



Article

Public Policies, Open Innovation Ecosystems and Innovation Performance. Analysis of the Impact of Funding and Regulations

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Abstract: Open innovation (OI) has been implemented to develop competitive advantages based on the management of innovation with external players. As such, it is expected that the generalized adoption of OI practices needs to be nurtured by governmental public policies in order to enhance OI-based ecosystems. The role of open innovation ecosystems is known by the importance of multiple synergies among players/stakeholders, which are expected to be supported by regulations and funding to consolidate firms' innovation results. This paper analyzes the role of regulations and funding on firms' innovation performance using the double-hurdle estimation procedure. The results show that, in the first tier, inbound knowledge flows positively affect performance, and, in the second tier, public funds further reinforce innovation performance and fiscal and security regulations. In contrast, as regulations are perceived as barriers, they fail to impact innovation performance. With this paper, we manage to shed light on the importance of public policy funds in the support of thriving OI-based ecosystems as enhancers of firms' innovation performance.

Keywords: open innovation; regulations; funds; innovation performance; CIS; double-hurdle model; Cragg's Tobit



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1. Introduction

Open innovation (OI) emerged as a smart business strategy to enhance firms' competitiveness derived from external knowledge acquired to foster innovative strategies for improving performance [1,2]. Following recent developments, this OI framework was defined as the use of knowledge flows to accelerate the internal innovation process, so that firms are able to expand to new markets based on the use of external innovation and knowledge [1,3]. This OI framework has received considerable attention since its introduction because it shifted away from the previously closed paradigm [4–6], enabling firms to combine both external and internal knowledge, in addition to ideas, as alternatives for improving their innovation performance through an enlarged and distributed innovation process that relies on purposively managed, inter-organizational knowledge flows [7].

OI involves a multidimensional perspective, operating with long-run outcomes demanding complementary resources from the entire value chain [8]. Innovative ecosystems emerge with enterprises interacting with agents—i.e., other enterprises, organizations, and individuals—classified into three categories: internal innovators, primary stakeholders, and external participants. They are the basic elements and processes that support the implementation of OI practices and enhance firms' competitive advantages and sustainability [9,10].

Organizations have increasingly embraced the ability of OI strategies to leverage the centrality of external stakeholders—such as the user community [11–13], value chain (competitors and suppliers), universities and academics [5,14,15], and other external organizations—in order to open up their boundaries and raise performance [10,16–18]. This OI strategy enhances the knowledge base of the firm by combining knowledge from close stakeholders (such as suppliers, customers, and competitors) and external sources (such as universities and research institutes, consultants, investors, and the government) [6,19]. Notwithstanding, firms differ regarding the extent to which they implement these collaborations. The externalization of R&D activities may act as an efficient option due to the lack of internal abilities for these actions. Conversely, the exploitation of spare technology is far less used by firms due to the complexity of putting these assets on the market. The extent to which firms use OI varies; thus, deep integration may not be achievable by all types of firms [20,21].

Considering inter-organizational knowledge flows, inbound OI processes still dominate *vis-à-vis* outbound OI processes, as it is easier for most firms to absorb external information arising from the ecosystem. Hence, outbound OI literature focusing on the exploitation of internal knowledge has become more sought after; moreover, inbound and outbound coupled strategies are also presented more often [21–23]. Still, OI outside-in and inside-out processes are always present as dimensions of knowledge flows [1,24]. Therefore, research on knowledge management among firms and other players located in innovation ecosystems still plays a major role in the operationalization of the processes, as well as in firms' success [22,25,26]. As such, despite knowledge regarding the importance of OI strategies for firms, this paper seeks to address a gap in previous studies by considering not only inbound and outbound knowledge flows arising from OI strategies among firms, but also the complementary role of the innovation ecosystem. Moreover, another gap addressed is the importance of policy measures as enhancers or barriers to innovation performance within the ecosystem.

Based on the importance of inbound and outbound OI flows, this paper has two main purposes in shedding new light on OI and Innovation ecosystems literature. First, it seeks to explore and confirm if inbound OI is more important than outbound OI processes when explaining innovation performance. For that, inbound and outbound OI strategies will be used as predictors of innovation performance, although it is expected that inbound OI strategies are more important than outbound OI strategies, as referred above [21–23]. Second, another purpose of this paper is to address how public funds and regulation influence firms' innovation performance, i.e., we seek to shed new light on how public funding instruments and regulations influence (reinforce or deter) innovation performance within the innovation ecosystem. In order to address those two important aspects, this research uses the double-hurdle method, which is a two-stage appraisal procedure assessing innovative performance, combining firms with null impact of innovative activities along with those with positive impacts. The adoption of OI strategies is expected to be the pillar of dynamic innovation ecosystems. This topic is central in the international policy agenda as sustainable communities will better accommodate the challenges demanded by the present economic context, and multilayer policy actions will enhance policy efficacy.

The structure of the article is as follows. After this introduction, Section 2 covers the literature review. Section 3 presents how data were obtained and what methods were used. Section 4 presents the results. Section 5 discusses the results. Finally, Section 6 presents the conclusions and recommendations.

