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Two Sides of the Same Coin. University-Industry Collaboration and Open Innovation as Enhancers of Firm Performance

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Abstract: Open innovation is proved to be determinant in the rationalization of sustainable innovation ecosystems. Firms, universities, governments, user communities and the overall environment are called to contribute to this dynamic process. This study aims to contribute to a better understanding of the impact of open innovation on firms' performance and to empirically assess whether university-industry collaborations are complementary or substitutes for this activity. Primary data were collected from a survey encompassing 908 firms, and then combined with performance indicators from SABI (Spanish and Portuguese business information). Econometric estimations were run to evaluate the role of open innovation and university-industry collaboration in the firm innovative propensity and performance. Results highlight the importance of diversity in collaborations with the academia and inbound open innovation strategy as enhancers of firm performance. The two activities reinforce each other. By testing the impact of open innovation practices on company performance, the need for heterogeneity in terms of contact type and university is also demonstrated. Findings cast light on the need to reformulate existing policy packages, reinforcing the ties with academia as well as the promotion of open innovation strategies. The connection to the innovation ecosystem needs to be further encouraged as well as the promotion of persistent connections with the knowledge sources in an open and multilateral framework.

Keywords: open innovation; university-industry collaboration; firm performance; multinomial regression

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1. Introduction

In a business environment that has been more and more competitive, firms are provided competitive advantages through innovation [1]. An accurate innovative strategy can help the promotion of sustainable practices, leading to a differentiation from their competitors. At present, convergence and technological fusion have become key for sustainable growth [2], and the companies can no longer barely focus on research and development (R&D) in order to innovate [3]. Given the constraints to maintaining high investments in closed innovation mindsets, providing the full maintenance of integration and control of the entire R&D chain, companies would better be to look for options beyond their borders to strengthen the internal innovation processes [4].

Under this spell, open innovation (OI) appears as the natural strategy to adopt. Knowledge and ideas may be originated from outside the firm and embedded in the internal

R&D processes or even directly as innovations. While, the diffusion of knowledge and ideas can also be moved from the company to the market to be commercialized [4–6].

The interest of the academics in OI has grown exponentially, with growing literature in the field, emerging with insights from economic theory, economics of innovation and management over the last two decades, being therefore classified as emergent [7–9]. Plenty of studies focus on the positive effects of OI on the financial and innovative performance [6,10,11]; nevertheless, so far, only a small effort was made to empirically quantify the effects of these innovative strategies in firm performance or even in appraising the importance of university-industry collaborations in this process.

The present research contributes to the debate on the role of the effectiveness of the open innovation strategies in the promotion of financial performance. It combines two perspectives: the importance of open innovation as a catalyst of knowledge production and diffusion and its combination with university-industry collaborations; as a consequence, a strong recommendation towards the promotion of dynamic innovation ecosystems is addressed. Despite some beliefs (e.g., [3]) that the ultimate innovation ecosystems would be self-sustained, becoming dynamos of the innovation cycles, there is still room for financial boosters which will reduce the burden of innovation costs [12].

Firms implement OI practices with a variety of sources, including universities, research institutes, suppliers, competitors, among others [8,13]. This unbounded innovation strategy is really important for the accomplishment of the universities' entrepreneurial vision, as it relies on a network and it focuses on the transference and commercialization of knowledge [14]. Developing collaborative innovation processes has influenced the universities' involvement in cooperation activities with the industry [15], as companies demand and absorb R&D externally developed to further improve the process and create self-value [5,6]. As a consequence, universities and research institutes become knowledge suppliers for the industry [16].

As universities and companies have different mission statements, their contrasting realities, mindsets and objectives, entrepreneurial universities focus on the cooperation with firms, promoting technology and knowledge transfer [14,17], which permits the access to different areas of knowledge by the companies and contributes to the improvement of their innovative capacity, consequently improving market performance [18]. Usually, corporations strive to survive, thinking in terms of short-term goals, preferring proven solutions with low risks, focusing on cost reduction [6,11,19].

Accordingly to the European Innovation Scoreboard, in 2020, Portugal became a strong innovator. The innovative performance improved, with an important breakthrough in 2018 concerning the indicators included on the Community Innovation Survey (CIS). The strengths identified relate to the ecosystem, the research system and the entrepreneurial innovation levels. The absence of equity and venture capital in research and development (R&D), as well as patenting and exports in knowledge intensive business services, are the most relevant weaknesses. The innovation ecosystem including private firms, public and private R&D labs were responsible for an important evolution [20].

The article aims to make a twofold contribution to extant literature in the topic: first, by theoretically supporting the complementarity of these sources of knowledge to produce innovation, thus leveraging firm performance; secondly, the empirical model reinforces the quantitative dimension of these effects, evidencing that the both open innovation strategies and university-industry collaborations matter as performance enhancers, notwithstanding the adoption of only one of them could be a backlash in performance promotion.

In detail, the empirical models were built with the objective to investigate the impact of open innovation in business performance and cast light on the role of university-industry collaborations in this process; it is aimed to quantitatively address if these sources of knowledge behave as complements or substitutes in the promotion of financial performance. The academia is one of the major players in the innovative ecosystem, as a consequence, it is important to understand the specific contribution of this source as knowledge is a public good and the smart policy making must encompass sharing and co-creation to upscale

the outcomes of the public policy. The empirical analysis has two major sources: the first includes primary data from a purposeful survey and covers all the convenient innovation topics, the second, covers financial and structural indicators from official reports presented on the SABI (System of Analysis of Iberian Balance Sheet) platform for the previous firms. This combination allows the appraisal of both dimensions, sectionally covering 908 firms, with information for the period between 2016 and 2018.

The remaining of the article is structured as follows: Section 2 presents the literature state of the art. It is followed by the methodological practicalities. Section 4 presents and describes the empirical results. Next, Section 5 presents the discussion and conclusions. Lastly, Section 6 describes theoretical and practical implications, research limitations and policy recommendations.

