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Drivers of Innovation Capacity and Consequences for Open Innovation

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Abstract: The main objective of the present research is to identify the knowledge flows responsible for promoting the innovation capacity of Portuguese companies. Specifically, we intend to identify which variables influence Portuguese innovation capacity from a macro and micro perspective, so that we can establish possible ways to promote open innovation (OI) in Portugal since Portuguese companies have little maturity in terms of open innovation when compared to companies in other countries of the European Union. To achieve this goal, the methodological design used consisted of two phases. In the first phase, a literature review was conducted to identify the main variables associated with innovation performance. After identifying the most influential variables in the literature, in a second phase, data were collected through three distinct databases, namely Pordata, the Portuguese Tax and Customs Authority, and SABI. To identify the most influential variables in the Portuguese innovation capacity, the multivariate multiple regression technique based on the ordinary least square (OLS) method was applied. The results of the present research bring empirical evidence that researchers dedicated to R&D from non-profit institutions (i.e., inbound OI) and researchers from firms (i.e., outbound OI) exert a significant influence on innovation capacity so the development of an optimal strategy for the strengthening of open innovation by Portuguese firms should take into account the use and combination of these two specific knowledge flows. In this sense, the originality of this research lies in the fact that it is the first attempt to understand the possible implications of the determinants of innovation capacity on open innovation, from an exploratory study concerning the flows of knowledge.

Keywords: innovation capacity; open innovation; patents; trademarks; inbound OI; outbound OI; Portugal

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1. Introduction

The combination of internal and external sources of information has intensified the probability of innovations in the services market. Evidence shows that companies in scientific collaboration for the development of products, and economic actors that combine internal information with other information obtained in the market, have a greater chance of innovating [1]. For instance, the use of the external knowledge obtained through electronic word-of-mouth has contributed to the implementation of improvements in recommendation systems in the entertainment industry, which have a significant impact on purchase decision processes [2].

In this context, innovation is strongly linked to the ability of companies to acquire, generate and apply knowledge [3], thus innovation capacity, rather than intangible assets, has gained attention from researchers dedicated to the study of open innovation (OI), especially concerning absorptive capacity, entrepreneurship, and radical innovation, as a consequence of a major shift in the paradigm from closed innovation to open innovation [4].

In this sense, open innovation, first conceptualized by the author of [5], can be understood as a process by which organizations seek to acquire knowledge and resources both internally and externally through the management of knowledge flows that go beyond their organizational boundaries. This is premised on the idea that companies should use internal and external flows of knowledge to stimulate their internal innovation processes [6]. In other words, it is a paradigm in which companies can and do use internal and external ideas, as well as internal and external paths to the market, as they seek to advance the current technology they have to increase the potential sources of innovation and hence the likelihood of it occurring [7]. Therefore, open innovation can be understood as a rich concept, to the extent that it can be operationalized in different ways, especially concerning its content, context, and processes [8].

The inputs of open innovation (inbound OI) have been studied systematically in the literature [9–11]. Additionally, the outputs of open innovation (outbound OI) have been largely investigated in the literature [4,12]. In relation to the outbound OI, is it detected that to date no attention has been paid to the relationship between them and these flows.

Besides, although several studies [3,13] have investigated which are the main sources and sectors most involved in open innovation in Portugal, the adoption of open innovation by Portuguese Clusters [14], the relationship between innovation capacity and financial performance, as well as between organizational ambidexterity and innovation capacity [15], there is a dearth of research on the determinants of innovation capacity and its possible relationships with open innovation.

Given this context and considering mainly the scarcity of research on the relationships between the inbounds and outbounds of open innovation, as well as the relationship between innovation capacity and open innovation in the Portuguese context, this research aims to identify the knowledge flows responsible for promoting the innovation capacity of Portuguese companies to fill the gaps previously highlighted in the literature. Specifically, we intend to identify which variables influence the Portuguese innovation capacity in a macro and micro perspective, so that we can establish possible ways to promote open innovation in Portugal since Portuguese companies have little maturity in terms of open innovation when compared to companies in other countries of the European Union [13].

Reference [16] points out that an adequate strategy for open innovation should be based on the context in which companies operate so that the design of policies for the promotion of open innovation can take into account the unique characteristics of each country. Based on this premise, this research is a first attempt to understand the possible implications of the determinants of innovation capacity for open innovation, from an exploratory study on the flows of knowledge that determine innovation capacity.

Data were collected from the Pordata, Portuguese Tax and Customs Authority, and SABI databases and analyzed using the multivariate multiple regression technique based on the ordinary least squares method (OLS), using the stepwise-backward procedure as the data entry method to identify the most influential variables on innovation capacity, given possible suppressor effects.

