). Hence, previous empirical studies do not contradict each other, they are only studying different types of firms.

Regarding the role of academic partners in industry scientific publications, this study provides evidence that the publication of scientific articles (which is the measure for industry science in previous literature) is not a profitable activity in itself. Collaborations with academic institutions are the actual firms' behaviors that lead to profitable results; the production of publications being only a by-product of these collaborations. This study also shows that not all collaborations are profitable, only successful collaborations (that lead to high-quality publications) in high-tech sectors lead to larger profits. In their quest for survival and profitability, companies competing in sectors at the frontier of technological progress often need the help of academic partners to exploit scientific knowledge. On average, in high-tech sectors, a rise of about 7% in successful I-A co-publications raises profit of firms of about 1%. In addition, given the high profitability of such collaborations, it is not surprising that firms publish their own research to attract academic collaborators (as evidenced in chapter 4). Some implications may be derived from these conclusions.

First, this study demonstrates that the quality of the journal in which I-A co-publications are published is an efficient measure for the quality of the research output of I-A collaborations - as journals' qualities are highly correlated with firms' profits. This measure might be useful for innovations policies. In fact, Veugelers (2014a) underlines an issue specific to the EU, she argues that "the policy initiatives that seek to stimulate university-industry linkages all suffer from a lack of a proper evaluation strategy prohibiting systematic evidence collection on the causal effects of the policies. To progress, policy makers should be more serious about evaluating their instruments and support more systematic data collection on the various pathways for universities' contribution." Veugelers (2014b) add that "the indicators available for empirically demonstrating the strength of the links between industry and science across countries and time are extremely limited." Although the innovation scoreboards of the European Commission use the quantity of co-publications as an indicator value for the intensity of public-private co-publications, the latter do not consider the quality of the publication as a performance measure of these collaborations.

Hence, this study provides one more evidence that publications having at least one academic author could be considered as indicators of I-A collaborations (as argued in chapter 4). If it were not the case, there is no reason for these publications to show different effects on firms' profits compared to the other publications. Hence, considering future researches, publications having at least one academic partner may be an alternative measure of firms' collaborations activities with academic institutions. Indeed, many studies assessing the benefits of I-A collaborations use survey data with a binary variable to measure the collaborations with universities (e.g. Faems et al., 2005; Belderbos et al., 2004; and Simeth and Raffo, 2013). However, binary variables do not represent the intensity of collaborations. In addition, given that the quality of the journal (represented by the SJR indicator) in which the article is published directly affects firms' profit, it is most likely that the journal SJR indicator is a reliable measure of the quality (or the innovativeness) of the of the output of I-A collaborations.

Second, the conclusion of this study may draw some policy implications. This study provides reasons for policy makers to concentrate their policy on promoting I-A partnerships in high-tech sectors only. These collaborations often lead to highly profitable results by generating important innovations. However, high potential profitable results issued from the collaboration of firms with non-profit institutions may raise concerns. Such high profitable results might provide incentives to firms to "capture" in different ways non-profit open knowledge institutions. For example, it can arise that firms impose delay or partial or full secrecy on the publication of the research results (Blumenthal et al.1986, 1996a, 1996b, 1997, 2006; Campbell et al. 2002; Czarnitzki et al., 2015). Additionally, some concerns should be raised about contracts of exclusive collaborations and acquisitions of universities departments. Finally, an important concern is derived from figure 58 (chapter 3). This figure presents the number of EU academic authors who collaborate with US industries versus the number of US academic authors who collaborate with EU industries. This figure shows only collaborations in the framework of high-quality I-A co-publications in high-tech sectors because these co-publications are found to be highly correlated with profitable results. We observe that increasingly more "skilled"[20] EU academic researchers are working with US firms compared to "skilled" US academic researchers working with EU firms. The balance weight therefore in favor of US firms who benefit more from EU academic findings than EU firms benefit from US academic findings. EU policy makers should

[20] In this context, skilled means co-authors that generate high-quality publications

consequently be aware that the EU is losing many of its scientific inventions to US firms and that the opposite is not as important. Further studies on this subject could bring important results for policy makers.

