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Unlocking the Code to Continuous Innovation: A Study of Key Determinants for Serial Innovators

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Abstract: This study investigates the fundamental role of collaboration in promoting a culture of continuous innovation in companies, driving them to become serial innovators, as evidenced by their industrial property registrations. Furthermore, it explores, in an innovative way, how various factors, such as the level of technological advancement in the sector, government support for innovation, investments in research and development, the degree of international involvement, and the level of education of employees, influence the probability of a company achieving the status of serial innovator. Based on data extracted from CIS reports spanning from 2012 to 2018, this research employs Logit models to explore the relationship between these variables. The findings clarify the positive impact of collaboration on a company's ability to sustain innovation over time, thereby establishing itself as a serial innovator. The promotion of collaborative networks and partnerships with external entities, such as partner companies, research institutions, and government organizations, emerges as a powerful strategy for promoting innovation in organizational contexts. Furthermore, the study reveals the critical roles played by public support for innovation, the educational level of the workforce, and investments in R&D in increasing companies' innovation capabilities. These factors contribute to increasing a company's propensity for innovation and increasing its likelihood to become a serial innovator. A qualified and educated workforce is known to have the skills and knowledge required to actively engage in innovative activities, thus positioning companies as serial innovators.

Keywords: CIS; collaboration; higher education; public support; serial innovator

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1. Introduction

In today's rapidly evolving business landscape, where disruptive technologies and changing market dynamics pose both unprecedented challenges and remarkable opportunities, the ability of companies to innovate has become a critical determinant of success (Alam et al. 2020). To maintain their competitive edge and stay relevant in an increasingly dynamic marketplace, organizations must embrace a culture of constant innovation (Tuzovic et al. 2018). However, the complexity and scope of innovation often require collaborative efforts beyond the boundaries of individual companies (Haus-Reve et al. 2019).

Innovation has emerged as a fundamental driver of progress, enabling companies to thrive in an era defined by rapid change and intense competition. The traditional paradigm of relying solely on incremental improvements is no longer sufficient to sustain long-term success. In this dynamic landscape, where disruptive technologies, shifting customer preferences, and global interconnectedness are the norm, the ability to constantly innovate has become a strategic imperative for companies across industries (Ra et al. 2019).

Companies that prioritize innovation establish themselves as trailblazers, capable of identifying emerging trends, foreseeing customer demands, and adapting swiftly to evolving market conditions. Such organizations not only survive but also excel amid turbulence, consistently propelling themselves ahead of their competitors. However, to truly embrace

the transformative power of innovation, businesses must recognize the limitations of internal capabilities and look beyond their own boundaries to foster collaborative synergies (Vojak et al. 2012; Griffin et al. 2014).

Collaboration, both within and between organizations, has emerged as a potent catalyst for innovation, unlocking new avenues for growth and amplifying the impact of individual efforts. By joining forces with external partners, businesses can tap into diverse knowledge pools, leverage complementary expertise, and co-create solutions that surpass the possibilities of solitary endeavors. The collective intelligence and shared resources that result from collaboration fuel a virtuous cycle of innovation, enhancing competitiveness and propelling industries forward (Esposito 2015; Ahmed et al. 2016).

There are several examples of companies joining forces for innovation. Innovation and collaboration, in this context, refers to how companies combine their knowledge and resources to achieve results beyond individual reach. Emblematic examples of this synergy include partnerships such as Nike and Apple, who combined their expertise in technology and design to develop products such as the Nike + iPod, integrating music and physical activity in a revolutionary way (Belal et al. 2013). Likewise, the partnership between Uber and Spotify offers users a personalized travel experience, combining transportation services and digital entertainment (Gogris 2022). Additionally, the collaboration between Tesla and Panasonic has resulted in significant advances in the production of batteries for electric vehicles, driving the adoption of sustainable technologies (Dan 2021). These cases highlight how strategic collaboration between companies can boost innovation, generating benefits for both partners and consumers.

The benefits of collaborative innovation extend beyond the individual organizations involved. By collaborating, companies can accelerate the pace of discovery, drive breakthroughs, and generate transformative solutions that address complex societal challenges. Collaborative ecosystems foster the exchange of ideas, nurture cross-fertilization of expertise, and foster a culture of openness and shared learning. Through collaborative innovation, companies not only fuel their own growth but also contribute to the greater good, creating positive ripple effects that resonate across entire industries and economies (Fawcett and Jones 2013; Cross et al. 2021).

It is possible to state, therefore, that the uniqueness of this study is related to the fact that it considers several dimensions, such as collaboration, investment in R&D, degree of export, and level of technological development, among other aspects. This multidimensional approach allows for a more complete understanding of the factors that contribute to serial innovation. In addition, the use of CIS data from the years 2012 to 2018 gives the study a robust and reliable foundation.

It should also be noted that instead of considering innovation as an isolated event, the article investigates the probability of companies being innovative continuously over time. The research gap identified in this study lies in the multidimensional approach adopted to analyze the factors that contribute to serial innovation. Furthermore, by combining data from three CIS reports, the analysis is more reliable and robust. While previous studies have often focused on isolated aspects, such as collaboration, R&D investment, or export level, or on analysing more information, they do so for a shorter time horizon. This research stands out when considering a wide range of dimensions, including collaboration, investment in R&D, degree of export, and level of technological development. This holistic approach provides a more complete understanding of the determinants of serial innovation and allows for a more comprehensive analysis of the strategies that companies can adopt to maintain a consistent pattern of innovation over time.