In this regard, the present investigation brings both theoretical and practical contributions. As theoretical contributions, the present research brings empirical evidence that researchers dedicated to R&D from non-profit institutions, ultimately characterized as inbound OI, and researchers from companies embodied as outbound OI exert significant influence on the innovation capacity of Portuguese companies. As a result of this evidence, as a practical contribution, the results found suggest that the development of strategies for enhancing open innovation practices by Portuguese companies can start from the combination of these specific flows of knowledge, operationalized both by the absorptive capacity of companies and by the adoption of a general model of open innovation, especially that of integrated collaboration.

Besides this brief introduction, the present investigation is structured as six other sections. The next section presents the theoretical framework, in which the relationship between patents, trademark, and innovation capacity is discussed, as well as the determining factors of innovation capacity pointed out in the literature and the research hypotheses developed. Next, the results and discussion are presented, characterized as the focal points of the research, where the relationship between the determinants of innovation capacity and open innovation is established and, finally, the concluding remarks of the research and the references used are listed.

2. Theoretical Framework

2.1. Patents, Trademarks, Innovation Capacity, and their Determinants

The strategic management of technology is one of the influential factors in innovation capacity and among its processes is the protection of intellectual property [17,18].

In this sense, intellectual property (IP) rights play an important role in the entire cycle of innovation, from discovery to protection and commercialization of an idea. Therefore, countries with stable IP infrastructure and legislation are more economically successful than those without such measures [19]. Among these IP rights are patents and trademarks.

Patents are legal rights to exclude others from producing a certain technology when it is protected by one or more underlying patents [20,21]. There is a growing awareness of the role of patents for the development of innovation and the commercial success of organizations [22–24], countries [25], and regions [26,27]. In this sense, patent portfolios are important for the strategic layout of corporations and to promote corporate protection of technological innovation [28]. On the other hand, brands are a sign used to distinguish the products or services of a company in the commercial environment [29].

Despite the scarcity of studies associating the number of trademarks and the capacity of innovation [30–32], it is possible to reinforce this relationship from studies that relate the value of the trademarks with the market value of the companies that own these trademarks [33–35], as well as their financial performance [36,37]. Additionally, empirical evidence suggests including brands among the metrics to model the relationship with innovation capacity [34,38].

Innovation is an important driver for the technological and economic development of a nation since the application of advanced technologies together with innovative approaches by enterprises allows the development of new products and services that are reflected in advances for productive economic activity [39]. Despite the importance of innovation capacity, there is no consensus in the literature on its determinants or its measurement, so the question remains open, although it can be said that factors such as the skills of the workforce, as well as the organization's interactions with its environment, contribute to innovation capacity [40].

Accordingly, the number of patent applications can be considered a good indicator for measuring innovative performance [41], since several studies [39,42–48] have used the number of patent applications as an indicator or proxy of innovative performance, while others [49–51] recommend its use for the evaluation of the productive and technological efficiency of companies.

In terms of the determinants of innovation capacity, economic and political factors are important mediators between a nation's educational level and its innovation capacity. Workers with good educational backgrounds favor the adoption of cultural practices to support innovation by people in positions of leadership [52]. Furthermore, high-performance work practices have a direct and positive influence on the number of patent applications, partly mediated by the relational coordination skills of the employees, which involve cross cooperation between departments, and the sharing of knowledge and objectives that enable the identification of consumer needs, the generation of ideas and the continuous improvement of innovation processes [44].

Therefore, Reference [53] found empirical evidence that workforce skills, as well as R&D spending as a function of the number of workers, are directly related to the innovation capacity. In particular, spending on R&D as a function of the number of workers has a positive and moderate correlation with the number of patents. Another finding made by [45], concerns the fact that culture plays an important role in innovation activity, specifically in the number of patent applications, although this influence is not direct.

Regionally integrated networks, as well as global strategic partnerships, are other important facilitators of innovation capacity. This is mainly because they are based on an open innovation model in which the various actors can access a set of complementary skills, competencies, and knowledge, as well as the share risks and uncertainties, which favor organizational ambidexterity in that they enable the development of strategies for current and future exploitation [54,55]. In the specific case of public–private partnerships, the relationship established can stimulate the development of products and services, as well as the diffusion of knowledge that substantially reduces the technological gap between public and private initiatives [56].

In addition to the factors mentioned, it is evident that in developed countries, such as the members of the European Union, R&D investments have received increasing importance as a result of their role in economic growth. In this sense, the authors of [57], in assessing the influence of R&D spending in EU member states after the 2000s, found empirical evidence that R&D investments have a positive impact on the number of patent applications.

Within this perspective, R&D investments, understood in a broader sense, both financially and in human resources, enable companies to develop patented knowledge or new products [58]. Therefore, due to the increased awareness of public policymakers and the business sector about the importance of R&D activities for sustainable economic growth, tax incentives and government subsidies have been used as important policies to increase the competitiveness of the companies and industries to which they belong, to induce companies to perform R&D, covering part of their costs and minimizing possible financial risks, since market failures, as well as the risks associated with R&D activities, may decrease the propensity for private investment in these activities [59–62].