2. State of the Art

2.1. University-Industry Collaboration

Over the last decades, firms gained awareness about the importance of establishing solid networks to innovate rather than exclusively relying on their internal R&D efforts [18]. The establishment of open innovation strategies forces the erosion of the firm boundaries, enhancing the development of information and communication technologies; additionally, it promotes the establishment of dynamic collaborations with external entities, emphasizing the centrality of universities and R&D labs [21,22].

University-industry collaborations (UIC) are an important source of knowledge production, being an important engine of knowledge production promoting technological pushes. The importance of this collaboration rises when targeting cutting edge information about R&D processes [23] and turning itself into an instrument to face social and economic challenges [24].

Technology transfer is the common link between universities and firms [18], leading to the establishment of strategies focused on cooperation, with integrative R&D. However, these partnerships relate to the specific contexts as well as their actions; the establishment of persistent collaborative relations between universities and firms is not evident [25].

Notwithstanding, both parts fully understand the importance of their connection as a facilitator of technological innovation, beneficial for both. Universities are directed to respond to the stimulus of purely scientific challenges and under a technological perspective, making them key actors of the innovation and technological diffusion processes encompassing multiple agents [26]. Universities are sources of general knowledge required for basic research activities [27], as well as sources of specialized knowledge related to industrial applied technology. Furthermore, they are responsible for the shaping of high-qualified professionals with the accurate skills to address innovation related problems in the working context [23].

Traditionally, universities transfer knowledge through education. Being the external partner which contributes the most to the innovation structure, as they connect in different ways to the human capital [23,28], promoting critical spirit [29]; knowledge transfer and all the intangible assets provided put universities in the center of the innovation process [23,26]. The academia prepares professionals for the industry which may benefit from this interaction through the improvement of innovative opportunities, product, service and process innovations. Hence, the university also benefits from this interaction, acquiring conscience of the concerns and technological trends, whilst providing their students with the accurate skills for their jobs [30].

Expectably, the collaboration between university and industry naturally includes scientific research, and its results; when in practice, this is a very similar procedure to the commercial technology transfer [27,31]. Universities and research centers currently occupy a prominent place, as scientific research has granted radical changes in the industrial technological landscape [31]. The search for technological progress as well as disruptive innovation create a stimulus for companies in exploring collaborations with universities, given their importance as sources of information [16].

According to Hurmelina [32], the most frequent motivations from academics for establishing ties with firms were: educational improvement through the applied investigation, access to financial resources, availability of empirical data and immersion in real-world problems. From the firms' point of view, the motivating factors include: increased competitiveness through early access to scientific or technological knowledge; risk reduction through the sharing of certain research activities; use of unique research capabilities, greater efficiency and reduced hiring costs.

In the context of "entrepreneurial university" [33], the institutional renovation is an increasingly closer reality, labeled as pro-active and involved with the local community, benefiting the industrial development, by creating links with local actors [34]. In this framework, universities and companies are complementary and non-competing institutions, their collaborations are very likely to generate win-win situations, not only because of the ease in trust creation, but also for the awareness that the partner will not act in an opportunistic way [35]. The combination of physical and experienced human resources [28] moves the universities from traditional organizations to specific business-oriented organizations [33].

For Guerrero and Urbano [36], the "entrepreneurial university" is characterized by systematically implementing different institutional strategies, working together with the government and industry to facilitate the availability and exploitation of technological knowledge or innovation.

The universities seek and accept the possibility of collaborating with firms to apply the results of their investigations and contribute for the existing market needs, managing to approach the business environment with practical applications for the innovations and investigations developed, making it possible to obtain financial profits [29]. The intensity of the collaboration is influenced by the university's resources and skills, as well as the institutional orientation of the science commercialization [27,28,37].

The research performed by the university permits knowledge creation and diffusion, being an important contribution to the development of new technologies and for the entrepreneurial initiative [16]. The construction of scientific networks helps companies to boost the innovation processes [17] and further contributes to the reduction of their associated costs. Often, companies have the possibility to use university facilities and technology, reducing costs and valuing knowledge [33].

The possibility of access to public funding by universities boosts the connection with the external environment, boosting the integration of the social and regional needs in the knowledge transfer process, whilst contributing for the development of society [24]. On the other hand, the emerging entrepreneurial universities focus on the UIC and may become embedded in the type of research performed in the institution. The research may depend on private agents with a solution-oriented logic, which will serve the purposes of the ecosystem in the short term, restricting other types of fundamental research [16]. In this case, some profitable, despite biased initiatives may arise, as universities will depend less on public funding [29,30]. The fact that researchers are more interested in the scientific results of innovation and not so much in its market value, but have a different perception of time, can also represent an important challenge for companies in the interaction [38].

2.2. University-Industry Collaboration and Open Innovation

The innovation process is increasingly characterized by activities embedded in cooperation networks, which result in collaborations and interactive participation of multiple actors, such as firms and universities. Countless studies have shown the importance of this model of open innovation instead of closed models [18]. According to Xie and Wang [13], the firms may get involved in OI through different ways: (a) UIC, (b) collaboration between companies, (c) collaboration between intermediate companies, (d) firm–user collaboration, (e) disposal of assets, (f) technology transfer. Throughout this work, the first point will be approached.

According to the OI paradigm, organizations should combine both internal and external resources in the innovation processes, as a way of enhancing their innovative

capability [18,39]. This condition influences university dynamics, forcing this institution to rethink collaboration models with industry and society [34].

Notwithstanding, the interaction between university and firm has received little attention in the OI literature [16], further reinforcing the importance of the present contribution. Additionally, current empirical literature does not focus on the mechanisms with which companies may take advantage in the exploitation of a more open innovation model based on the relationships with the universities, not highlighting the emergency of the topic, its evolution and sustainability, under a collaborative framework [21].