2. Literature Review

The fast-changing and unpredictable environment in which firms are embedded makes innovation an imperative key factor for organizations to promote competitiveness and overcome market challenges [22,27]. The development of new products, technologies, and services has exponentially grown in recent decades due to globalization, connectivity, and

technological development. Moreover, fast-paced product obsolescence and globalized competition have compelled firms to develop smart, environmental-led innovations [1,8].

The concept of innovation is broad. It relates to scientific inventions, patents, technological breakthroughs, new production processes, and organizational methods. It relates to alternative frameworks that aim to generate value for the organization and other efficiency gains for the ecosystem [28]. Innovation is directly tied to value creation, as well as increased efficiency in the use of resources [28,29], as they are key strategies for organizations to survive and scale up in the highly competitive and dynamic global market [29].

Over the last decade, there has been a growing concern with the ethics and legitimacy of the full internalization and exploitation of innovation outcomes by private organizations [2,24]. This stream of research gained momentum with the seminal article of Kramer and Porter [30] advocating the “shared value” that should be the target of any innovation, which should generate prosperity in the entire ecosystem [31].

2.1. Open Innovation—A Comprehensive Perspective

OI is a multi-agent innovation process based upon shared knowledge flows extended outside of organizational boundaries, using pecuniary and nonpecuniary schemes to promote knowledge sharing [4,8,9]. Under this framework, firms can combine internal and external information to move forward and improve innovation performance. As a result, external stakeholders need to be involved in the innovation process that rests upon purposively managed, multi-agent knowledge flows [9,32,33].

OI covers three main strategies: outside-in (inbound), inside-out (outbound), and coupled. The first encompasses input knowledge flows associated with mechanisms such as (in)licensing, acquisitions, short-term fellowships, (in)spinning, venturing and incubation, user-driven innovations, and supplier/competitor-driven innovation. Outbound strategies involve mechanisms such as (out)licensing, patent selling, divestments, R&D selling, and spinning out. Alliances, cooperation agreements, joint ventures, joint R&D, and co-creation are the mechanisms associated with the coupled strategy [2,29]. Despite the vastness of theoretical and empirical literature on the topic, outbound strategies are still overlooked; thus, they need further efforts to be fully understood [2,34]. In general, the focus is put on external search and collaboration activities, as they are the most commonly mentioned inbound strategies [10,31,35].

The shift to this long-run business strategy is a complex phenomenon, which also demands resource investment for both the firm and its partners. The main participants that move from firms to individuals are classified into three categories: internal innovators, primary stakeholders, and external participants [2,10,31].

Inbound OI still plays a vital role in what concerns the direction of the information flows to establish connections to the environment. Despite the advances in the other directions and the recent emergence of several studies on both outbound and coupled OI, these dimensions are still unexplored [22], perhaps due to the previous acknowledgment of the importance of absorptive capacity as an innovation enhancer. At the same time, there must be awareness that durable knowledge-sharing networks need to develop bi-directional flows of information with gains for all agents involved, as the maintenance of the agents inside the network depends on the perceived interest in community membership [18,26,31,33,36]. Addressing the multiple dimensions and facilitators of knowledge management between firms and other participants located in innovation networks is of major importance. The knowledge-based view and the absorptive capacity theory are the dominant theoretical frameworks used to test different hypotheses regarding OI flows [2,37,38]; moreover, the establishment of solid roots among players will allow these knowledge flows to exist and generate positive synergies in the long run [7,39].

In its recent developments, the concept of OI has become more complex by orchestrating large numbers of participants [2,40] with heterogeneous identities, with participation across multiple phases of innovation processes, such as acquisition, integration, and commercialization, creating a complete innovation ecosystem [21,41]. These efforts will

positively affect the firm performance due to the effective gains in terms of the cost of the innovative activities, as well as the exploitation of profitable ideas not invented within the firms' borders [31,42].

The internal mechanisms of knowledge creation and diffusion are mostly exploited in what concerns their acquisition and integration. In what relates the knowledge transfer, much more has to be done, which is one of the present challenges in the field of research. The importance of collaborative networks, their composition, and the roles being played by each agent needs to be detailed to understand the joint value created for them and for the community [41,42].

The creation and development of new products, technologies, or services are now faster than in the last decades due to globalization, connectivity, and technological advances [7]. From the resource-based view perspective, all innovative activities demand the optimal combination of four ingredients: human capital, financial resources, technologies, and ecosystem [7,11,13]. In recent years, online communities have become a vibrant channel of information for professionals to expand their networks and initiate new strategic collaborations [13,43,44]. Notwithstanding, OI focuses on the search—mainly done by R&D departments—for knowledge and information obtained through external channels and the sharing of resources such as skills, knowledge, and technology [7,40].

This OI strategy has developed new methods for individual firms, along with their partners, to expand and distribute innovative activities in order to generate smarter and efficiently managed inter-organizational knowledge flows [8,45,46]. The knowledge flows have two major pillars—globalization and digitalization [47]—which allow free movement of resources and assets, as well as the acceleration of the technological pace and complexity [7,39] demanding for cost reduction in the R&D. These vectors reinforced the importance of the OI as a vehicle to improve competitiveness [8,27,32].

Over the last fifty years, in order to outperform their rivals, companies only focused on their internal innovation capabilities and on hiring the most talented human capital. The pace of innovation was set by the ability to invest highly and become sectoral leaders [48]. This enabled achieving monopoly profits and setting additional barriers for competitors [49].