2.2. Research Hypotheses

Since the present research aims at identifying which variables influence Portuguese innovation capacity, considering the macro and micro perspectives of analysis, the following research hypotheses were established:

Hypothesis 1. *The human resources of the corporate segment influence the number of requests for deposits of inventions/patents and trademark registrations.*

The conceptual framework of this hypothesis is based on the premise that the skills of the workforce, as well as R&D spending according to the number of workers, are directly related to the innovation capacity. In this sense, the greater the involvement of employees in R&D activities, the greater the innovation capacity of a company, considering that innovation is directly influenced by the number of employees involved in research activities. Adding to this, high-performance work practices, which involve among other aspects training sessions for problem-solving, cross practices of R&D between departments, collective incentive systems and the sharing of objectives and knowledge to stimulate in the workforce the development of skills for coordination and mutual adjustment, all positively influence innovation capacity [44,49,53,63].

Hypothesis 2. *Public investments in R&D influence the number of requests for deposits of inventions/patents and trademark registrations.*

The increase in R&D spending can have a direct effect on innovation, because to the extent that more investments are made in basic research, the greater is its capacity to generate new knowledge and discoveries, constituting core competitiveness in scientific and technological innovation. Moreover, R&D investments considerably improve innovation capacity, since they provide the necessary support for researchers to have access to tools and equipment that help them make discoveries, publish high-impact articles, and apply for new patent applications. Thus, investments have a positive influence on the production of patentable knowledge [43,47,57,58,63,64].

Hypothesis 3. *Scientific production influences the number of requests for deposits of inventions/patents and trademark registrations.*

The justification for the research hypothesis in question is based on the fact that the creation of codified knowledge, in the form of scientific publication, by public research institutions and universities, contributes to innovation as they serve as a subsidy for the development of technological innovations by companies [44]. Although variations in new patent applications reflect not only variations in research productivity but also variations in the appropriability and filing strategies adopted by firms [65], increasing the intensity of basic research can increase the number of invention patent applications in the context of universities [42]. Moreover, countries that are more productive in science are often the most productive technologically as well [66]. Additionally, since the consideration of patent data in isolation may not adequately represent the entire invention ecosystem, the use of scientific information such as scientific production has been recommended by several investigations [63,64] as a variable to be studied together with the number of patent applications to determine the innovation capacity.

Hypothesis 4. *Researchers dedicated to full-time R&D influence the number of requests for deposits of inventions/patents and trademark registrations.*

This research hypothesis is based on the fact that the focus on basic research leads to an increase in the number of patent and invention filing requests [42]. Additionally, researchers who have support for the development of their activities are in a better position to promote research that solves problems that are on the verge of the unknown and bring new knowledge that is reflected in scientific publications and requests for patent/invention filings [67,68]. Within this perspective, public and private economic actors directly involved in research play an important role in the process of developing innovations [69].

Hypothesis 5. *Tax incentives for the promotion of R&D by companies influence the creation of value through intangible assets.*

The conceptual framework of this research hypothesis is based on the fact that R&D activities have received increasing attention from both public policymakers and the business sector, recognizing these activities as key factors for sustainability and economic growth, such that several countries have adopted programs to support these activities [61]. Accordingly, tax incentives, in conjunction or isolation with direct subsidies through concessions and loans, have been commonly used by several countries as an instrument to encourage R&D activities in companies, to increase their competitiveness and in the industries to which they belong, covering part of their costs and part of the financial risks associated with R&D activities [59,60,62].

Table 1 summarizes the investigation hypotheses, the main variables used, as well as the expected relationships, as pointed out by the literature on the subject.

Table 1. Summary of Research Assumptions and Expected Relationships.

Level of Analysis	Dimensions	Variables	Authors	Hypothesis	Expected Relationships
Macro		Patent Applications (Y_1) Trademark Registrations (Y_2)			
	Workforce *	MSE's human resources (X_1); Human resources of large enterprises (X_2).	[44,49,53,63]	H_1: Human resources of the corporate segment influence the number of requests for deposits of inventions/patents and trademark registrations.	+
	Public R&D expenditures	Public R&D investments (X_3).	[43,47,57,58,63,64]	H_2: Public investments in R&D influence the number of requests for deposits of inventions/patents and trademark registrations.	+
	Scientific Production	Scientific Production in Exact Sciences (X_4); Scientific Production of Engineering (X_5); Medical Scientific Production (X_6); Scientific production in Agrarian (X_7); Scientific Production in Social Sciences (X_8); Scientific Production in Humanities (X_9).	[42,44,63–66]	H_3: Scientific production influences the number of requests for deposits of inventions/patents and trademark registrations.	+
	Researchers dedicated to full-time R&D **	Companies Researchers (X_{10}); State Researchers (X_{11}); University Researchers (X_{12}); Non-profit Researchers (X_{13}).	[42,67–69]	H_4: Researchers dedicated to full-time R&D influence the number of requests for deposits of inventions/patents and trademark registrations.	+
Micro		Intangible Asset Value Indicator (Y_3)			
	Tax incentives for R&D	Sifide-2013 (X_{14}); Sifide-2014 (X_{15}); Sifide-2015 (X_{16}); Sifide-2016 (X_{17});	[59–62]	H_5: Tax incentives for corporate R&D influence the creation of value through intangible assets.	+