There is indeed a certain bias in studies, only focusing in business realities for which relations with universities do take part on their innovation activities. Based on these gaps, the presented work intends to investigate the impact of OI, specifically the university-company collaborations in the entrepreneurial performance, beyond looking forward to understanding if these types of strategies complement each other in the companies' practice.

Shifting towards an OI paradigm, through the development of innovation collaborative processes, has influenced the involvement of the universities in collaboration activities with the industry [15]. Knowledge exchange over institutions is significant to the accomplishment of the universities' entrepreneurial vision, once it is based on a network organization and focused on knowledge transfer and commercialization [14]. In general, universities are increasingly participating in OI activities, mainly through the disclosure of research [31], which enables the improvement of R&D practices [16], technology commercialization [14] and regional development [24]

Factors such as changes in legislative environments, increasing number of governmental initiatives to promote the knowledge transfer [40] and public-private partnerships in research [41], as well as the increase of political pressure for the universities to help the improvement of the national economic competitiveness, have contributed to a growing approach of the university and the industry. This is further reinforced by several trends: an increased propensity to patent by the universities [42], raising university licensing revenues [43], growing number of university researchers involved in academic entrepreneurship [44], and the spread of technology transfer offices, industry collaboration support offices and science parks [45,46].

The UIC can also take place through generic connections, such as hiring graduate students or using and exploring scientific publications or university patents within companies. However, within the OI context, it is precisely these intensive relationship links that are of special interest [21].

Although the use of coded knowledge in teamwork research, patents or prototypes may occur in some circumstances, the OI concepts point out for the role of collaboration and other types of relationships that sustain and enable that transference [21]. Research about R&D linkages and other organizational networks show that the involvement of the user community, also, often depends on informal means and formal social connections [47].

Hypothesis (H1). *Open innovation enhances firm financial performance.*

The university must be acknowledged as a strong innovation partner due to its endowments of knowledge-related resources and especially when considering the demand in globalized markets, the innovation process and the continuous changes in organizations and society [15,26]. In this line, the option for UIC constitutes a fundamental strategic decision in fighting competition and monitoring technological evolution [4]. UIC enriches the entrepreneurial fabric, catalyzing science development, with universities guarantying greater versatility in terms of technological innovations [21,22]

Fraser and Mancl [48] pointed out other ways of collaboration such as research contracts, internship programs, product transfer and prize awards, consortia stating that each of them presents objectives, costs, governmental requirements and different interactions. Etzkowitz [49] considered consulting as an extremely important mechanism for the collaboration between university and firms, as it represents the basis on which other forms of collaboration can be established. However, these collaborative relations face significant

challenges imposed by the differences in the level of the goals to accomplish, as the university is more knowledge and training oriented, while the firm is concerned with value creation making it more competitive. Indeed, the universities are bureaucratic organizations, with their own rules, norms, incentive and reward systems, with various objectives ranging from the teaching mission, the research or the connection with industry [29].

Nelson [50] considered five main academic activities which contribute for the innovative process within firms to take place: (i) knowledge and technological development carried out by academic research and linked to the industry for various purposes; (ii) access to specialized knowledge related to the firm technological area; (iii) training and development of engineers and scientists able of dealing with problems associated with the innovation process within companies; (iv) creation of new scientific instruments and techniques; (v) creation of spin-offs by the academic community. In this vein, the UIC occurs in distinct ways, according to the firm economic sector, knowledge; therefore, incentives can be effective for a specific set of companies and universities. For Albuquerque et al. [51], the collaborations between universities and firms is a fundamental building block of the national innovation system and the interactions between these players is a key element for a dynamic addressment of the importance, role and nature of science and technology.

The university's entrepreneurial mission may also be understood by collaborative structures with firms, as science parks, technology transfer offices [46], knowledge transfer offices for industrial clusters, incubators and other infrastructures, which are placed around the university to simplify the connection between the players [52]. Consequently, the change from conventional to networked structures has been the priority of many institutions [33,37].

On the other hand, firms are organizations moved by specific objectives such as productivity, sales and profit [11]. The increase of product, process and service complexity has been hampering towards the accomplishment of business' objectives, which leads to the demand of external capabilities, available in the academy. Overcoming economic uncertainty relies on building long-term inter-organizational networks which guarantee stable environments for the companies, moreover, that is proved to be determinant towards the persistence of innovation activities, therefore to firm resilience [53]. Worldwide, firms face globalized business environments and their integration in competitive markets, as a consequence, the inclusion in innovation networks seems to be a challenge to be addressed in a smart way, and the collaboration with the academia unavoidable.

Hypothesis (H2). *University-industry collaboration enhances financial performance.*

For all the above, it is important to combine the OI and UIC. This framework will provide plethora of resources allowing firms to address competition due to the performance empowerment causes by the adoption of OI strategies encompassing the university in the set of network partners. Adding the academia to the OI equation will diversify the knowledge sources as well as provide broader sets of knowledge and leverage synergies from outside the value chain, which will naturally raise performance and sustainability levels. Firms involved in this process will take full advantage of the innovation ecosystem [3]. In doing so, they will find alternative ways to bridge gaps inside the value chain, which is why empirical analysis will focus on this combination.

Hypothesis (H3). *University-industry collaboration combined with open innovation further leverage firm financial performance.*

3. Database, Methods and Variables

3.1. Database Description and Structural Traits

The empirical analysis was performed using two main data sources. At first, the data will be collected from a purposeful survey sent to 11,252 firms operating in Portugal from all economic sectors, encompassing the period between 2016 and 2018. The disclosure of

the survey allowed to collect recent and updated information about OI practices in the Portuguese context, by means of a comprehensive research on issues related to innovative strategies. The questionnaire received a total of 908 valid responses, which corresponded to a response rate of 8%.