By understanding the importance of companies being serial innovators and recognizing the power of collaboration, companies can position themselves at the forefront of their industries, embracing tomorrow's opportunities while shaping the future of business (Tuzovic et al. 2018).

2. Literature Review

2.1. Innovation and Serial Innovation

Innovation is a driving force behind the growth and development of countries in today's dynamic and highly competitive global landscape. It plays a pivotal role in improving productivity, enhancing competitiveness, and fostering sustainable economic and social progress, and serves as a catalyst for productivity growth, enabling countries to generate higher outputs with the same or fewer resources. Innovation-driven productivity growth accounts for a substantial share of total economic growth. It enables firms to develop and adopt innovative technologies, streamline processes, and create novel products or services (Bloom et al. 2020).

Productivity growth is a key driver of income per capita, allowing nations to raise living standards and improve the overall quality of life (Acemoglu and Restrepo 2019). Innovation-driven competitiveness is critical for sustainable economic growth (European Commission 2016). By continuously introducing new and improved products, services, and business models, countries can differentiate themselves from competitors and capture market share. Nations with a strong innovation ecosystem tend to attract more investment, create high-value jobs, and enjoy a favorable trade balance (European Commission 2016; Xiao et al. 2022).

Knowledge-intensive industries, such as information technology and biotechnology, have a higher growth potential and generate greater economic value. Through investments in research and development (R&D) and the promotion of entrepreneurship and startups, countries can foster an innovation ecosystem that stimulates the development of new industries and creates opportunities for economic diversification and resilience (Acemoglu and Restrepo 2019; Johnson et al. 2022).

Technological advancements and innovative solutions are critical for tackling pressing issues such as climate change, healthcare access, and poverty alleviation. For instance, the development of renewable energy technologies and clean technologies is essential for reducing carbon emissions and ensuring a sustainable future. In addition, the application of innovative healthcare technologies and telemedicine can enhance healthcare access and quality, particularly in remote or underserved areas (Shaheen et al. 2022).

Innovation thrives in an environment that encourages knowledge exchange, collaboration, and interdisciplinary research (Hou et al. 2019). Collaboration between academia, industry, and government is vital for fostering innovation (Ferreira et al. 2023). Effective knowledge transfer mechanisms, such as research partnerships, technology transfer offices, and incubators, enable the translation of scientific discoveries into practical applications (Castañer and Oliveira 2020). By fostering a culture of collaboration, countries can harness the collective intelligence and expertise of various stakeholders, leading to breakthrough innovations and sustainable development (Yang et al. 2021).

Companies that are serial innovators and engage in fruitful collaborations are better equipped to meet market challenges, stay ahead of the competition, and achieve sustainable growth (De Noni et al. 2018).

Recurrent innovation is crucial for companies to maintain their competitive edge. This is particularly relevant in an era characterized by rapid technological advancements and shifting consumer preferences. The ability to continuously innovate ensures that companies remain relevant, engage customers, and create value (Baierle et al. 2020).

Recurrent innovation allows companies to enhance their market resilience. By regularly introducing new products, services, or processes, organizations are better positioned to withstand disruptions and economic downturns (Binns et al. 2022). As such, companies that embrace recurrent innovation are more likely to succeed in the long term.

Innovation also plays a pivotal role in meeting evolving customer expectations. Recurrent innovation allows companies to develop products and services that align with customer needs, preferences, and emerging trends. By consistently delivering innovative solutions, companies can cultivate customer satisfaction, increase loyalty, and foster long-term relationships (Tidd and Bessant 2021).

2.2. Determinants of Serial Innovation

2.2.1. The Role of Collaboration

There are several determining factors for serial innovation. One of these determinants is collaboration, which serves as a catalyst for innovation, enabling companies to leverage diverse expertise, resources, and perspectives (Fawcett and Jones 2013). The relevant literature underscores the importance of collaboration in driving innovative activities within companies (Haus-Reve et al. 2019; Esposito 2015; Tortoriello et al. 2015; González-Benito et al. 2016).

It is also important to highlight the impact of cross-functional collaboration, where individuals from different departments collaborate to generate innovative ideas and solve complex problems (Wright et al. 2022). By promoting a collaborative culture, companies encourage the exchange of knowledge, creativity, and new perspectives. In other words, cross-functional collaboration promotes creativity and innovation, breaking down silos and facilitating the flow of information (Ahmed et al. 2016; Cross et al. 2021).

Companies are increasingly recognizing the value of open innovation, which involves collaborating with external partners, such as suppliers, customers, research institutions, and startups. Open innovation practices foster a broader ecosystem of knowledge sharing and idea generation (Bertello et al. 2023). By embracing external collaborations, companies gain access to diverse expertise, resources, and novel perspectives, thereby enhancing their capacity for innovation (Radicic et al. 2020).

2.2.2. The Role of Technological and Educational Levels

In addition to the collaborative intensity, there are other factors that can impact the company's innovative initiative. Factors that influence the company's innovative activity and condition the outputs of innovation, namely regarding industrial property registrations: patent registration, trademark registration, and design registration (World Intellectual Property Organization 2022).

It should also be noted that there is a strong relationship between the specific technological level of a company's sector and its innovative capacity. Sectors characterized by greater technological intensity, such as biotechnology or artificial intelligence, tend to foster greater innovation potential due to constant advances and disruptive changes in these fields (Hong et al. 2016).

Firms operating in sectors with higher technological levels tend to have a stronger commitment to innovation, invest more in research and development (R&D), and exhibit a higher rate of product innovation. It is thus possible to state that technological intensity stimulates companies to continually push boundaries and develop innovative solutions (Hou et al. 2019).