The implementation of this framework has been presented as the erosion of the boundaries between companies, which become increasingly more open and interested in sharing or commercializing ideas, as well as opening themselves to absorbing external knowledge that comes from outside-in strategies, and profiting from internal knowledge that is commercialized from inside-out strategies or both. This process demonstrates that innovative activities and the organization can benefit from the combination of internal and external knowledge such that the innovation process can be faster, more efficient, and less costly to the agents involved [34]. In the case of outside-in flows, firms use external knowledge to obtain new advantages that will be embedded in the internal processes; these flows arise from competitors, the value chain, user communities, universities, and others. The inside-out knowledge flows build new pathways to the market, commercialization of ideas, selling “false positives” already used inside the firm, and other companies in order to exploit the “false negatives” and, thereby, unlock knowledge [50].

In this vein, external R&D can now add new value to companies and move in to deploy new business models [8,51]. In addition, some of the mechanisms that promote these actions include start-ups and licensing agreements where all the agents involved can benefit from knowledge sharing and the creation of networks and partnerships [52].

The literature vastly refers that the human dimension is the first to take into consideration when implementing OI [3,34,53]. Several authors [34,54–56] investigated how employee diversity affects openness to external knowledge sources underlying their conceptual lens to human capital and absorptive capacity theory.

The literature has evidenced several external participants leveraging the sharing of knowledge flows, which are heterogeneous agents such as [10]: consultants [57], universities and research institutes [15,18,58], suppliers [59], consumers [34,60], competitors [61],

networks [62], user communities [11,13], and governments [63,64]. They can be grouped into two categories: stakeholders, with direct and indirect interests in the supply chain, and external participants, who can bring disruptive knowledge.

More recently, given the urgency for better solutions in global domains, more than focused on commercialization and the unleashing of innovative ecosystems, the framework was restyled with the proposed version 2.0 [65]. It promotes integrated collaboration and co-shared value through an ecosystem-centric view of innovation, which is driven by teams of boundary spanners endowed with multidisciplinary skills, where the *milieu* is the core of success [66]. This framework strongly ties OI with the Quadruple Helix, adding civil society to the previous version (Industry, Government, and Academia) [49,66,67].

Another improvement of the framework from its original version concerning products and processes is the connection to a sustainable and ecological perspective. Innovation 3.0, also called ‘embedded innovation’, forges new mindsets and promotes consumer enrolment, creating a long-term value-added strategy in a self-sustained process, and proposing innovation from the inside out and placed at the core of the ecosystem [68].

Impoverished and frail environmental conditions that were allowed to happen in the last decades required the quintuple helix OI approach, proposing a natural environment-centered innovation paradigm promoting sustainability practices [69]. This collaborative network is expected to promote the efficient use of natural resources [1,11]. The third generation of OI proposes a model that can restore balance with nature, maintaining the focus on quality management and prosperity [69].

Even more recently, the transition to a digital society has demanded that OI and innovation ecosystems adapt and evolve. OI 4.0 is the future of open innovation, requiring an ecosystem that is more extensive, more collaborative, and more engaged with the community. It will extend beyond technology and business models, embracing all kinds of innovations, and promoting and ensuring a human-centered future for the next generations [26].

2.2. Conventional Policy Instruments

At present, public and private monies are combined to consistently develop innovation. Public funds are used to subsidize industrial projects and industrial funds are used to help subsidize government-funded research projects and vice versa [70]. More than ever, OI is the determinant for the reformulation of new business models, the redesign of network relationships, and the preservation of resource endowments [1,8].

As research networks, partnerships or joint alliances enhance knowledge exchange as well as relevant information flows [41]. Knowledge and information flows need to be bi-directional in order for both partners to benefit [44,62,71], which means that these structures will naturally benefit from coupled OI strategies [48,49]. Research partnerships not only improve absorptive capacity, but also increase innovation spillovers, leveraging performance [17,55]. This is of particular importance in the case of SMEs as innovation ecosystems are natural environments to enlarge and consolidate networking and cooperation, thus increasing firms’ technical competencies [72,73]. Belonging to these active networks, along with knowledge acquisition, allows all agents to increase the effectiveness and competitiveness of the innovation processes [17,55,73]. As the promotion of these activities is consequently vital for the generation of shared value and knowledge spillovers, which will lead to societal gains, the existence of a public policy to support these R&D activities is a critical factor of success [74,75].

Innovation is a complex, finance-consuming, and risky activity, despite its central role in firms’ growth and survival [74]. The development of innovative efforts is core to the promotion of the ecosystem and magnifies its initial effects due to the spread of knowledge [75]. The existence of public support in these sectors will further reinforce the results of OI strategies, and private and public investments need to coexist [75,76], as these efforts will promote firm performance [77].

In a digital world, technological advances cannot be stopped, and innovation needs to be considered as a persistent activity rather than a sporadic problem-solving aid [78]; OI plays a crucial role in the ability to create an ecosystem where people, companies, and sectors can foster co-creation [4]. Therefore, public support for R&D activities through subsidization is vital for the generalized adoption of these practices and the active membership of firms in these ecosystems [79]. Given the double gain generated by innovation, both private and public firms are also involved with their own financial support in the promotion of innovative efforts [80]. Moreover, on one hand, subsidies are proven to enhance innovative performance and, on the other hand, the existence of regulations also plays an important role as disciplining factors in agent behavior. Policy mixes are proven to be more effective encompassing both [81].