A second part of the database was constructed, encompassing financial and human resources variables as well as organizational indicators, extracted from SABI for the corresponding firms. This combination permits the present work to stand out from the previous ones due to the combination of multiple dimensions concerning innovative strategies, in order to assess their impact on business performance, something that had not been done so far, casting light on a new perspective of analysis towards these topics. The number of valid observations collected guarantees the robustness of all the statistical procedures as well as the econometric estimations. However, given the randomness of the sample, generalization of the findings to the Portuguese fabric needs to be careful. Sectoral or territorial representativeness were not verified as these segmentations were not the focus of the analysis.

From Table 1, the number of firms which perform internal R&D activities is nearly the same from those who do not. Among those, two thirds do contact with universities, and, nearly 85% perform OI strategies. The most chosen contact relates to training and internships immediately followed by protocols and joint R&D projects and the least popular is consulting. Moreover, there is an even distribution of university contact and the turnover levels; notwithstanding, OI is more prone to be found in higher turnover firms. Inbound innovation practices are used far more often than the outbound, regardless of firm dimension.

Table 1. Database structural traits.

Internal R&D Activities	**N**	**Firms Connected to Universities**		**Firms Performing Open Innovation**		**Contact Type**	**N° Firms Per Contact**	**Total Contacts**	**Average Frequency**
		N	**%**	**N**	**%**				
Yes	486	315	64.81%	409	84.16%	1. Informal Contacts	228	5161	23
						2. Seminars, conferences and joint publications	148	1679	11
No	422	86	20.38%	84	19.91%	3. Consulting	89	388	4
						4. Training and Internships	238	2262	10
Total	908	401	-	493	-	5. Protocols, Partnerships and R&D Projects	218	2097	10

Performance	N	Firms connected to Universities		Firms performing Open Innovation		Dimension	Inbound	Outbond	Coupled
		N	%	N	%		N	N	N
up to 500 k *	188	62	32.98%	52	27.66%	Micro and Small (0–49 workers)	129	42	31
500–1000 k	216	82	37.96%	89	41.20%	Medium (50–249 workers)	142	41	35
1000–3000 k	238	92	37.66%	114	47.90%	Large (250 or more workers)	114	35	28
more than 3000 k	248	158	63.71%	149	60.01%				
Total	890	394	.	404	.	Total	385	118	94

* k-thousands of euros.

3.2. Variable Construction and Descriptives

3.2.1. Dependent Variable

The connection between performance, OI and UIC is somehow overlooked in the literature [21]. However, previous studies evidence that there is an inversed U-shape relation between open innovation and firm performance [54]. It is accepted that open innovation strategies enhance firm competitive advantages; still, they differ in the ability and context to capture its value [55]. As we focus in performance, the appraisal was

made throughout the turnover; being proxy by the sum of total sales and the total service provision, to avoid over dispersion and heterogeneity, the logarithmic form is included in the econometric models. The information is grasped from the SABI database.

3.2.2. Independent Variables

Knowledge produced by the university and its correspondent transfer creates conditions for establishing collaborations with the industry, making possible the access to other technological foundations that boost firm innovative capacity [23]. The exploitation of collaborations with the university is considered an essential factor for the technological development of firms [16]. Much of the literature focuses on possible ways for the company to collaborate with the university, whether through patents [42], licensing [43], hiring postgraduates, spin-off companies [21]. In the present work, five different types of university-company collaboration are proposed: R&D partnerships and projects; training/internships; consulting; seminars; conferences; joint publications; and informal contacts. Additionally, intensity and multiplicity indicators are built based on the number of contacts and the different universities contacted.

On the other hand, OI helps companies to create their own value, combining external sources of knowledge with internal innovation capabilities, through the involvement with external partners [7]. The development of collaborative innovation processes influenced the involvement of the universities with collaboration activities along with companies [15], as the universities may become firm knowledge suppliers, contributing to the development of internal R&D processes and innovation, and consequently developing business strategies.

The literature reveals the positive effect that the application of OI activities has in the companies' innovative performance [4]. It is indeed expected that the interaction with other organizations generates access to new ideas, skills, technologies and other intangible assets, as well as greater possibilities for successful innovation. The shift to an OI paradigm through the development of collaborative innovation processes has influenced the universities' involvement in cooperative activities along with the industry [15], which allows firms to approach universities in order to acquire useful external knowledge for their internal R&D process.

To Mazzola et al. [6], the diffusion of knowledge and ideas can move from the firm to the market to be commercialized (outbound) or can be originated outside the company and included in the internal R&D and innovation processes (inbound). In addition, a third possibility, coupled, is considered combining internal and external elements. In the present work, the three proxies were appraised.

3.2.3. Control Variables

Other factors that might also affect firm performance were included in the model as control variables such as firm dimension (size), firm maturity (age), availability of human capital in terms of undergraduates (edu_int) and engineers (skill_int) as well as the economic sector in which the firm develops its activity (tech_reg) A variable list with definitions is presented in Table 2. Detailed calculations and descriptive for all variables are shown later in this section.

3.3. Descriptive and Correlations

Table 3 presents the descriptive statistics and correlations for all variables. The objective of this step is to better understand the variable distribution as well as their connections. As the results do evidence, there is a strong correlation among the proxies describing UIC; after performing the VIF tests, it was evident that they were not collinear to the dependent variable, so, they were alternatively included in the econometric models to address different perspectives in the role of UIC as a driver of firm performance.

Table 2. Variable description.