While a high technological level in a sector offers significant opportunities for innovation, it also presents challenges that companies must navigate. One key challenge is the need for a skilled and adaptable workforce (Davey et al. 2016). As technology advances rapidly, companies must ensure their employees possess the necessary skills to leverage emerging technologies effectively. Firms operating in highly technologically intensive sectors face increased demand for specialized talent, leading to fierce competition for skilled individuals. In this way higher education plays a pivotal role in shaping the innovative capacity of individuals (Li 2022). There is a positive correlation between educational attainment and innovation. Individuals with higher education possess advanced analytical and critical thinking skills, critical thinking abilities, and domain-specific knowledge, which are crucial for generating innovative ideas (Ra et al. 2019).

In this way, it is possible to highlight the importance of higher education institutions as sources of knowledge creation and diffusion (Chais et al. 2017).

Several studies highlight the importance of collaboration between universities and industry as this collaboration plays a crucial role in advancing knowledge and technological innovation (Chais et al. 2017; Huggins and Johnston 2009). This collaboration stimulates academic research, producing innovation that meets the needs of companies, boosting

investment in scientific capital and encouraging patenting in the most diverse areas (Faria et al. 2019). For example, the interaction between R&D activities in medical schools and hospitals is fundamental given that R&D activities in medical schools influence R&D activities in hospitals, and vice versa (Faria et al. 2021).

Universities and research institutions serve as hubs for research and development activities, fostering collaborations between academia and industry. This interaction enables the transfer of innovative knowledge and promotes the development of innovative solutions (Huggins and Johnston 2009).

Companies that employ workers with higher education qualifications tend to have a competitive advantage in terms of innovation. Such workers bring a range of valuable skills to the table, including technological expertise, research capabilities, and the ability to apply theoretical knowledge to practical challenges (Haskel and Westlake 2023).

2.2.3. The Role of Public Support and R&D Investment

Other factors, such as public support for innovation, play a crucial role because public funding of R&D significantly enhances companies' innovative capabilities (Guellec and Pottelsberghe 2000). It provides resources and financial incentives that enable firms to engage in riskier, long-term research projects, which may not be financially viable in the short run (Hong et al. 2016).

Innovation is inherently risky, particularly for smaller companies with limited financial resources. Public support acts as a risk-sharing mechanism by mitigating financial and market risks. Government grants, tax incentives, and subsidies can alleviate the burden of high upfront costs associated with innovation, enabling companies to experiment and invest in disruptive ideas. Public financial support reduces the aversion to risk, encouraging companies to undertake ambitious innovation projects with higher potential societal impact (Mina et al. 2021).

With or without public support, the truth is that the investments made by the company in R&D are important. These investments may refer to internal R&D expenditures or they may refer to external expenditures, and they serve as a catalyst for technological advancements, propelling companies to develop cutting-edge solutions. By allocating resources to R&D, organizations can explore new technologies, experiment with ideas, and uncover breakthrough innovations (Alam et al. 2020; Greve 2003).

Effective product development is crucial for organizations seeking to meet evolving customer needs and preferences. Recent studies highlight the vital role of R&D expenses in enhancing product development processes. As such, increased R&D spending allows companies to conduct extensive market research, identify emerging trends, and design innovative products accordingly (Kim and Lee 2022; Delgado-Verde and Díez-Vial 2023).

2.2.4. The Role of Internationalization

Another factor that influences the innovative activity of companies and the result of this activity is the degree of internationalization of companies. The degree of internationalization can be evaluated according to the turnover resulting from exports. In this sense, exports enable companies to reach larger markets, providing them with increased opportunities to sell their products and services. Firms that engage in exporting tend to have a stronger focus on innovation compared to their non-exporting counterparts (Li et al. 2011). The access to larger markets leads to increased demand, motivating companies to invest in R&D to improve existing products or develop new ones to meet the varied needs of international consumers (Ortigueira-Sánchez et al. 2022).

In this way, it is possible to state that exports expose companies to different international markets, customers, and competitors, promoting learning and knowledge transfer. That is, it acts as a facilitating element in the acquisition of knowledge about innovative technologies, production processes, and marketplaces. This knowledge can stimulate innovative thinking in companies, leading to the development of new products, services, and business models. In addition, it also drives companies to adapt their products and

processes to meet the standards, regulations, and preferences of international customers (Ortigueira-Sánchez et al. 2022).

In conclusion, it is possible to point out that export-oriented companies operate in clusters or supply chains, promoting collaboration and knowledge propagation effects (Hou et al. 2019). These collaborations allow companies to leverage the complementary strengths of their partners, leading to accelerated innovation processes and the development of new and improved products (Baierle et al. 2020).

3. Methodology

3.1. Variables Used

According to our literature review, serially innovative companies are expected to belong to sectors of activity with greater technological development, that receive public support for innovation, invest in R&D, are more international and have a reputation in foreign markets, have a highly qualified workforce, and present a high degree of collaboration. This list of concepts is summarized in Figure 1.