2.3. Innovation Ecosystems

Innovation ecosystems gained momentum over the last decade, as they represent the foundation of OI. In these *milieux*, the different stakeholders actively get involved in the development of mutually beneficial solutions, creating an inclusive ecosystem that allows a wider approach to problem-solving. Innovation ecosystems encompass a broader group of stakeholders, building collaborative community engagement around specific challenges and issues. As the innovation process is inclusive and responsible, it is sustainable [40,41,45].

It is the combination of the different actors and objects that establish connections capable of complementing each position that reinforces the ecosystem, involving and shaping the institutions and the environment, while co-creating value and enhancing sustainability [27,33,40].

Sustainable innovation encourages sustainable development, respecting ethical, social, economic, and environmental norms [36,45,67]. Free exchange of knowledge and best practices supports the optimization of resource allocation, the respect for the environment, and the shift towards the sustainability of ecosystems [10,27,34].

The creation of these frameworks demands knowledge exchange, as well as absorptive capacity, from all actors involved [73]. During this process, each player benefits from other players' competencies and gives back their support to create a symbiosis of entities in which innovation is supposed to thrive [31,51,70]. Purposeful knowledge infrastructures—such as clusters, science parks, knowledge transfer offices, and incubators—are concentrated on consolidating the university's third mission retro-feeding the ecosystem and supporting each other's capabilities [37,48,82]. In this case, public policy needs to identify and cultivate common ground, building common objectives [58,70].

The removal of firm borders through OI enables multilateral knowledge flows hovering over the ecosystem, which supports the globalization of innovations that underpins private and external benefits emerging from this knowledge-sharing process. Solid connections with external sources of knowledge, such as other firms, community users, and the *milieu*, are desirable to all organizations that intertwine internal and external knowledge and persist in their connections within the ecosystem, enabling the speeding up of the innovative process [4,8,26].

3. Materials and Methods

The Portuguese Community Innovation Survey (CIS) 2018, the most recent wave of the survey, is the empirical foundation of the present analysis. It is undertaken by Statistics Portugal following the recommendations of the European Commission. This wave of the CIS is the biennial endeavor of the European Union statistical agency to address innovation practices in several European countries; it covers the 2016–2018 period. The sample encompasses firms operating in all economic sectors with 10 or more employees. Additionally, firms are asked about several aspects of their innovative strategies, as well as their structural characteristics concerning activity, firm size, and human capital. The Portuguese CIS18 includes information on 13,701 firms operating in Portugal.

Firms provide information about their R&D expenditures, their connections to external institutions to enhance knowledge, the innovation types performed, and the importance of their new products in total turnover among others. Similar procedures were adopted in the empirical parts of previous studies, e.g., [83–85]. As such, the CIS database provides information related to all the variables in use, covering the period between 2016 and 2018, in which Portugal was considered a moderate innovator (EIS 2018) [86]; the country became a strong innovator in 2020.

The double-hurdle estimation is applied to address the goals set out in the introduction section. This parametric double-hurdle model encompasses an implicit double equation, setting lower or upper bounds simultaneously. It considers the prevalence of open innovation strategies, i.e., when the hurdle is clear, and the extent to which the innovation performance is conditional on having cleared the hurdle. As such, it tests policy impact given the existence of OI practices [87].

To the best of our knowledge, the double-hurdle model has not yet been applied in this field; thus, this study also constitutes an empirical contribution, given the possibility of the model addressing a sort of two-stage decision without removing heterogeneity in the dependent variable.

Innovation performance is used as a dependent, exogenous variable. In the first hurdle, inbound and outbound flows of knowledge, R&D internal and external to the firms, and human capital are used as exogenous, explanatory variables and, in the second hurdle, public policy instruments, security, environmental and taxes regulations as enhancers, or security, environmental and taxes regulations as barriers are used as explanatory variables. The exogenous and endogenous variables are addressed in the following subsections, and more details are provided regarding the estimated model.

3.1. Endogenous Variable

As this paper aims to explain what affects innovation performance, it uses a proxy relating the proportion of the firm turnover emerging from new or significantly modified products related to the year 2018. The survey breaks down two types of products: new to the market and new to the firm; however, for the sake of the present analysis, the focus is the overall share of turnover triggered by product innovation, regardless of its origin. As a consequence, this proportion is the dependent variable. The choice for this variable can be observed in previous studies, e.g., [88,89], with similar purposes evidencing the importance of new products in total turnover.

3.2. Exogenous Variables

The purpose of the empirical analysis is to address the importance of the innovative network, relying upon OI practices. In this vein, two independent predictors are included in the first equation: inbound and outbound flows of knowledge. Then, the second tier includes conventional public policy instruments, which aim to operate as enhancers or barriers in innovation-related domains.

As it is commonly accepted that innovative activities need to be partially supported by public policies, the use of public funds is a natural predictor of the second tier, and it is believed to positively influence innovation performance.