Note: * Data from 2004–2018; ** Data from 1982–2006. All other variables refer to the 1982–2019 period.

3. Method

3.1. Objective, Data Collection, and Analysis

The main objective of this research was to identify the knowledge flows that are responsible for promoting the innovation capacity of Portuguese companies to fill the gaps in the literature, particularly concerning the types and combinations of knowledge flows of open innovation, as well as the scarcity of studies on the relationship between innovation capacity and open innovation in Portugal.

Accordingly, an analysis of the literature was initially carried out to identify the main variables associated with innovative performance, the results of which were expressed in the determination of the research hypotheses together with the expected relationships, as presented in Table 1.

For the macro level of analysis, data were collected using the Pordata database (https://www.pordata.pt/, accessed on 7 December 2020), chosen because it presents official and certified statistics on Portugal during the month of December 2020. Additionally, for the micro-level of analysis, data was collected through the Portuguese Tax and Customs Authority databases, during the month of January 2021, (available at https://info.portaldasfinancas.gov.pt/pt/dgci/divulgacao/Area_Beneficios_Fiscais/Listas_de_contribuintes_com_beneficios_fiscais/Paginas/default.aspx, accessed on 18 January 2021) and, through the SABI database [70] during the month of February 2021, as it contains detailed information on Portuguese companies, particularly concerning their accounting characteristics.

The data were processed and analyzed with the help of R Studio software, in its version 1.2.5042 and the Statistical Package for the Social Sciences (IBM SPSS Statistics), in its version 24.

3.2. Variables and Statistical Techniques

To achieve the objectives of this research, the multivariate multiple regression technique based on the ordinary least square (OLS) method was applied, since it allows the simultaneous evaluation of the relationships between each independent variable as a function of a dependent variable, allowing the determination of the relative importance of each independent variable [71,72].

For the macro level of analysis, the variables investigated were dependent variables (proxy of innovation capacity): number of patent applications (Y_1) and trademark registrations (Y_2) made by Portuguese residents in the period 1982–2019; independent variables: total human resources employed by both micro and small companies (X_1) and large companies (X_2); public investment in R&D (X_3); scientific production by area of specialization (X_4 to X_9); researchers dedicated to full-time R&D by sectors (X_{10} to X_{13}).

Regarding the micro level of analysis, variables referring to 339 Portuguese companies benefiting from tax incentives were investigated, which were dependent variables (proxy of innovation capacity): intangible asset value creation indicator (ratio of sales to intangible assets) (Y_3); independent variables: Sifide-2013 (X_{14}), Sifide-2014 (X_{15}), Sifide-2015 (X_{16}), Sifide-2016 (X_{17}).

Additionally, the data entry method in the estimation of model parameters was stepwise-backward, which, considering the nature of the investigation, is the most recommended data entry method for exploratory investigations due to the possible suppressive effects presented when one variable has a significant effect but only when another variable is kept constant [73]. Accordingly, the stepwise-backward input method is more likely to avoid the exclusion of predictors in suppressive effects, that is, to exclude variables that contribute to a given model.

In a complementary way, all estimated models for predicting the innovation capacity were validated using the criteria of the Adjusted R^2; normal distribution of the residuals; independence of the residuals, homoscedasticity, and multicollinearity [71,74].

4. Results

4.1. Macro Analysis

4.1.1. Influential Variables in the Number of Patent Applications

The estimated regression model for identifying which variables are most influential in the number of patent/invention filings (Y_1) made by Portuguese residents during the 1982–2019 period is shown in Table 2. According to the model estimated using the stepwise-backward method, the most influential variables in the number of patent/invention filings were the researchers of non-profit institutions dedicated to R&D (X_{13}) and the researchers of companies dedicated to R&D (X_{10}), jointly responsible for 64.39% of the variation in the number of patent/invention filings during the period considered, according to the adjusted coefficient of determination (Adjusted R^2).

Table 2. Multiple Regression Model for the Number of Patent Applications.