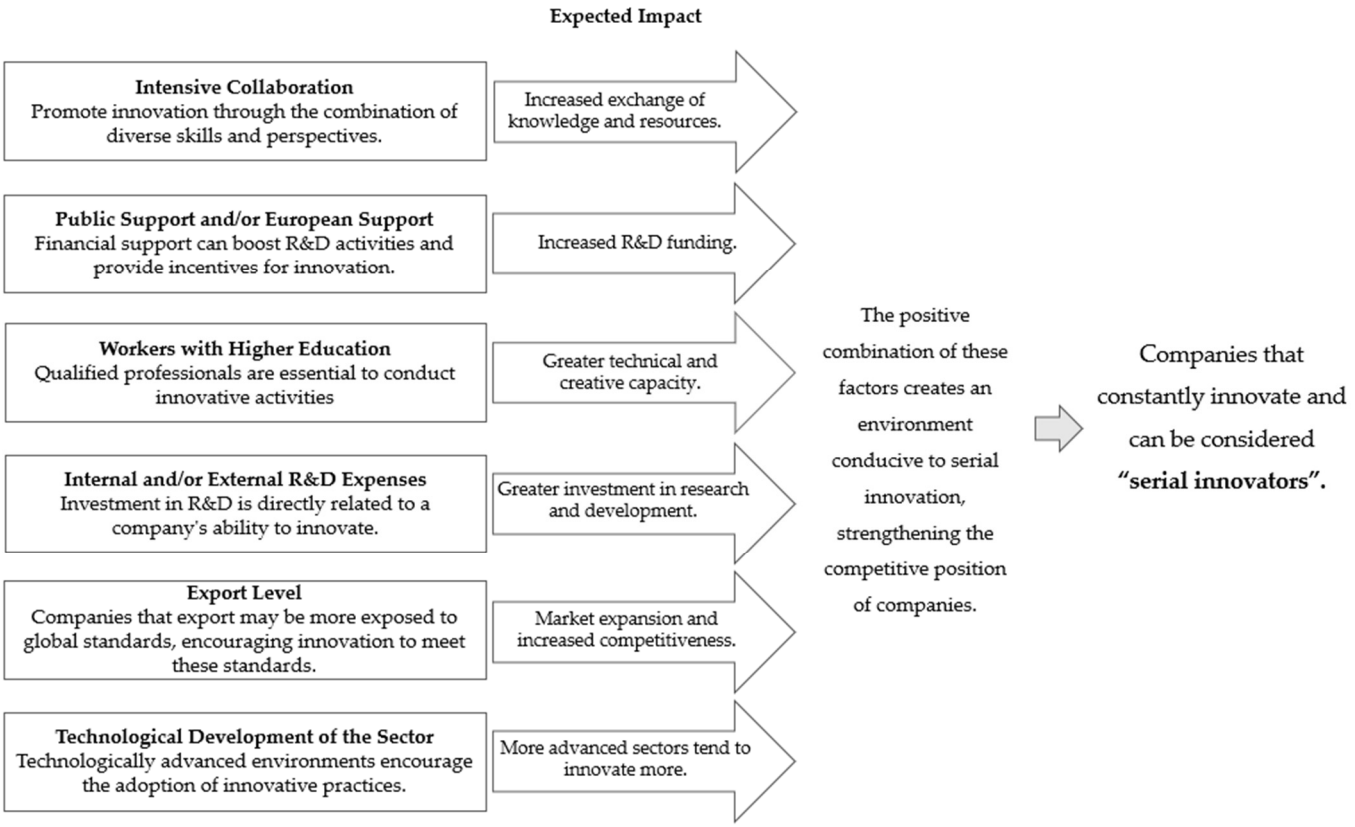

Figure 1. Importance and expected impact of explanatory variables on the dependent variable "Serial Innovator".

Based on the literature review carried out previously and summarized in Figure 1, this study seeks to answer the following question: What impacts do the degree of collaboration, public support, workers with higher education, investments in R&D, degree of internationalization, and degree of technological development have on the likelihood of companies being serial innovators, promoting their innovative performance and competitiveness through the production of results of industrial property registrations?

To achieve the proposed objective, data were collected from the Community Innovation Survey (CIS), which is the main statistical survey (mandatory for EU member states) on innovation in companies. These data refer to companies in Portugal.

CIS operations are based on the conceptual framework set out in the Oslo Manual (Organization for Economic Co-operation and Development. European Commission and Eurostat 2005), as well as Eurostat's methodological recommendations. This survey, which takes place every two years, aims to produce and update statistical indicators on innovation in companies through a survey harmonized at the European level, which allows the international comparison of data, as well as responding to national and international collection commitments and the treatment and dissemination of official Science and Technology statistics, namely the commitments assumed with Eurostat to produce statistics on Innovation.

The 2018 CIS survey comprises 13,701 companies, the 2016 CIS survey comprises 6775 companies, and the 2014 CIS survey includes 7083 companies. By compiling these three surveys into a single database, ranging from 2012 to 2018, 1857 companies common to the three surveys were identified.

When constructing the survey every two years, the questions and information collected may differ; therefore, the three CIS surveys were compared and common information was identified, defining the variables shown in Table 1.

Table 1. Variables.

Acronym	Variable
SI	1 if companies presented innovation results (industrial property registrations) over the period 2012 to 2018 being called "serial innovators"
HT	1 if the company belongs to a high-tech technology sector
MHT	1 if the company belongs to a medium-high technology sector
MT	1 if the company belongs to a medium technology sector
MLT	1 if the company belongs to a medium-low technology sector
LT	1 if the company belongs to a low technology sector
ESI	1 if company received European support for innovation at least once in the period 2012 to 2018
NSI	1 if the company received National support for innovation at least once in the period 2012 to 2018
ENSI	1 if the company received European and National support for innovation at least once in the period 2012 to 2018
iR&D	Average value of internal expenses on R&D in the period 2012 to 2018
eR&D	Average value of external expenditure on R&D in the period 2012 to 2018
EXP	Average percentage of turnover resulting from exports for the period 2012 to 2018
WHE	Average percentage of workers with higher education for the period 2012 to 2018
HC	1 if the company always cooperated from 2012 to 2018
MC	1 if the company collaborated for 4 years in the period 2012 to 2018
LC	1 if the company collaborated for 2 years in the period 2012 to 2018
NC	1 if the company never collaborated in the period 2012 to 2018