Conversely, the use of regulations in the security and the environmental field will naturally affect firms' actions. In this vein, the inclusion of an accurate legal framework will force firms to shape their initiatives to fit within the boundaries of regulatory procedures. Moreover, the fiscal effect is implemented through a variable dealing with taxes, which is believed to be a vehicle for positive or negative discrimination. Fiscal policies, and the tax system in particular, have a key role in the promotion of innovation practices, as they can affect organizations and products available in the market. An accurate fiscal framework will generate incentives and disincentives, reshaping organizational conduct while generating public resources that can be reallocated for innovation purposes.

Additionally, these instruments are included in the estimations firstly as a policy mix of enhancers, and secondly as barriers. The purpose of this segmentation is to detail the specific effects of the negative and the positive discriminations caused by the innovative performance of public policy.

3.3. Control Variables

Firms' structural characteristics will undoubtedly affect their general performance, as well as their innovative performance. To control for these effects, four controls were included in the model: size [90–92], human capital intensity [54], and internal and external R&D expenditures [77,79,80]. This combination of characteristics and strategic options can be considered to some extent as a technological capability, as it is a key factor in the successful implementation of innovative practices.

Optimally combining productive scales, human capital skills, R&D management, funding, policy, and governance is required to fully explain firms' innovative performance. The entire set of variables in use is better depicted in Table 1.

Table 1. Variable Description and Measurement.

Variable	Description	Measurement
(1) Innov_performance	Proportion of the sales turnover emerging from new or significantly improved products	Continuous
(2) Size	Firm size (1 = small; 2 = medium; 3 = large)	Scale
(3) Human_capital	Proportion of undergraduates among the labor force (1–7)	Scale
(4) RD_internal	Having performed R&D by employing internal resources	Binary
(5) RD_ext	Having performed R&D by employing external resources	Binary
(6) Inbound_know	Having received inflows of knowledge	Multinomial
(7) Outbound_know	Having sent outflows of knowledge	Multinomial
(8) Funds	Beneficiary of public funds (different sources)	Count
(9) Enhancers_security	Having perceived security regulations as enhancers	Binary
(10) Enhancers_environ	Having perceived environmental regulations as enhancers	Binary
(11) Enhancers_taxes	Having perceived tax regulations as enhancers	Binary
(12) Barriers_security	Having perceived security regulations as barriers	Binary
(13) Barriers_environ	Having perceived environmental regulations as barriers	Binary
(14) Barriers_taxes	Having perceived tax regulations as barriers	Binary

3.4. Estimated Model

In order to quantify the impact of the explanatory variables on innovation performance, the double-hurdle estimation was applied. This model encompasses an implicit double equation, setting lower or upper bounds simultaneously. In the first equation, it is possible to observe if the hurdle is clear, which in the present case relates to the prevalence of open innovation strategies. In the second equation, it determines the value of the outcome, conditional on having cleared the hurdle.

Although the estimation could instead use a Tobit model, which is far more popular among extant literature, the key limitation of this model is that the probability of a positive outcome and the actual outcome, given that it is positive, are determined by the same underlying process (the predictors in the equation must be the same). Additionally, when the dependent variable is constrained to be non-negative, taking the value of zero in a large portion of the sample, OLS estimates become biased; when that is the case, the usual estimation strategy is to implement a truncation, left-censoring the sample at 0 in the original Tobit model [93].

In the present estimation, we have a dependent variable that weights the proportion of the total turnover arising from new or significantly modified goods, which will often take the value 0 for non-innovative or innovation-unsuccessful firms. The first stage separates the 0 from all other outcomes, and the second moves to the analysis of the predictors of increased probability. The advantage is that the two stages of innovation performance are estimated jointly without the need to remove the firms that scored 0 in terms of the dependent variable. Despite not being used frequently, this formulation was originally proposed by Cragg [92] as a generalized form of the Tobit model.

In a parallel interpretation of the original model, firstly, we intend to have a positive amount of turnover explained by the new or significantly improved goods, proxying a positive result from innovation efforts. Secondly, favorable events must be fulfilled for this positive outcome to be allowed to happen [87].

Concerning the present estimation, in the first hurdle, innovation performance is a binary variable that takes the value 1 if the turnover proportion arising from new products is any non-null outcome, and the second tier encompasses any positive outcome in the dependent variable. The two equations, the first hurdle equation—which determines the probability of a non-zero outcome—and the second hurdle—which determines the intensity—are jointly estimated by means of the maximum likelihood method. In the second-hurdle equation, only the positive outcomes were included, or in other words, the observations that cleared the first.

This estimation will provide unbiased coefficients for the predictor of innovation performance, as the null impacts will not be removed from the model. Furthermore, the model permits the inclusion of different predictors in both equations. This enabled the possibility of implementing a multi-layer policy package, which in the first step focuses on the innovation network and in the second step on the effect of the different sets of instruments in the innovation performance for those clearing adoption open innovative practices.