Model	B	SE B	β	t-Value
(Y_1) Number of patent applications	Intercept: 0.8197	0.481	−1.154	−1.703
	Non-profit Researchers (X_{13}): 8.545×10^{-4}	1.356×10^{-4}	0.769 *	6.303
	Companies Researchers (X_{10}): 5.919×10^{-5}	2.942×10^{-5}	0.246 **	2.012

Note: R^2 = 64.39%; * $p < 0.01$; ** $p \leq 0.05$.

Additionally, taking into account the values of the standardized coefficients by which the effects are measured not in terms of the original units of y and x, but in units of standard deviation allowing a more accurate direct comparison of the magnitude of the coefficients of the exploratory variables [75], and consequently, of their importance, it is possible to perceive that the most influential variable in the number of patent/invention applications is the researchers of non-profit institutions dedicated to R&D (β = 0.769) variable.

In this sense, the model that represents innovation capacity concerning the number of patent applications is:

$$\text{Innovation Capacity} = 0.8197 + 8.545 \times 10^{-4} \times \text{Non-profit Researchers} + 5.919 \times 10^{-5} \times \text{Companies Researchers}$$

4.1.2. Validation of the Model Assumptions for Patents/Inventions

The development of a regression model based on the ordinary least squares (OLS) method must take into account the satisfaction of some assumptions so that the model obtained from the sample can be applied accurately to the population, which in other terms means that the estimated coefficients are not biased [73]. In this sense, for the estimated model to be generalizable, the satisfaction of the assumptions related to (I) normal distribution of the residuals, (II) independence of the residuals, homoscedasticity, and multicollinearity should be evaluated [71,74], whose tests were applied with the help of the R Studio software, for presenting both the value of the test and its significance.

Namely, for the normal distribution of the residuals, the Shapiro–Wilk test was applied, considering that it is more robust than its Kolmogorov–Smirnov counterpart, as some investigations point out [76–78]. The test value was 0.038 (w = 0.91; p-value = 0.038 > 0.01), allowing to validate the hypothesis of the normal distribution of the residuals considering a significance level of 1%. The independence of the residuals was verified by applying the Durbin–Watson test, whose result obtained (dw = 1.5; p-value = 0.032 > 0.01) indicates that the residuals are not significantly correlated with each other, that it is independent, thus validating the assumption in question at the significance level of 1%.

To verify the assumption of homoscedasticity, the Breusch–Pagan test was applied, which is usually used to evaluate whether the variances of the residuals at each level of the predictors are the same [74,75]. The result (bp = 6.89; p-value = 0.032) allows us to conclude that the variances of the residuals are significantly homogeneous at the level of significance of 1%. Last but not least, the verification of the multicollinearity assumption, according to which there should not be a perfect linear relationship between the predictors [73], was made by applying the variance inflation factor (VIF), the result of which was 1.033 indicating the non-existence of multicollinearity [79].

In addition to the validation of the regression assumptions, an analysis of the isolated contribution of the variable researchers of companies dedicated to R&D (X_{10}) to the model was carried out. It was carried out bearing in mind that its test value is at the limit for rejection (p-value ≤ 0.05) at the level of significance of 5%, using as criteria the coefficient of determination [72,74,80], the corrected Akaike criterion (AICc) for measuring the quality of the model [81], and the analysis of variance (ANOVA) [71,72,75], whose results are expressed in Table 3.

Table 3. Analysis of the contribution of the variable Researchers of Companies dedicated to R&D to the Regression model.

Models	Adjusted R^2	Akaike (AICc)	ANOVA
Model with the inclusion of the variable researchers of Companies dedicated to R&D	64.39%	86.50	p-value ≤ 0.05
Model without the inclusion of the variable researchers of Companies dedicated to R&D	59.66%	87.87	-

Taking into account the values expressed in Table 3, specifically those that refer to the coefficient of determination, it can be stated that the addition of the predictor contributes significantly to the model in that its explanatory power is greater (R^2 Adjusted = 64.39%) than it would be in the absence of the predictor (R^2 Adjusted = 59.66%). Other than this, one can conclude through the evaluation of the corrected Akaike information criterion (AICc) that the inclusion of the variable leads to a lower relative loss of information and, consequently, to a lower AICc value (86.50 compared to 87.87), so the model with the inclusion of the variable has superior quality, therefore being preferable to the model without the inclusion of the variable. In the same sense, the result obtained through the analysis of variance (p-value ≤ 0.05), allows us to conclude that the estimated value of the coefficient of the variable in question is significantly different from zero at the level of significance of 5%, so the inclusion of the variable contributes significantly to the estimated model and should therefore not be excluded.

4.1.3. Influential Variables in the Number of Trademark Registrations and Other Distinguishing Trade Signs

To determine which variables are more influential in the number of trademark registrations and other distinctive trade signs (Y_2) made by Portuguese residents during the period 1982–2019, the application of a multiple regression based on the ordinary least square (OLS) method was once again used, whose values are presented in Table 4.

Table 4. Multiple Regression Model for the Number of Trademark Registrations.