3.2. Data

To empirically assess the impact of the previously identified factors on companies' innovative behavior, we first analyzed the data using SI as the dependent variable in a multivariate logit model. The variable SI takes the value 1 if the company was a serial innovator, that is, if it presented innovation results throughout the period from 2012 to 2018 as measured by registering industrial property in all periods (and takes the 0 value otherwise). Using a likelihood function that is constructed to be appropriate for binary dependent variables, the logit model allows the estimation of the probability that serial innovation occurs or not by predicting the binary outcome from a set of explanatory variables. The

remaining variables shown in Table 1 were used as independent (explanatory) variables in the model. As a robustness test, and to further enhance our understanding of companies' innovative behavior, we then analyzed the same data using SI_ORD as the dependent variable in an ordered logit model. In this case, the dependent variable SI_ORD takes the 0 value if the company did not present innovation results during the period from 2012 to 2018; takes the value 1 the company innovated once in the period from 2012 to 2018; takes the value 2 if the company innovated twice in the period from 2012 to 2018; and takes the value 3 if the company innovated three times in the period from 2012 to 2018.

To build the models that allow us to analyze which characteristics led some companies to have proven to be serially innovative for the period under analysis, it was necessary to reorganize the database; to this end the explanatory variables were defined based on the average values for the period from 2012 to 2018 as defined by the three CIS reports used in this study.

Starting with the characterization of the sample of data used in this study, we determined that of the 1857 companies, about 67.10% of the companies never registered industrial property, that is, they did not present outputs of their innovative activity. In turn, 17.02% of the companies presented innovation outputs once, which corresponds to two years; 8.67% of the companies presented results in 4 of the 6 years under study. Finally, 7.22% of the companies, that is, 134 of the 1857 companies, constantly innovated throughout the period, being serial innovators, as we can see in Table 2.

Table 2. Relative frequencies and means of variables.

Variables		Value 0	Value 1
Binary variables	SI	92.78%	7.22%
	HT	94.99%	5.01%
	MHT	88.15%	11.85%
	MT	85.95%	14.05%
	MLT	67.37%	32.63%
	LT	63.54%	36.46%
	ESI	82.44%	17.56%
	NSI	71.46%	28.54%
	ENSI	92.46%	7.54%
	HC	90.90%	9.10%
	MC	89.23%	10.77%
	LC	82.98%	17.02%
	NC	36.89%	63.11%
Variables		Average	Companies with registration 0
Non-binary variables	iR&D	256,445.72	57.84%
	eR&D	50,147.59	75.18%
	EXP	27.19%	24.82%
	WHE	-	8.29%

Concerning the level of technological development of the sector of activity to which the companies belong, 5.01% belong to high technology sectors, 11.85% belong to medium-high technology sectors, 14.05% correspond to medium technology sectors, 32.63% belong to medium-low technology sectors, and the remaining 36.46% belong to low-technology sectors.

Regarding public support for innovation, of the 1857 companies studied, 46.37% never received any kind of support; 17.56% received European support and 28.54% received national support for innovation.

As for investment in R&D carried out internally, more than half of the companies (approximately 57.84%) did not invest during the period 2012 to 2018. As for the rest, the average investment was approximately EUR 256,446. This investment was considerably higher than investments in R&D carried out outside the companies, which have an average value of EUR 50,148. Furthermore, most companies did not make any external investment

in R&D, given that approximately 75.18% of the 1857 companies indicated that they had not incurred these expenses.

Regarding the export activity of the companies, evaluated by the percentage of their turnover resulting from sales to foreign markets, we determined that around 24.82% of the companies did not sell to markets other than the national market. In turn, only 0.5% indicated that all their sales were to foreign markets. On average, for the 1857 companies, the turnover resulting from exports was 27.19%.

When we analyze the qualified workforce of the companies, on average, 31.29% of companies have less than 5% of workers with higher education. Most companies (about 43.46%) have between 10% and 25% of workers with higher education and 20.73% of companies have between 25% and 75% of workers with higher education. Finally, only 4.52% of the 1857 companies have more than 75% of their workers with this level of training.

Of the 1857 companies analyzed, the majority (about 63.11%) never participated in collaborative activities for innovation. Of those who claimed to have collaborated, 17.02% collaborated in 2 of the 6 years analyzed, 10.77% collaborated in 4 of the 6 years, and the remaining 9.10% (169 companies) were involved in collaborative activities for innovation throughout the entire analyzed period.

Having presented the characterization of the sample used in this study, it is now important to analyze only those companies deemed to be "serial innovators". As mentioned, of the 1857 companies, 134 were deemed "serial innovators" in the period from 2012 to 2018.

Regarding the level of technological development to which those companies considered serial innovators belong, it appears that the majority (36.6%) are companies that belong to sectors of medium-low development, followed by the sector of low technological development (22.4%). Approximately 16% of the companies belong to sectors of high technological development.

As for the public support received by these companies to finance their innovation activities, it appears that of the 134 companies considered serial innovators, 99 received support for innovation and 35 did not receive any support in the period from 2012 to 2018. Of the companies that received support, 37 received European support and/or national Support, that is, about 28% of the companies studied.

As for investments in R&D activities, it appears that investments made internally are considerably higher than investments made externally. In this case, on average, serial innovative companies invested EUR 1,358,565.60 internally and EUR 202,289.33 externally. That is, internal investments are about 6.7 times greater than external investments in R&D activities.