4. Empirical Results

4.1. Descriptives and Correlations

Table 2 displays the descriptive statistics for the variables in use. In general, the correlations appear statistically significant, albeit with low levels, which reinforces independence and deters the presence of multicollinearity. Moreover, the moderate level of correlation among the policy instruments permits the simultaneous use of enhancers and barriers. Notwithstanding, variance inflation factor (VIF) tests were run and the values of the tests lie below the threshold

4.2. Econometric Estimations

Three alternative models were estimated to address the role of OI and policy action on firms' innovative performance. All models are double-hurdles, and the effect of open innovation is appraised in the first tier, immediately followed by conventional policy instruments in the second. Model 1 details the effect of funding on innovative performance for firms that have overcome the OI hurdle. The second model infers the impact of the performance of funds and regulatory enhancers upon firms performing OI strategies. Lastly, Model 3 quantifies the impact of regulations on the environment, health and security, and taxes, as well as funds among those who passed the open innovation hurdle. Firms' structural characteristics, such as size or human capital, were kept unchanged in all models to capture other determinants of firm performance rather than innovative strategies or policy actions. This procedure ensures that the impact of the explanatory variables is not overestimated due to the omission of relevant predictors. The estimation results are described in Table 3.

4.3. Econometric Results

In the first tier, firms' structural characteristics affecting innovative performance were included. Additionally, the first tier encompasses the OI strategies, and, following the previous belief that inbound and outbound strategies present different maturities, they were included separately, allowing for a finer understanding of their particular effect on innovative performance. Regardless of the model in use, increasing firm size positively influences the importance of innovative performance among total turnover; these results are in line with previous literature [90–92].

Table 2. Descriptive Statistics and Correlations.

	Min	Max	Mean	S.D.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
(1) Innov_performance	0	1	0.075	0.190	1													
(2) Size	1	3	1.36	0.583	0.071 **	1												
(3) Human_capital	1	7	3.39	1.859	0.150 **	0.156 **	1											
(4) RD_internal	0	1	0.11	n.s.	0.295 **	0.248 **	0.227 **	1										
(5) RD_ext	0	1	0.06	n.s.	0.205 **	0.196 **	0.154 **	0.487 **	1									
(6) Inbound_know	0	2	0.17	0.424	0.119 **	0.294 **	0.273 **	0.218 **	0.198 **	1								
(7) Outbound_know	0	2	0.16	0.416	0.114 **	0.297 **	0.274 **	0.250 **	0.218 **	0.811 **	1							
(8) Funds	0	4	0.23	0.571	0.187 **	0.133 **	0.145 **	0.295 **	0.234 **	0.066 **	0.090 **	1						
(9) Enhancers_security	0	1	0.09	n.s.	0.152 **	0.063 **	0.038 **	0.120 **	0.105 **	0.095 **	0.088 **	0.074 **	1					
(10) Enhancers_envIRON	0	1	0.09	n.s.	0.122 **	0.067 **	0.014	0.129 **	0.123 **	0.091 **	0.091 **	0.098 **	0.680 **	1				
(11) Enhancers_taxes	0	1	0.05	n.s.	0.111 **	0.038 **	0.027 **	0.070 **	0.086 **	0.060 **	0.064 **	0.049 **	0.491 **	0.473 **	1			
(12) Barriers_security	0	1	0.07	n.s.	0.079 **	0.029 **	0.051 **	0.095 **	0.085 **	0.062 **	0.050 **	0.048 **	−0.007	0.011	0.008	1		
(13) Barriers_envIRON	0	1	0.07	n.s.	0.052 **	0.014	−0.019 *	0.059 **	0.045 **	0.031 **	0.028 **	0.057 **	0.031 **	−0.020 *	0.014	0.589 **	1	
(14) Barriers_taxes	0	1	0.13	n.s.	0.076 **	−0.032 **	−0.016	0.023 **	0.013	0.006	0.009	0.025 **	0.050 **	0.050 **	−0.043 **	0.437 **	0.478 **	1

Notes: ** Significant correlation at 0.01 (2-tailed); * Significant correlation at 0.05 (2-tailed); n.s. not significant.

Table 3. Double-Hurdle Estimations.

Variables	Model 1			Model 2			Model 3		
	Tier1	Tier2	Sigma	Tier1	Tier2	Sigma	Tier1	Tier2	Sigma
Size	0.057 ** (0.022)			0.057 ** (0.022)			0.057 ** (0.022)		
Human_capital	0.075 *** (0.007)			0.075 *** (0.007)			0.075 *** (0.007)		
RD_internal	1.315 *** (0.043)			1.315 *** (0.043)			1.315 *** (0.043)		
RD_ext	0.573 *** (0.056)			0.573 *** (0.056)			0.573 *** (0.056)		
Inbound_know	0.268 *** (0.048)			0.268 *** (0.048)			0.268 *** (0.048)		
Outbound_know	−0.035 (0.049)			−0.035 (0.049)			−0.035 (0.049)		
Funds		0.260 *** (0.085)			0.237 *** (0.076)			0.258 *** (0.083)	
Enhancers_security		−			0.535 *** (0.207)			−	
Enhancers_environ		−			−0.405 ** (0.204)			−	
Enhancers_taxes		−			0.516 ** (0.207)			−	
Barriers_security		−			−			−0.122 (0.209)	
Barriers_environ		−			−			−0.149 (0.224)	
Barriers_taxes		−			−			0.397 ** (0.172)	
Constant	−1.277 *** (0.039)	−2.678 *** (0.769)	0.960 *** (0.115)	−1.277 *** (0.039)	−2.516 *** (0.677)	0.922*** (0.103)	−1.277 *** (0.039)	−2.650 *** (0.746)	0.948 *** (0.112)
Observations	13,701	13,701	13,701	13,701	13,701	13,701	13,701	13,701	13,701

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

In the same vein, raising human capital intensity also increases the role of innovation in explaining performance [3]. This result is in line with the idea that absorptive capacity, which depends on the availability of skilled personnel inside the firm, is vital to absorb the knowledge flows emerging from the ecosystem.