Model	B	SE B	β	*t*-Value
(Y_2) Number of trademark registrations	Intercept: 0.327	0.117	0.327	2.794
	Non-profit Researchers (X_{13}): 1.066×10^{-4}	3.297×10^{-5}	0.502 *	3.233
	Companies Researchers(X_{10}): 2.024×10^{-5}	7.154×10^{-6}	0.439 *	2.829

Note: R^2 = 42.28%; * $p < 0.01$.

Similar to the results of the model estimated above, the results of Table 4 show that the most influential variables in the number of trademark registrations and other distinctive trade signs were also the researchers of non-profit institutions dedicated to R&D (X_{13}) and the researchers of companies dedicated to R&D (X_{10}). These two variables together explain 42.28% of the variation in the number of trademark registrations and other distinctive trade signs, according to the adjusted coefficient of determination (Adjusted R^2).

In terms of the importance of the variables, the analysis of the standardized coefficients allows us to identify the researchers of non-profit institutions dedicated to R&D (β = 0.502) as the most influential variable in the number of trademark registrations and other distinctive trade signs, a result similar to that found in the estimated model for the number of requests for patent/invention applications.

In this sense, the model that represents innovation capacity concerning the number of trademark registrations is:

$$\text{Innovation Capacity} = 0.327 + 1.066 \times 10^{-4} \times \text{Non-profit Researchers} + 2.024 \times 10^{-5} \times \text{Companies Researchers}$$

4.1.4. Validation of the Model Assumptions for Trademark

As mentioned above, for a regression model obtained from the sample to be generalized, it is necessary to satisfy a series of assumptions, such as (I) normal distribution of the residuals, (II) independence of the residuals, homoscedasticity, and multicollinearity [71,74].

Regarding the normal distribution of the residuals, the Shapiro–Wilk test was once again used, whose result (w = 0.954; *p*-value = 0.311 > 0.05) allows the validation of the hypothesis of the normal distribution of the residuals, considering a 5% significance level. Regarding the independence of the residuals, the result of the Durbin–Watson test (dw = 1.3; *p*-value = 0.01 < 0.05), points to a possible non-validation of the assumption of independence of the residuals at a 5% significance level. However, taking into account that only values lower than 1 and higher than 3 should be a cause for concern [73], the value of this test (dw = 1.3), does not indicate serious problems of association between the residuals. Hence, given the differences in the conclusion using the two criteria, it cannot be stated unequivocally that the errors are independent, which constitutes a limitation of the model.

For checking the assumption of homoscedasticity, the Breusch–Pagan test was once again applied, whose result (bp = 0.955; *p*-value = 0.621 > 0.05) allows us to conclude that the variances of the residuals are significantly homogeneous at the 5% significance level. Furthermore, the result of the variance inflation factor (VIF) of 1.033, similar to the previous model, indicates the inexistence of a perfect linear relationship between the predictors, thus validating the assumption of multicollinearity.

4.2. Micro Analysis

Influence of Tax Incentives on the Creation of Value through Intangible Assets

From a micro perspective, to analyze how tax incentives for companies' R&D activities influence the creation of value through intangible assets, the application of a multiple regression based on the ordinary least square (OLS) method, whose values are presented in Table 5, was once again used.

Table 5. Multiple Regression Result for Value Creation through Intangible Assets.

Model	B	SE B	*t*-Value
Intangible Asset Value Indicator (Y_3)	Intercept: 9.425×10^2	1.874×10^2	5.030
	Sifide-2013 (X_{14}): 1.047×10^{-4} *	4.333×10^{-4}	0.242
	Sifide-2014 (X_{15}): 8.037×10^{-4} *	6.219×10^{-4}	1.292
	Sifide-2015 (X_{16}): -9.171×10^{-5} *	2.206×10^{-4}	−0.416
	Sifide-2016 (X_{17}): -3.914×10^{-4} *	7.587×10^{-4}	−0.516

Note: R^2 = 0.01%; * $p > 0.05$.

Unlike the results of the models previously estimated for a macro perspective, the results of Table 5 show that none of the variables that measure the tax incentives for R&D activities by companies exert influence on the creation of value through intangible assets, since it is possible to conclude significantly that the value of the beta coefficient parameters is equal to zero (B = 0), not rejecting the hypothesis of nullity of the coefficients at a significance level of 5%. Additionally, the result of the adjusted determination coefficient (R^2 Adjusted), brings evidence that the tax incentives granted for R&D activities are not useful to explain the variability in the creation of value by the intangible assets of companies.

5. Discussion

5.1. General Discussion Concerning the Drivers of Innovation Capacity

Given the analysis carried out, it is possible to conclude that only the research Hypothesis 4 can be partially validated, given that researchers dedicated to R&D from non-profit institutions and companies have a significant and positive influence on both the number of patent/invention applications and the number of trademark registrations and other distinctive trade signs.