Much can still be done in assessing the profitability of firm's publications/science/collaborations with academic partners. Our preliminary results may be improved by distinguishing basic from applied research (as Pellens and Della Malva, 2017). Both types of knowledge creation issued from I-A collaborations might have different effects on firms' profitability. Interesting results might also be found by replacing the profits by the sales or the patenting activities (representing the innovations activities) and by testing different stocks of publications rather than high and low-quality publications stocks (e.g. very-high-quality publications). It would also be interesting to differentiate young leading innovators form older firms (as Veugelers and Cincera, 2015). These analyses would provide additional insights on the benefits of I-A collaborations.[21] Possible endogeneity should also be taken into account. Further studies may also differentiate high-tech sectors from each other to study if it is more profitable for some sectors to work with academia than other sectors. To further improve the above study, it would be also interesting to include conferences proceedings into the analysis.

[21] Which was not the main objective of this empirical analysis as its main objective is to provide new insights on the literature about the profitability of industry science.

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Appendix

Table A1. Sectors classifications

Sector	**R&D/Sales**	**Classification**	**Number of firms**
Pharmaceuticals & Biotechnology	0,145	High-tech	559
Software & Computer Services	0,096	High-tech	541
Technology Hardware & Equipment	0,086	High-tech	483
Leisure Goods	0,068	High-tech	61
Health Care Equipment & Services	0,062	High-tech	168
Aerospace & Defense	0,043	High-tech	78
Electronic & Electrical Equipment	0,043	High-tech	372
Automobiles & Parts	0,041	High-tech	184
Alternative Energy	0,040	High-tech	12
Chemicals	0,030	Medium-tech	204
Industrial Engineering	0,028	Medium-tech	300
Household Goods & Home Construction	0,022	Medium-tech	72
Personal Goods	0,021	Medium-tech	80
General Industrials	0,021	Medium-tech	118
Financial Services	0,019	Low-tech	54
Media	0,018	Low-tech	57
Fixed Line Telecommunications	0,017	Low-tech	38
Oil Equipment, Services & Distribution	0,015	Low-tech	36
Support Services	0,014	Low-tech	136
Food Producers	0,014	Low-tech	100
Banks	0,013	Low-tech	54
Real Estate Investment & Services	0,011	Low-tech	14
Tobacco	0,011	Low-tech	8
Mobile Telecommunications	0,010	Low-tech	18
General Retailers	0,010	Low-tech	47
Construction & Materials	0,009	Low-tech	119
Travel & Leisure	0,009	Low-tech	57
Industrial Metals & Mining	0,008	Low-tech	69
Electricity	0,007	Low-tech	44
Beverages	0,007	Low-tech	14
Mining	0,006	Low-tech	26
Gas, Water & Multi-utilities	0,006	Low-tech	21
Forestry & Paper	0,005	Low-tech	22
Industrial Transportation	0,004	Low-tech	35
Nonlife Insurance	0,004	Low-tech	17
Oil & Gas Producers	0,003	Low-tech	44
Food & Drug Retailers	0,003	Low-tech	18
Life Insurance	0,002	Low-tech	7

Table A2. Variables summary

VARIABLES	(1) N	(2) mean	(3) sd	(4) min	(5) max
Profit	17946	765,6	2553	0,01	56843
Pub_stock	17946	72,16	288,70	0	8797
Pub_stock_NA	17946	28,33	123,10	0	2600
Pub_stock_A	17946	45,44	188,20	0	7733
Lq_pub_stock_NA	17946	17,20	68,26	0	1460
Hq_pub_stock_NA	17946	10,45	54,98	0	1242
Lq_pub_stock_A	17946	21,30	88,25	0	4273
Hq_pub_stock_A	17946	23,21	102,20	0	3460
High_tech	17946	0,52	0,50	0	1
Tax	16724	16,05	7,29	0,31	35,08
GDP	17418	42669	12925	640,60	157093
Gov_rd	16830	0,27	0,09	0,02	0,59
Rd_stock	17788	874,2	2623	0,06	35116
Capex_stock	16584	5483	19268	0,44	465173
Empl	17297	24805	56266	6	1,60E+06
Patent_yes	17946	0,62	0,49	0	1
H_sec	17946	0,07	0,05	0,02	1
Firm_ms	17944	0,02	0,05	1,19E-06	1