ABBREVIATION	VARIABLE NAME	DESCRIPTION	MEASUREMENT
performance	Firm performance	turnover + service provision	logarithm of turnover + service provision
inbound	Inbound knowledge flows	Use of knowledge emerging from external agents	0 = does not use; 1 = sporadic user; 2 = persistent user
outbound	Outbound knowledge flows	Externalize excedentary technologies	0 = inexistent; 1 = sporadic commercialization; 2 = persistent commercialization
open_innov	Open Innovation	Performs inbound/outbound/coupled strategies	0 = no; 1 = yes
skill_int	Skill Intensity	% of engineers over total staff	decimal
edu_int	Education Intensity	% of undergraduates over total staff	decimal
firm_uni	Firm contact with university	Linkages with universities	0 = no; 1 = yes
u_diversity	Contact diversity	nº of different universities with contact	0 = 0; 1 = 1; [2,3] = 2; >3 = 3
u_type_cont	Contact intensity	Highest complex contact with the universities	0 = does not contact;1 = informal contacts; 2 = seminars, conferences, joint publications;3 = consultancy; 4 = training, internship; 5 = protocols, partnerships, R&D projects
u_intensity	Connection level	Overall number of contacts with the universities	0 = 0; [1–3] = 1; [4,5] = 2; [6–10] = 3; [11–30] = 4; >30 = 5
size	Firm dimension	nº of employees	number
age	Years in operation	age	absolute figure
tec_reg	Economic Sector	Technological regime adapted from Costa and Matias [3]	1 = supplier dominated; 2 = scale intensive ;3 = specialized supplier; 4 = science based

Table 3. Descriptive statistics and correlation table.

	Min	Max	Mean	S. Dev	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1) performance	8.558	21.901	14.386	1.527	1											
(2) inbound	0	2	0.604	0,771	0.281 **	1										
(3) outbound	0	2	0.176	0.476	0.072 *	0.300 **	1									
(4) open_innov (oi)	0	1	0.454	0.498	0.267 **	0.860 **	0.404 **	1								
(5) firm_uni	0	1	0.443	0.497	0.271 **	0.378 **	0.220 **	0.364 **	1							
(6) u_diversity	0	3	0.835	1.077	0.349 **	0.413 **	0.259 **	0.394 **	0.870 **	1						
(7) u_type_cont	0	5	1.324	1.790	0.332 **	0.421 **	0.276 **	0.399 **	0.830 **	0.901 **	1					
(8) u_intensity	0	5	1.824	2.220	0.319 **	0.416 **	0.249 **	0.410 **	0.922 **	0.865 **	0.847 **	1				
(9) skill_int	0	1	0.129	0.211	0.094 **	0.183 **	0.297 **	0.208 **	0.364 **	0.427 **	0.407 **	0.366 **	1			
(10) edu_int	0	1	0.290	0.306	0.006	0.181 **	0.230 **	0.191 **	0.357 **	0.404 **	0.383 **	0.359 **	0.654 **	1		
(11) tech_reg	1	4	2.067	1.207	−0.058	0.049	0.137 **	0.078 *	0.198 **	0.247 **	0.233 **	0.207 **	0.468 **	0.447 **	1	
(12) age	3	127	23.329	15.411	0.390 **	0.090 **	−0.006	0.053	0.026	0.046	0.046	0.036	−0.147 **	−0.178 **	−0.190 **	1
(13) size	0	5884	69.014	269.447	0.485 **	0.176 **	0.021	0.140 **	0.154 **	0.226 **	0.202 **	0.189 **	0.014	−0.011	0.031	0.169 **

**. $p < 0.01$ (2 tailled); *. $p < 0.05$ (2 tailled).

4. Econometric Analysis

4.1. Econometric Estimations

The following econometric analysis aimed to empirically test the validity of the hypotheses theoretically constructed. Table 4 presents 10 alternative econometric models. Model 1 merely encompasses the control variables to understand their importance in determining the financial performance of firms. Model 2 adds the effect of open innovation strategies, either with inbound or outbound knowledge flows. Models 3 to 6 analyze the importance of IUC in different perspectives. As aforementioned, these perspectives could not be included together to avoid multicollinearity problems. Then, models 7 to 10 combine the simultaneous effects of OI and UIC in firm performance. In all models, the dependent

variable proxies performance as the logarithm of total turnover, as a consequence, the multinomial regression will evidence the impact of an exogenous change in the predictors on performance growth.

Table 4. Estimation of the financial performance.

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
inbound	-	0.343 *** (−0.058)	-	-	-	-	-	-	-	-
outbound	-	−0.046 (−0.095)	-	-	-	-	-	-	-	-
firm_uni	-	-	0.577 *** (−0.091)	-	-	-	-	-	-	-
u_diversity	-	-	-	0.362 *** (−0.044)	-	-	-	-	-	-
u_type_cont	-	-	-	-	0.206 *** (−0.026)	-	-	-	-	-
u_intensity	-	-	-	-	-	0.158 *** (−0.02)	-	-	-	-
open_innov (oi)	-	-	-	-	-	-	0.273 ** (−0.115)	0.204 * (−0.105)	0.254 ** (−0.104)	0.214 * (−0.11)
oi*firm_uni	-	-	-	-	-	-	0.444 *** (−0.131)	-	-	-
oi*diversity	-	-	-	-	-	-	-	0.289 *** (−0.055)	-	-
oi*type_contact	-	-	-	-	-	-	-	-	0.150 *** (−0.032)	-
oi*intensity	-	-	-	-	-	-	-	-	-	0.125 *** (−0.028)
skill_int	1.369 *** (−0.27)	1.315 *** (−0.279)	1.055 *** (−0.268)	0.866 *** (−0.267)	0.916 *** (−0.267)	0.991 *** (−0.265)	1.058 *** (−0.266)	0.979 *** (−0.264)	1.008 *** (−0.265)	1.033 *** (−0.264)
edu_int	−0.074 (−0.186)	−0.299 (−0.188)	−0.284 (−0.185)	−0.376** (−0.183)	−0.348* (−0.183)	−0.331* (−0.183)	−0.216 (−0.182)	−0.264 (−0.18)	−0.243 (−0.181)	−0.231 (−0.181)
tech_reg	−0.120 *** (−0.041)	−0.087 ** (−0.041)	−0.118 *** (−0.04)	−0.127 *** (−0.039)	−0.125 *** (−0.039)	−0.120 *** (−0.039)	−0.116 *** (−0.04)	−0.119 *** (−0.039)	−0.118 *** (−0.039)	−0.118 *** (−0.039)
age	0.032 *** (−0.003)	0.032 *** (−0.003)	0.031 *** (−0.003)	0.030 *** (−0.003)	0.030 *** (−0.003)	0.031 *** (−0.003)	0.031 *** (−0.003)	0.030 *** (−0.003)	0.030 *** (−0.003)	0.030 *** (−0.003)
size	0.002 *** (0.000)	0.002 *** (0.000)	0.002 *** (0.000)	0.002 *** (0.000)	0.002 *** (0.000)	0.002 *** (0.000)	0.002 *** (0.000)	0.002 *** (0.000)	0.002 *** (0.000)	0.002 *** (0.000)
Constant	13.550 *** (−0.116)	13.395 *** (−0.119)	13.434 *** (−0.115)	13.490 *** (−0.112)	13.496 *** (−0.113)	13.441 *** (−0.113)	13.421 *** (−0.117)	13.466 *** (−0.116)	13.454 *** (−0.117)	13.439 *** (−0.116)
Observations	866	834	866	866	866	866	866	866	866	866
R-squared	0.358	0.393	0.387	0.406	0.402	0.4	0.395	0.406	0.402	0.401