Such results are in line with other investigations [42,67–69], which show that public and private economic actors who are directly involved in research play an important role in the process of developing innovations, embodied in the number of patent applications, through basic research and the identification of solutions to hitherto unknown problems.

Regarding the influence of the workforce, represented by the number of total human resources of both micro and small companies and large companies, the results found point to the rejection of research Hypothesis 1, so the total number of human resources did not prove to be a significantly influential variable in the number of patent/invention filings and trademark registrations. Such results may be associated with the fact that not all innovations developed in the business sphere are effectively patented, which potentially hinders the identification of relationships between these variables. In this sense, the isolated analysis of the total number of workers employed according to the number of patent filings may not constitute an appropriate measure for the evaluation of innovation capacity, since not all innovations are protected by patents [43].

Regarding the influence of R&D investments on the number of patent/invention applications and trademark registrations, the non-validation of research Hypothesis 2 may be related to the fact that within the block of countries constituting the European Union, only countries like Finland, Switzerland, Denmark, Austria, and Luxembourg have increased their innovation capacities according to R&D investments, considering the period 2000–2010. Countries such as Spain, Portugal, Italy, the Czech Republic, Estonia, Hungary, and Slovakia performed poorly in this respect during the same period. However, this does not mean that R&D investments are not important, but that they cannot be analyzed as an isolated metric for determining innovation performance [39].

The non-validation of research Hypothesis 3, regarding the influence of scientific production on the number of patent/invention applications and trademark registrations, may be directly related to the fact that although some basic research accomplishments may promote development through technological innovations, they necessarily require a certain time to be accepted and absorbed by the public. They require time to present their concrete effects in terms of basic research results [42], among which there are new patent/invention applications and trademark registrations. Although it cannot be said that scientific publications have a direct influence on the number of patent/invention applications and trademark registrations when considering the Portuguese evidence, in the German context there is empirical evidence that the increase in scientific publications has a positive influence on private sector investments, as well as on the employment rate [63]. Additionally, it is worth noting that some scientific areas have, historically and naturally, less technological productivity than others [82,83]. Thus, when we analyze the influence of scientific production on the production of patents/inventions and trademark registrations, considering all scientific fields, that is, from a macro perspective, the results may diverge from many previous studies that analyze by technological area/field.

Concerning the influence of tax incentives on the ability to innovate by creating value from intangible assets, Reference [61] found empirical evidence that Portuguese startups that benefited from the tax incentives through SIFIDE during the period from 2012 to 2016 behaved differently from those that did not benefit from the same incentive in terms of business performance, profitability, the weight of intangible assets and value-added by employees. Accordingly, the non-validation of research Hypothesis 5 may be related to the fact that the influence of tax incentives through SIFIDE on the creation of value of intangible assets cannot be evaluated in a linear manner, embodied in a relationship of moderation, but rather, together with other intervening variables or mediators, related to the availability of resources (i.e., quality of the workforce, physical resources, total assets, etc.) and infrastructure (i.e., management styles, organizational culture, risk tolerance, among others) for solving problems [84] that bring innovation and consequently competitive advantages [85].

5.2. Drivers of Innovation Capacity and the Possibility of Fostering Open Innovation

Because of the challenges posed by the knowledge-based economy, external sources of specialized knowledge can be of great value to companies in dealing with uncertainty and instability to provide innovation [13]. In this sense, Reference [86] point out that the development of innovation capacity in Europe should be based on the creation of new sources of knowledge, especially given the empirical evidence that government programs such as the Research and Innovation Strategies for Smart Specialization have a positive influence on innovation capacity.

Given this context, the adoption of an open innovation strategy must be based on the optimal combination of internal and external resources to generate value, in such a way that the efficiency of the companies regarding the knowledge input (inbound OI) flows is based on the ability to manage the relationships with external sources and on the definition of strategies to combine internal knowledge (outbound OI) with those acquired externally [87].

However, as noted by [88], the mere openness of innovation processes does not result in positive effects on innovation performance. Thus, the authors suggest that managers should develop strategies for the opening of their innovation processes that focus both on the quality of relationships to favor the growth of trust and routines among agents, and on a reliable number of collaborations that enhance the external acquisition of knowledge.

Nevertheless, unlike Spain, which has focused on the use of specialized information sources, concerning the inbounds of open innovation, Portuguese companies have focused on the acquisition of technology and the use of external knowledge through Open innovation activities based on structured cooperations and pecuniary activities [89], which has characterized Portuguese companies as incipient in terms of open innovation when compared to companies in other European Union countries [13].

Accordingly, and considering the results of the present research, specifically the empirical evidence that researchers dedicated to R&D from non-profit institutions (i.e., inbound OI) and researchers from companies (i.e., outbound OI) exert significant influence on innovation capacity, it is argued that the development of an optimal strategy for the strengthening of open innovation by Portuguese companies should take into account the use and combination of these two specific knowledge flows.