According to previous literature [77–79], R&D expenditures also have a positive impact on firm performance, with internal activities weighing more than external activities; albeit, both present positive results.

Regarding the OI strategy, two predictors were used, separating inbound and outbound strategies. Concerning inbound strategy, it is proven to be positive and statistically significant and tuned to previous research [1,4]; however, outbound strategies fail to be statistically significant. These results further confirm extant literature, highlighting the importance of drawing upon the ecosystem to grasp information for innovative activities. The absorption of external flows of knowledge is often mentioned by the firms as an important source of knowledge. Once more, firms included in the sample who benefit from external flows of knowledge have an increased impact on firms' innovation performance. On the contrary, the outflows of knowledge fail to be significant, proving that the maturity of the implementation of the strategy has not yet been reached. It seems that the externalization of surplus technology is not fully exploited by those firms; consequently, it does not impact their innovation performance.

In the first model, policy action encompasses the use of funds as a single policy instrument. The second tier evidences the positive effect of public subsidization of innovation performance; this means that public funding will further reinforce its positive effect among those firms overcoming the first hurdle of OI strategies.

The second model proposes a policy package rather than the single effect of funds. Building upon funding, in this case, we have added regulations, presented as enhancers. Firms conceiving product security as an innovation enhancer will have a positive impact on innovation performance; the same happens with taxes, which, when perceived as boosters, will positively impact their performance. In what concerns environmental regulations, the impact on performance is negative.

The combination of public funds with regulations, operating as barriers, is mostly insignificant; however, the existence of taxes working as detractors of the innovative activity enhances performance. This result is tuned to those previously presented in the literature, e.g., [81], indicating that the existence of regulations imposing restrictions will discipline the behaviors, which in the mid-run should cause performance improvements.

In a general perspective, inbound OI strategies will enhance innovation performance, which will be further exploited by combined policy actions that act as complements. These results shed light on the effectiveness of policy segmentations, as applying previous innovative efforts will give public finance a better use.

5. Discussion

The present paper, based on the responses of 13,701 firms of the Portuguese CIS, identifies the relevance of OI within the innovation ecosystem, as well as the role of knowledge transfer among the different players in the ecosystem [34]. It also underlines the importance of inbound OI strategies *vis-à-vis* outbound OI strategies, which confirms the difficulty firms, and especially SMEs, encounter in crafting strategies to profit from internal idle technologies, indicating a lack of resources to fully appropriate the advantages of OI strategies and knowledge-sharing in supporting firms' innovative performance [10,21]. As previously mentioned, more efforts need to be developed to further reinforce the mechanisms conducive to the externalization of unexplored knowledge, which is an intangible asset that can reinforce firms' innovation performance if properly used.

Funding is proven to be an important driver of innovation performance, in the same vein as previous research [76,79,81]. This finding has important consequences when implementing new policy packages for supporting innovative strategies, which in present days need to rely on digital transformation and Industry 4.0 [26,94–96] as vehicles to promote and explore competitive advantages at both firms and the ecosystem level. From the econometric estimations of the first model, it is possible to conclude that in order to pave the way to future digitalization policies, funds are an important tool. However, it is important to be cautious, as funding strategies of individual firms and collaborative investments may not have the expected outcomes in terms of enhanced innovation propensity [97], and also, they may not generate the expected spillovers to the innovation ecosystem due to the inexistence of collaborative networks as a pre-condition.

The second and third models also provide important insights for supporting OI across the innovation ecosystem, which is tuned with previous results [81]. It is important to stress that subsidies are important mechanisms to deploy the diffusion of solutions, which may support, for example, the diffusion of digital technologies across innovation ecosystems [98]; however, firms need to be prepared to embrace an internal change [99] so that they can adopt new collaborative business models [99,100]. The implementation of multidimensional policy packages, combining conventional instruments, such as subsidization with regulations, norms, and environmental rules, further enhances innovation propensity when perceived as constructive tools. Moreover, the transition towards digital collaborative networks and frameworks in which the communities are involved is expected to raise the sustainability of the ecosystem [26]. Notwithstanding, negative policy actions are proven to be effective only when related to taxation. Intertwining these strategies in a digital and collaborative era in which firms are aiming to shift to the metaverse for efficiency and sustainability purposes is a master challenge for policy-makers, which needs to be further explored.

6. Conclusions, Limitations and Recommendations

6.1. Conclusions and Implications

The present paper underlines the importance of networks and knowledge sharing in supporting firms' innovative performance. Based on the sample analyzed, using 13,701 firms of the Portuguese Community Innovation Survey, it was possible to prove that firms benefit from external knowledge arising from other agents operating in the innova-

tion ecosystem; however, they fail to exploit delivering unexplored knowledge outwardly. As such, consistent efforts need to be made to uphold this knowledge dimension, as the externalization of these intangible assets is needed because they are unexplored intangible resources that, if properly explored, could optimize returns on innovation and enhance even further firms' innovation performance.