As a way of evaluating the degree of internationalization of the companies, the proportion of results from export sales was used. In this case, serial innovative companies report, on average, approximately 40% of their results from exports.

With respect to the level of education of the population employed in companies that are serial innovators, it appears that on average 10% to 25% of workers have higher education.

Finally, most of the serial innovators showed high levels of collaboration. It appears that 36.6% of the companies collaborated throughout the period under analysis. However, a considerable part (approximately 26.9%) never collaborated during the period from 2012 to 2018.

4. Result Analysis

Table 3 shows the results from the Logit model with the variable SI as the dependent variable. Data on the quality of fit of the model estimated in Tables 4 and 5 show the results of the estimates for the marginal effects of the logit model.

Table 3. Logit Model for constant innovation.

Serial Innovator (SI) as a Dependent Variable			
Variable	**Estimate**	**SE**	**Z**
HT	0.636556 *	0.366616	1.74
MHT	0.129417	0.336545	0.38
MT	−0.215119	0.383263	−0.56
MLT	0.301676	0.271714	1.11
ESI	0.802866 ***	0.222307	3.61
NSI	0.556317 ***	0.209302	2.66
iR&D	4.87×10^{-8}	3.13×10^{-8}	1.55
eR&D	1.92×10^{-7}	1.35×10^{-7}	1.42
EXP	0.352742	0.297178	1.19
WHE	0.197656 ***	0.073367	2.69
HC	1.455059 ***	0.294559	4.94
MC	0.637404 **	0.310611	2.05
LC	0.565539 **	0.283901	1.99
constant	−4.557746 ***	0.365878	−12.46

N = 1857; LR $\chi 2$ = 169.60; Log likelihood = −396.5134; p-value = 0.0000; Pseudo R^2 = 0.1762. ***: $p < 0.01$; **: $p < 0.05$; *: $p < 0.10$.

The likelihood ratio test for the null hypothesis that all the variables' coefficients are zero yields a $\chi 2$ statistic of 160.60, implying a p-value less than a significance level of 1%. Therefore, we reject the null hypothesis and conclude that the model is globally statistically significant. The percentage of correctly classified values was also estimated, indicating that the model correctly predicts 92.95% of the observations.

Table 4. Measures of Fit for logit of SI.

Correctly classified	0.9295	Log-Lik Full Model	−396.513
Log.Lik Intercept Only	−481.314	LR(20)	169.602
D (1843)	793.027	Prob > LR	0.000
McFadden's R^2	0.176	McFadden's Adj R^2	0.147
Maximum Likelihood R^2	0.087	Cragg & Uhler's R^2	0.216
McKelvey and Zavoina's R^2	0.240	Efron's R^2	0.131
Variance of Y	4.328	Variance of error	3.290
Count R^2	0.929	Adj Count R^2	0.022
AIC	0.442	AIC n	821.027
BIC	−1307.714	BIC'	−71.754

Table 5. Estimates of the marginal effects of regressors on SI.

Serial Innovator (SI) as a Dependent Variable						
Variable	**Estimate**	**SE**	**Z**	**95% CI**		**X**
HT	0.036008	0.02660	1.35	−0.016120	0.088135	0.050081
MHT	0.005861	0.01594	0.37	−0.025372	0.037094	0.118471
MT	−0.008689	0.01442	−0.60	−0.036951	0.019573	0.140549
MLT	0.013731	0.01301	1.06	−0.011771	0.039232	0.326333
ESI	0.044687 ***	0.01560	2.86	0.014108	0.075266	0.175552
NSI	0.027068 **	0.01131	2.39	0.004903	0.049233	0.285407
iR&D	2.11×10^{-9}	0.00000	1.53	-6.0×10^{-10}	4.8×10^{-9}	256,446
eR&D	8.29×10^{-9}	0.00000	1.41	-3.2×10^{-9}	2.0×10^{-8}	50,147.6
EXP	0.015267	0.01282	1.19	−0.009852	0.040387	0.271888
WHE	0.008555 ***	0.00312	2.74	0.002441	0.014669	3.44067
HC	0.111342 ***	0.03457	3.22	0.043576	0.179108	0.091007
MC	0.034924 *	0.02078	1.68	−0.005806	0.075654	0.107701
LC	0.029223 *	0.01703	1.72	−0.004147	0.062593	0.170167

Marginal effects after logit; y = Pr(NS) (predict) = 0.04533729. ***: $p < 0.01$; **: $p < 0.05$; *: $p < 0.10$.

Through the presented model, it is verified that the variables associated with the degree of technological development are not statistically significant. Therefore, it is not possible to state that companies belonging to sectors with a higher technological level are more likely to be serial innovators.

The ESI and NSI variables correspond to public support from European funds and national funds, respectively. As the two variables are statistically significant, we find that companies that receive European support are more likely to be serial innovators (4.47 percentage points). Firms that receive national support are also more likely (2.71 percentage points) to be serial innovators.

Investments in R&D, whether made internally (iR&D) or externally (eR&R), do not seem to have an impact on whether companies are serial innovators. Likewise, the EXP variable, referring to the percentage of turnover resulting from sales to foreign markets, does not seem to contribute to the probability of companies being serial innovators.

A highly skilled workforce has a positive impact on the likelihood of companies being serial innovators. The results obtained suggest that this impact is positive by about 1 percentage point.