More specifically, the use and combination of these flows can stem from the absorptive capacity of companies, insofar as it refers to the ability to exchange and combine information with different sources for the creation of new information [4] being fundamental to the conception of new ideas that lead to innovation, especially when considering the empirical evidence found by the authors of [90]. They state that that Knowledge Management Capacity (KMC), embodied by absorptive capacity, readiness for collaboration, inventive capacity, and connective capacity, is an important mediator of the relationship between open innovation and innovation capacity, enhancing its effects.

On the other hand, the flows of knowledge identified as influential for innovation capacity can also be used as a starting point for the adoption of an open innovation model called integrated collaboration, since in this model companies seek external contributions concerning technology and know-how for various points or phases of their innovation processes, although limited to a few partners [91]. Thus the systematic adoption of this model centered on the use and combination of researchers dedicated to R&D from non-profit institutions (i.e., inbound OI) with researchers from companies (i.e., outbound OI) can enhance both performances in terms of open innovation and innovation capacity per se.

6. Concluding Remarks

6.1. Main Findings and Implications for Open Innovation

The main objective of this research was to identify the knowledge flows that are responsible for promoting the innovation capacity of Portuguese companies to fill the gaps in the literature, particularly concerning the types and combinations of knowledge flows of open innovation, as well as the scarcity of studies on the relationship between innovation capacity and open innovation in Portugal.

In this sense and considering that an adequate strategy for open innovation must be based on the context in which companies operate, the design of policies for the promotion of open innovation must take into account the unique characteristics of each country [16], the originality of this research lies in the fact that it is the first attempt to understand the possible implications of the determinants of innovation capacity on open innovation from an exploratory study concerning the flows of knowledge that determine the ability to innovate more pointed out in the literature.

Considering the analysis carried out at a macro level, the results found indicate that researchers dedicated to the R&D of non-profit institutions and companies exert significant influence on both the number of patent/invention applications and the number of trademark registrations and other distinctive trade signs. Adding to this, in terms of relative importance, the variable researchers dedicated to R&D of non-profit institutions proved to have the greatest influence on the two estimated models.

In light of these results, especially the evidence that the researchers dedicated to R&D of companies exert influence on the number of applications for patent/invention filings and trademark registrations and because the same influence has not been verified about the total human resources of the companies, it is possible to see that the involvement of employees in R&D activities becomes more important for the capacity of innovation than the total number of employees. This follows the precepts of the current knowledge-based society, in which knowledge becomes perceived as more important than capital and workforce [92].

On the other hand, as regards the analysis carried out for the micro perspective of innovation capacity, embodied in the creation of value through the intangible assets of Portuguese companies benefited by tax incentives for R&D activities, the results found did not indicate their direct influence, but did not mean that this variable is not important, but rather that it cannot be analyzed linearly in a moderation relationship.

Regarding theoretical contributions, the present research brings empirical evidence that researchers dedicated to R&D from non-profit institutions, ultimately characterized as inbound OI, and researchers from companies, embodied as outbound OI, exert significant influence on the innovation capacity of Portuguese companies. As a result of this evidence, as a practical contribution, the results found suggest that the development of strategies for enhancing open innovation practices by Portuguese companies can start from the combination of these specific flows of knowledge, operationalized both by the absorptive capacity of companies and by the adoption of a general model of open innovation, especially that of integrated collaboration.

6.2. Limitations and Avenues for Future Research

In terms of limitations, it is important to note that the econometric models were estimated from data on a single country, so the results reflect only the context analyzed, making it impossible to generalize them. In this sense, other variables may be significant depending on the particular characteristics of other regions, so it is suggested, in terms of future research, to replicate this analysis in a broader sample of countries, as well as to investigate fiscal incentives together with other intervening variables through Structural Equation Modeling (SEM) to determine the mediating effects on innovation capacity.

Besides this, universities have excelled in developing innovations in several countries and companies, especially in technology-intensive sectors. However, the management of patents by these institutions can be an extremely complex task, often requiring the presence of a legal department, generating excessive costs that make it impossible to transfer technology to small markets [93,94]. Within this context, the adoption of intellectual property management practices is essential, especially concerning academic patent portfolios [95].

In this sense, it is suggested as an area of future study to evaluate the current state of the patent portfolios of Portuguese Universities, to determine the degree of efficiency of these in their development and knowledge transfer processes. Besides this, empirical evidence indicates that patents in dispute (litigation) tend to be more important than those that are not in dispute [96], therefore, as a future study area, characteristics and/or factors that affect the value and importance of Portuguese patents should be identified. Finally, it would be interesting to measure the reverse effect, more specifically, the effect open innovation [97,98] has on innovation capacity drivers.

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