The econometric estimations comprise three alternative models, with the first a simple hurdle in which we observe the impact of classic instruments, such as funding enhancing firms' innovation propensity.

The second model then adds non-conventional incentives, which are proven to work as complements of the traditional instruments. Lastly, the third model appraises regulations as a burden to innovation processes, with the taxation system proving to be effective.

This paper goes even further and sheds new light on the unconditional role of public policy in the promotion of innovative activities, igniting performance. For example, subsidization, despite being regarded as a conventional public policy action, is proven to further reinforce the effect of inbound knowledge flows on firms' innovation performance, which clearly indicates that subsidies were an important complementary resource for firms in improving their performance—and perhaps in accelerating Portugal's path from moderate innovator to strong innovator. Furthermore, the existence of regulations as innovation pillars, such as security or the environment, does matter.

These findings reinforce the need for a multidimensional policy action combining, on one hand, the promotion of dynamic innovative ecosystems in which individuals share knowledge and speed up the innovation pace at a lower cost, and, on the other hand, the promotion of public support combined with effective regulations generating positive reinforcements with proper subsidization and taxation procedures.

The empirical results arise from a snapshot encompassing the 2016–2018 period, namely, failing to address cause-effect policy effects or continuous achievements based upon persistent innovation practices, which have a positive effect on performance leveraging performance [78].

6.2. Limitations and Future Research

Although the empirical findings highlight the importance of inbound knowledge flows and the lack of importance of outbound knowledge, one question that remains unanswered is: Why does deterring regulations fail to affect innovation performance? There is a need to further explore this result, as most of the policies are designed to discipline behaviors, acting purposefully as barriers. The potential benefit of OI is undermined by the lack of purposeful outbound OI strategies, which deters firms to use all the potential of OI strategies, on one hand, and limits the full potential of all the players of the Innovation ecosystem. All in all, managers and policymakers must consider this multi-layer proposal, which at first relies on the ecosystem to exploit the knowledge flows and then combines the conventional policy instruments to reinforce the performance results.

Future research should focus on the returns of continuous innovative strategies, as well as the dynamic effects of policy instruments and their appraisal as a package. Moreover, managers need solid evidence regarding the long-term effect of these actions as enhancers of firm performance. The analysis of the preferability of carrots or sticks will also be of use to policymakers [81,94,95]. The analysis could be complemented by the use of case studies addressing the interconnections between firms and other players of the innovation ecosystem in order to understand the intricacies of inbound and outbound OI strategies, as well as how intertwined firms' relations with other players support the innovation ecosystem [101,102]. Moreover, one of the limitations of this study is that the conclusions are valid for Portugal specifically. Thus, the enlargement of the study to other countries in order to address different innovation ecosystems and other timeframes would be of great importance and allow generalization of the results.

Another important aspect regarding the ecosystem is the appraisal of the interaction and homogeneity among players, checked from three different standpoints—innovation

alignment, technology alignment, and market alignment [101,102]—with consequences both for OI strategies and for public policy programs [83,98,99,103,104], as they need to tackle agents' specificities. These particularities may have implications for the implementation of new technologies, as well as the diffusion of new solutions that need to be embraced by firms toward the digitalization shift [98,100,105]

Finally, the research will be consolidated if a dynamic approach is run in the future, as policy actions tend to take time to produce their effects. For that, a time-based perspective involving several countries with different levels of innovation would be advisable. Furthermore, analyzing other innovative ecosystems in modest innovators, as well as innovation leaders, could be of use to reinforce the singularities of these environments and broaden the knowledge base of innovation barriers and enhancers.

6.3. Further Recommendations

Establishing vivacious and dynamic ecosystems will be essential to promote smart and effective knowledge networks, which will reduce the costs of the innovative process and increase the sharing of relevant information among different agents of the innovation ecosystem. However, shifting from closed to open innovation requires a public effort, as firms tend to fear openness, and the lack of an effective legal framework can deter a broader trust in the system. This knowledge-sharing atmosphere is likely to generate positive spillovers affecting the entire network, which will speed up the pace of innovation. As a consequence, it seems that policy actions become more effective when relying upon already existing ecosystems rather than supporting players that are not embedded in the network. Empirical results prove that raising the efficacy of subsidization and regulations will depend on the demand for previous conditions to become entitled. The present state of affairs demands policy redesign, and it seems that new funding schemes need to encompass the connection to the ecosystem. Moreover, policy packages should combine incentives and barriers to better address the different profiles of the players. Turning things around from the present downturn and speeding up economic recovery is strongly tied to the promotion of OI ecosystems that support, and are supported by, their entrepreneurial fabric and the local communities, promoting consistent growth and better use of resources.

Based on the empirical findings, perhaps a combined policy package that may serve as leverage for innovation activity needs to concentrate on outbound innovative strategies. The attribution of funds, or even the financial/tax benefits, may be dependent upon the establishment of interactions with the ecosystem—e.g., the higher the interconnectedness, the higher the tax cut given. Notwithstanding, to work as role models for the entire community, the precise impact of these combined strategies can only be addressed by means of qualitative research focused on particular successful cases.

Another important avenue for further research could be, instead of using the turnover triggered by product innovation, to use other types of innovation to test how the innovation performance alters.

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