Finally, when we analyzed the variables referring to the level of collaboration of the companies, we verified that the companies that present low levels of collaboration, that is, that collaborated in 2 of the 6 years, see their probability of being serial innovators increase by 2.29 percent points. For companies that are moderate collaborators, that is, they collaborated in 4 of the 6 years, the probability of being a serial innovator increases by 3.49 percentage points. However, the greatest impact on innovation (approximately 11.13 percentage points) stems from the intensive collaboration of companies that collaborated throughout the period from 2012 to 2018.

Table 6 shows the results from the Ordered Logit model with the variable SI_ORD as the dependent variable. Table 7 shows the results of the estimates of the marginal effects of the explanatory variables on the probabilities that SI_ORD takes each of its possible values.

Table 6. Ordered Logit Model (SI-ORD).

Variable	Estimate	SE	Z
HT	0.42893 *	0.23372	1.84
MHT	0.23223	0.17289	1.34
MT	0.09642	0.17736	0.54
MLT	0.26401 *	0.13444	1.96
ESI	0.88839 ***	0.13409	6.63
NSI	0.20655 *	0.11707	1.76
iR&D	7.32×10^{-8} **	3.01×10^{-8}	2.43
eR&D	1.21×10^{-7}	1.20×10^{-7}	1.00
EXP	0.24726	0.16291	1.52
WHE	0.19478 ***	0.03567	5.46
HC	1.19062 ***	0.18796	6.33
MC	0.57553 ***	0.16593	3.47
LC	0.71604 ***	0.13478	5.31

N = 1857; LR $\chi 2$ = 337.84; Log likelihood = −1633.8547; p-value = 0.0000; Pseudo R^2 = 0.0937. ***: $p < 0.01$; **: $p < 0.05$; *: $p < 0.10$.

In Table 7, it is possible to see that, regarding the level of technological development, companies that belong to high technology sectors increase the probability of innovating once or twice in the analysed period by four percentage points (pp) and by three percentage points, respectively. In other words, even though this variable (HT) did not prove to be statistically significant in the logit model in Table 5, it is a fact that it contributes positively to innovation even though it may not have any impact on serial innovation. In the same sense, the ordered logit model showed that companies belonging to medium-low technology sectors see their probability of innovating increased; however, the magnitude of this probability is reduced (around 1 to 2 percentage points).

Table 7. Estimates of the marginal effects of the explanatory variables on the probabilities of SI_ORD.

	Pr(SI_ORD = 0)	Pr(SI_ORD = 1)	Pr(SI_ORD = 2)	Pr(SI_ORD = 3)
HT	−0.09816 * (0.05612)	0.04237 * (0.02174)	0.03103 * (0.01879)	0.02476 (0.01595)
MHT	−0.05156 (0.03942)	0.02353 (0.01729)	0.01585 (0.01243)	0.012183 (0.00984)
MT	−0.02103 (0.03914)	0.00984 (0.01806)	0.00637 (0.01197)	0.00481 (0.00914)
MLT	−0.05776 * (0.02981)	0.02686 ** (0.1364)	0.01756 * (0.00925)	0.01334 * (0.00714)
ESI	−0.20629 *** (0.03236)	0.08256 *** (0.01155)	0.06715 *** (0.01223)	0.05658 *** (0.01144)
NSI	−0.04518 * (0.02597)	0.02104 * (0.0119)	0.01373 * (0.00804)	0.01041 * (0.00619)
iR&D	-1.58×10^{-8} ** (0.0000)	7.49×10^{-9} ** (0.0000)	4.73×10^{-9} ** (0.0000)	3.54×10^{-9} ** (0.0000)
eR&D	-2.60×10^{-8} (0.0000)	1.23×10^{-8} (0.0000)	7.80×10^{-9} (0.0000)	5.85×10^{-9} (0.0000)
EXP	−0.05325 (0.3508)	0.02529 (0.01672)	0.01599 (0.01059)	0.01197 (0.00793)
WHE	−0.04195 *** (0.00763)	0.019992 *** (0.00382)	0.012597 *** (0.00242)	0.00943 *** (0.00184)
HC	−0.28347 *** (0.04527)	0.09569 *** (0.1035)	0.09689 *** (0.01848)	0.09088 *** (0.02133)
MC	−0.13259 *** (0.04003)	0.05594 *** (0.01498)	0.04233 *** (0.0138)	0.03432 *** (0.0122)
LC	−0.16492 *** (0.03227)	0.06875 *** (0.01224)	0.05286 *** (0.01148)	0.04329 *** (0.01035)

***: $p < 0.01$; **: $p < 0.05$; *: $p < 0.10$.

When analysing the impact of public support for innovation, it is highlighted that European support is significant, increasing the probability of innovating once by around 8 pp, innovating twice by 6.7 pp, and innovating three times by 5.7 pp. Likewise, national support contributes positively, although to a lesser extent (1 to 2 pp). These results, analysed in a disaggregated manner, are in accordance with the results in Table 5.

Analysing the results corresponding to the variables of investment in R&D and degree of internationalization, the results obtained are in line with the results obtained in Table 5, confirming their reduced or no impact on the probability of companies innovating more.

When it comes to employee training, it is confirmed that the positive impact on the likelihood of companies innovating is very low. However, the ordered logit model allowed us to verify that, effectively for serial innovation, the impact of the WHE variable is practically zero. However, it is a determinant to take into consideration as it appears that for innovating once or twice, this variable increases the probability of companies innovating by 2.5 pp and 1.6 pp, respectively.

Finally, regarding the degree of collaboration, the results corroborate the results in Table 5, verifying that companies that present high levels of collaborative activities are the ones that are most likely to innovate recurrently (9.1 pp) but also more intermittently (9.6 pp and 9.7 pp).