Standard errors in parentheses. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

4.2. Econometric Results

Results in Model 1 quantify the role of control variables in performance growth. Raising the availability of skilled workers, such as engineers, will positively affect financial performance. Larger and older firms will also score higher performance growth. The effect of the control variables is very similar across all models.

Then, Model 2 proves the importance of inbound open innovation strategies in the promotion of performance growth, conversely, outbound knowledge flows fail to be statistically significant.

The connection to the academy enhances performance growth. Connecting to the university, regardless of diversity or intensity, raises the financial performance by 57.7%. Besides, each additional university contacted, raises performance by 36.2%. Additionally, deepening the type of contact established increases performance by 20.6%. Further, financial performance raises by 15.8% per additional contact established.

Lastly, OI and UIC are proved to leverage turnover growth. Model 7 evidences that among firms that collaorate with the academia, open innovation has a direct effect of 27.3% on performance added to a combined effect of 44.4%. Similar results are found concerning the other proxies in use for UIC. In terms of the specific proxies, the combined effect of OI with diversity is the one who leverages the most turnover growth.

4.3. Discussion

OI studies focus on inbound and outbound strategies and these knowledge flows are expected to increase firm performance. Market dominating firms are often innovation leaders compared to their smaller counterparts [56], it is therefore important to incorporate innovations generated by external agents in the internal innovative capacity. Mazzola et al. [6] reinforced that companies using inbound OI strategies leverage innovation and R&D processes. As a consequence, incentives that promote the firm access to external knowledge will reinforce innovative behaviors. Likewise, in the literature, outbound practices also have a positive effect on the firm likelihood to innovate. More collaborative models abandon exclusivity of R&D activities as a principle of the innovation process [18,57]. In model 2, inbound strategies have a positive impact in the firm performance which is in line with the theory of Bigliardi et al. [4], in what concerns the outbound practices, the results are statistically insignificant. In line with Chesbrough, [18,39], organizations present in the respondent sample mainly rely on the external knowledge flows combined with internal resources in their innovation processes, thus improving their innovative capacity, therefore the performance. This result is perhaps justified by the fact that the acquisition of technologies and patents, human resources, contracts and partnerships, reduce innovation cycles while minimizing the diffusion of knowledge to competitors [10]. The role of excendentary technologies needs further reinforcement in the future and perhaps a special support from policy makers.

Inbound OI strategies will permit lowering production costs, higher sales, more new products and less time to market [58], it is used primarily for tangible short-term benefits, and short-term R&D and marketing. In line with Lee et. [10], OI will raise per se firm performance, as presented by the OI coefficients in models 7, 8, 9, 10 (0.273; 0.204; 0.254; 0.214, respectively).

To Bianchi et al. [59], inbound OI activities include internal licensing, acquisitions, joint ventures, R&D contracts, research financing, and purchase of scientific and technical services, non-equity bonds and minority equity investments. Considering this argument, Models 7, 8, 9 and 10 demonstrate the existence of a combined effect of OI strategies with UIC regardless the perspective of the contact, the existence of OI strategies within firms connected to the university raises the performance growth. The effect is larger for when combined with contact diversity, meaning that connecting with different universities is favorable to financial performance.

According to the literature, knowledge emerging from the university enhances innovative performance. The academia provides plethora of resources for firm development, such as the availability of human resources [54], the developed research [16] and consequent construction of innovation networks [3,17], contributing with new technologies, enabling knowledge transfer to the industry [14], leveraging innovative processes and value added [5,6]. The connection with the academia is addressed in different perspectives; all in all, there is a positive effect over firm performance regardless of the proxy chosen. Diversity evidences the prominence of the connection with different institutions at a time, illustrating the potential heterogeneity and complementarity among them; in a nutshell, firms that benefit is related to multiple universities rather than concentrating on a single partner. Establishing more solid ties, based on more complex relations also raises performance; moving from frugal to deep contacts positively influences the evolution of the total turnover. The number of contacts established still has a positive effect; however, the magnitude of the effect is smaller than what is found for the other proxies. This result further reinforces the awareness of firms about outlines of their connection to the academia.

The control variables also provide interesting insights in terms of the drivers of financial performance. Along with the literature, raising dimension improves performance, which is perhaps justified by the existence of internal R&D departments leveraging innovative processes [60]. Years in operation also have a positive effect on performance, maybe due to the experience associated with firms' former investments. Another aspect indirectly related to UIC is the availability of human capital. According to the literature, availability of

qualified human resources enables the companies' innovative activity [54]. Here, engineers (skill intensity) do influence performance; hence, undergraduates (education intensity) fail to be statistically significant as performance drivers.