The findings of the scientific article provide valuable insights into the factors influencing a company's propensity for serial innovation. Through rigorous statistical analysis, the researchers demonstrate that variables associated with the degree of technological development do not hold statistical significance in determining whether companies are

serial innovators. This challenges previous assumptions regarding the correlation between technological advancement and innovation propensity. However, the study identifies that public support, both from European and national funds, significantly increases the likelihood of serial innovation, indicating the pivotal role of governmental funding in fostering innovative activities within companies. Interestingly, investments in R&D, whether internal or external, as well as the percentage of turnover from foreign markets, do not appear to affect a company's serial innovation status. On the other hand, a highly skilled workforce emerges as a crucial factor positively impacting the probability of serial innovation, highlighting the importance of human capital in driving innovation processes. Moreover, the level of collaboration among companies demonstrates a substantial influence, with intensive collaboration over a prolonged period exhibiting the most significant impact on innovation propensity.

5. Conclusions

In conclusion, this scientific article underscores the paramount significance of collaboration for companies in their pursuit of constant innovation. The dynamic landscape of the global marketplace demands that businesses proactively engage in collaborative efforts to remain competitive and drive progress. Through collaboration, companies can leverage the collective expertise, diverse perspectives, and complementary resources of individuals and organizations, fostering an environment conducive to innovation.

Furthermore, this study emphasizes the crucial role of public support in fostering innovation within the business sector. Governments, policymakers, and regulatory bodies play a pivotal role in creating an enabling environment that encourages and supports innovation. By implementing policies and initiatives that promote research and development, provide financial incentives, and foster collaboration between industry and academia, public support can catalyze innovation and enhance a company's ability to innovate.

Another significant finding of this research is the indispensable contribution of workers with higher education to the innovation process. Employees with advanced knowledge and expertise in their respective fields can drive innovation through their critical thinking, analytical skills, and ability to apply theoretical knowledge to practical challenges. Encouraging and investing in higher education and lifelong learning programs can contribute to a skilled and adaptable workforce, capable of driving innovation in various sectors.

These conclusions have significant implications for decision-making by both companies and public entities. Companies need to recognize and prioritize collaboration as a core value, promoting cross-functional teamwork, knowledge-sharing platforms, and open communication channels. By doing so, they can foster an innovative environment that thrives on the collective intelligence of their employees.

Public entities, on the other hand, should prioritize policies and initiatives that support and incentivize innovation. This can include funding programs for research and development, tax incentives for innovative companies, and partnerships between academic institutions and industries. Additionally, promoting higher education and continuous learning opportunities can contribute to a knowledgeable workforce that can drive innovation across sectors.

Collaboration, public support for innovation, and a highly educated workforce are indispensable pillars for companies and public entities seeking to foster a culture of continuous innovation. Embracing these principles can not only lead to competitive advantages for companies but also drive economic growth, societal progress, and the overall betterment of communities. By incorporating these findings into their decision-making processes, both companies and public entities can chart a path towards a future marked by innovation, prosperity, and sustainable development.

The analysis of the characteristics that drive companies to be serial innovators revealed valuable insights that can guide future strategies in the business landscape. An in-depth understanding of these essential elements provides a solid foundation for designing and implementing policies aimed at continuous innovation. Furthermore, this study plays a

fundamental role in transcending the limits of business development, paving the way for more specific and sustainability-oriented investigations. Therefore, by using the findings presented here as a starting point, future studies can deepen our understanding of the synergies between innovation and sustainability, promoting balanced and sustainable economic development.

In summary, the study emphasizes two main implications, both theoretical and practical, in the context of business innovation. Theoretically, it highlights the importance of collaboration, public support, and a qualified workforce as fundamental pillars to drive continuous innovation in companies. This theoretical perspective suggests that innovation is not just a product of internal effort, but rather a result of the interaction between different agents, including employees, public entities, and highly trained professionals. In practical terms, the study suggests that companies should prioritize the creation of collaborative environments, invest in continuing education programs for their employees and seek strategic partnerships with the public and academic sectors. Furthermore, public entities are urged to implement policies to support innovation, such as funding for research and development, tax incentives and higher education programs. These theoretical and practical implications provide a roadmap for companies and public entities interested in promoting innovation as an engine for sustainable growth and economic development.

Despite the results of this study, it is important to consider its limitations, which will serve as starting points for future research.

One of these limitations is the restriction to data exclusively from Portuguese companies, which makes it impossible to extrapolate the results beyond this specific context. Given that Portugal does not stand out as a leading country in innovation, it would be important to include data from companies in other nations for a more comprehensive understanding of the drivers of serial innovation.

Furthermore, when extending the analysis period from 2012 to 2018, it was necessary to consolidate information from three CIS reports, which may have resulted in the loss of relevant data. To mitigate these limitations, it is suggested that future research adopt approaches that allow for more comprehensive and detailed data collection, possibly through a questionnaire designed to identify a broader range of factors influencing serial innovation and its relationship to economic performance.

Likewise, future studies would highlight the investigation of the role of collaboration with the public sector and the availability of financing as potentially relevant factors for contributions to serial innovation between companies.

Furthermore, other possibilities could be considered, such as the lack of in-depth analysis of the human resources management strategies of the companies investigated, as well as the lack of analysis of macroeconomic variables that can influence the innovation capacity of companies.

To advance the understanding of these issues, it is suggested that future investigations incorporate more comprehensive and multidisciplinary methodologies, which allow a more complete analysis of the determinants of serial innovation and its impact on business performance.

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