In sum, UIC improves performance; however the connection requires heterogeneity and deepness, it seems that knowledge becomes more useful when collaborations are multidisciplinary. Combining the use of this knowledge source with the adoption of OI strategies will allow the exponentiation the positive results over performance. Alongside this impact, OI stands out as the development of companies' innovative capacity and specifically the inbound strategy as a positive impact on performance. There is a complementarity of these activities as results evidence a mutual reinforcement of these activities. These results evidence that H1 is partially supported given the insignificance of the outbound knowledge flows, and H2 and H3 being supported, notwithstanding the differentiated importance of the different proxies in use to address UIC.

5. Concluding Remarks

Innovation is determinant as an enhancer of firm resilience raising efficient and sustainable practices, promoting an increasingly dynamic and competitive market. Firms must combine both internal and external resources in innovation processes, as a possibility to improve their innovative capacity [18,39]. At present, firms need to develop the ability to acquire and absorb knowledge generated from external sources [3]. This mind-set influences university dynamics, such that the theory and practice of OI led universities to rethink their models of connection with industry and society [34].

Recently, UIC collected enormous interest from academics and practitioners becoming increasingly evident in collaborative activities to obtain cutting-edge information on R&D processes [23] becoming central to face economic and societal challenges [24]. Entrepreneurial universities highly focused on UIC may be relatively limited to the type of research carried out at the institution. This situation may convince innovative firms on the uselessness of contacting this source of knowledge [61], demanding for diversification of contacts to obtain more accurate knowledge applications. However, university research may also depend on the requests of the private sector, with a solution-oriented logic in the short term. In this perspective, exploratory research may not be at risk, but long-term research requires large investments in R&D and, therefore, long-term relationships must be rethought, as they may not meet immediate industrial needs. As universities become less dependent on public funds, mostly due to research orientated funding, such as patents or international research projects, connecting to the private sector becomes even more relevant. Researchers are increasingly involved with OI, trying to get involved with industry and explore it in various ways.

Despite the centrality of the role of universities in national and regional innovation systems, considerations about its support is still debatable. On the government side, policymakers need to rethink the social role of public universities and its optimal organization among stakeholders at national and regional levels. In addition to the preliminary teaching and research functions, the focus of policy makers has shifted to the third mission, in which universities must contribute to society through the creation, transfer of knowledge and technologies [62].

Governments should therefore encourage academic innovation as a foundation of economic development, which reflects changes in the relationship with their stakeholders [29]. According to quintuple helix framework [63], co-creating an innovation ecosystem requires an exchange of knowledge and the ability to intertwine all the actors involved. The change from a traditional structure to a corporate structure has been set as a priority.

The present work aimed at investigating the role of OI along with UIC in firm performance and further addressing if they behave as complements or substitutes. Empirical evidence proves that OI and UIC are mutually reinforcing. There is an effective gain in promoting UIC, however, the link must be developed considering a multi-institutional network, enhancing formal contacts rather than informal channels. Companies are profit-

targeted towards their sources of knowledge and information; as a consequence, their connection to the academia must generate value. In what concerns OI strategies, little effort was previously made to address their impact on economic performance [10]. These strategies have often been developed by the companies; in this vein, the effect of inbound and outbound OI strategies fulfill a research gap as well as the analysis of their complementarity; the empirical results reinforce the importance of external flows of knowledge and shed light on the importance of further addressing the mechanisms to promote the commercialization of surplus technology.

In a nutshell, the empirical results have shown that the efficacy of the public policy actions in these vectors will depend on smart and specific incentives as broad recommendations will fail producing the expected outcomes. At first, policy makers need to bear in mind that the promotion of open innovation strategies needs to be complemented with an approach to the universities.

It seems more effective to promote a multichannel ecosystem of collaborations rather than a single connection; this result is very important as it sheds light on the richness of the institutional diversity and opens new avenues to multi-university collaborations. Besides, establishing more persistent contacts with the academia is more fruitful than sporadic connections.

Finally, given the insignificance of the outbound knowledge flows, more work needs to be done both in the field of policy instruments and in future research. This dimension of open innovation is too important to be neglected, and, perhaps firms are unaware of the value of the outward transfer of technology, or effective regulation is missing. Future research should consider this gap and further explore the problem and identify the tools to promote the full use of open innovation potential.

6. Implications and Policy Recommendations

6.1. Theoretical Implications

The evidence reinforces the importance of absorbing knowledge emerging from the ecosystem. Notwithstanding, the results only partially validate the connection between OI and financial performance, as outbound flows of knowledge appear as irrelevant. However, UIC does matter in raising firm performance. Additionally, these two strategies present some complementarities and leveraging financial performance. These results reinforce the importance of a combined adoption of OI and UIC, as their combined effect is larger than the single effect.

Another important contribution to extant theory relies on the fact that depending on the proxy used to address UIC, the results do vary. Most of the previous works underline the importance of establishing ties to the academia, lacking the detail about the accurate measures to appraise the relevance of the connection. Here, four alternative proxies were used, one generalist and three specific, to capture if the connection to the academia, per se affects firm performance, or, in alternative, if precise protocols of collaboration are required. Despite all proxies appearing as significant, reinforcing the importance of the collaboration, eclectic collaborations with different institutions are more effective than abundant connections with a single one. As a consequence, it is fundamental that the companies improve their ability to manage relationships with external agents from whom technology emerges and to combine them with internal knowledge, avoiding inefficiencies and accelerating innovation processes consequently increasing performance. The exploitation of surplus technology needs to be redesigned to be fully exploited by firms; following the recommendation of Bigliardi et al. [4], this process requires a new approach to be appropriability along with an ascertain appreciation of the risks involved in knowledge sharing. The maintenance of various channels of collaboration involves additional costs and extensive investments in their coordination, jeopardizing firm profitability [4], and firms' connections should follow strict criteria to maximize their return.

Connections to the academia leverage firm performance; nevertheless weaving the links needs a multi-layer strategy exploiting diversity and intensity. These returns will

be increased when combined with open innovation strategies. The combination of collaborative strategies with the inclusion of a scientific partner in innovation processes will leverage entrepreneurial performance. Present results contribute to the theory placing OI and UIC as central drivers of increased performance, moreover, their effect should be combined as they act as complements, evidencing two sides of the same coin. This fact should be considered by managers, practitioners and policy makers seeking improving firm performance.

6.2. Practical Implications

The present work focused on quantifying the impact of OI and UIC on business performance. Econometric results quantify the positive effect on performance of exploring external knowledge emerging from the ecosystem. The use of OI is, according to the literature, an enhancer of the company's performance; however, the outbound variable presents an unexpected insignificance, requiring further attention. Long-term strategic and intangible benefits must be considered when appreciating outbound OI [10], given that, in the short term, this type of strategy exploits internal knowledge externally, which may explain the lack of impact in the internal performance. Several empirical studies have found that companies focus more on incoming than outgoing knowledge flows for developing their innovation processes [59]. Present results can justify, once more, such an argument.

Collaboration with the university allows companies to acquire external knowledge and apply it to their existing market requests, managing to get closer to practical applications of the innovations and investigations developed inside the universities, contributing to the reduction of associated costs [33], and making it possible to obtain financial profits [29]. Currently, collaboration with the university is seen as a way to reduce internal costs, since the internal R&D costs can be minimized and firms will now rely upon the transfer of knowledge from academic research.

Networking with multiple organizations is an enhancer of performance, promoting the access to a wider range of knowledge, which increases the likelihood of finding specific resources capable of responding to their internal needs. The intensity of collaboration also plays an important role, notwithstanding the type of contact established seems to have a stronger influence in the promotion of performance. Restricting informal contacts as a way to redirect towards more formal mechanisms was previously proposed by Link et al. [64] being also reinforced here. The promotion of multi-institutional formal interactions seems to be the most effective strategy to profitably approach universities and firms.

The evidence aims at casting light on the accurate combinations of instruments that will develop innovation ecosystems; it also enlightens managers and practitioners about the innovative strategies that should be pursued to promote performance improvements, therefore competitiveness.

6.3. Limitations and Future Research

The question that remains unanswered is: what is the optimum model of collaboration between universities and firms to increase firm performance? This problem deserves further analysis to shed some light on what is hampering the establishment of solid and profitable collaborations between academia and industry. OI is harmed if that pillar is missing. In short, professionals and managers must be aware of the importance of this source of knowledge for their innovation processes to succeed.

However, the present work also has some limitations. The database is not representative of the country entrepreneurial fabric. It is uncertain that collaborations made by each university are fully represented in the database, given that it only has several types of contacts present in the survey. Sectoral generalization was an option, as a consequence, the impact of OI on the performance of companies in specific sectors, cannot be discussed. Additionally, this investigation relates to Portugal and may differ in other locations. Thus, it would be important to analyze these hypotheses in different geographies; with different

technological capabilities. Future studies should also try to use different methodological approaches and different tools to measure the impact of different OI activities as well as collaboration frameworks.

6.4. Policy Recommendations

In terms of policy recommendations, the focus should remain on the university's third mission [62], highlighting the boundaries of the entrepreneurial university. Government must encourage the exchange of knowledge between the university and industry, promoting innovation as the natural path to a sustainable future. OI is the key to supporting networks rather than individual companies in promoting market competition. A more detailed analysis is necessary to understand the lack of significance of the outbound OI strategy in the companies' performance. Perhaps the problem relies in the fact that, to sell surplus knowledge, organizations need to reveal some parts of in-use knowledge to external agents, which needs to be protected, from being copied by competitors. More solid regulations are required in this field [65]. Public policy must ensure credibility, for companies to remain open to information sharing; additionally, appropriability needs to be guaranteed such that companies can mutually benefit from this process. Support programs that stimulate innovation must generate more profound effects [66,67], promoting the accumulation of technological knowledge, development of internal learning processes in innovative firms, widening the scientific and technological base, essential to sustainable growth [68]. Policy intervention must go beyond investment in infrastructure or guarantee the smooth functioning of markets. The state must have an "entrepreneurial" role, acting on the allocation of public resources to strategic areas, where private initiative has not yet invested; fulfilling markets in which there is too much uncertainty [69].

Policymakers should reinforce innovative practices, entrepreneurship and the presence in new markets, becoming more active rather than a simple regulator. Adequate environments must be provided to firms so they can establish relationships of trust with communities, networks and actors [70].

Firms can no longer remain closed; as a consequence, the government must guarantee democratic access to knowledge and technology; promoting innovation and competitiveness a pillar of growth. In this vein, university has a fundamental role, contributing to a diversified offer of resources, possible for the training of the industry. These practices require new funding structures that combine the strengths and weaknesses of the ecosystem through smarter policy packages, such as mandatory consortia to obtain public subsidies [3].

Managers certainly understand the importance of public support to approach universities and firms. Governments must promote innovative strategies based on latent capacities and focusing on relevant problems, universities will further reinforce this ability. The innovation ecosystem will allow firms to overcome their weaknesses and the innovation requirements will be addressed with smart and individual knowledge supply, reinforcing the need for public action towards a sustainable development model; and, industrial potential will be supported by a multi-contact channel that enhances key knowledge.

In short, there seems to be insufficient maturity in the university's entrepreneurial mission, despite the valuable efforts done so far. Albeit, the positive path already developed and the optimistic expectations posited in the long run, the immediate development of smart and sustainable policies promoting the intertwining of firms and academic institutions under an open innovation paradigm should be in the agenda of policy makers as a pillar of firm performance.

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