



Science and Technology Parks: Opening the Pandora's Box of Regional Development

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Received: 10 November 2021 / Accepted: 24 February 2022

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Abstract

For the last decades, Science and Technology Parks (STPs) have been emerging to help in the development of regions; as a consequence, there has been an improvement in RIS (Regional Innovation System) performance. This research aims to assess the contribution of STPs to the performance improvement of RIS in Portugal. A quantitative methodology is used, based on a framework, which is supported by four latent variables: (1) Policy Instrument (PI); (2) Regional Innovation Inputs (INNI); (3) Regional Innovation Outputs (INNO), and (4) Regional Idiosyncrasies (REG). The data was collected from Regional Innovation Scoreboard reports available for the seven Portuguese regions: North, Center, Lisbon, Alentejo, Algarve, and Autonomous Regions of Azores and Madeira between 2007 and 2018. The working sample is composed of 392 observations. Our findings show a clear innovation delimitation in Portugal. The North, Center, and Lisbon areas are the areas that have strong innovation. The rest of the country has moderate innovation, including the autonomous regions. Nonetheless, an improvement in innovation was registered between 2016 and 2019 in all regions except Alentejo and Algarve. This aligns with the Policy Instrument's positive influence on the Regional Innovation inputs, which positively influences the Regional Innovation Outputs. The outcome allowed practical suggestions for regional stakeholders. This research is original for its methodological approach, never applied to the Portuguese context.

Keywords Regional innovation systems · Science and technology parks · Regional innovation scoreboard · Efficiency · Dominant policy input · Structural equation modelling

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Introduction

Since the end of 2019, the world has faced the COVID-19 pandemic, which has affected millions of people in several countries, leading to a global health calamity and consequently to an economic and social crisis, affecting companies and their workers (Guaralda et al., 2020; Peiró et al., 2020). In this context, we have witnessed changes in the behaviour of individuals and society, consequently resulting in social distance, mandatory confinement, teleworking, and online teaching. Moreover, we are observing a movement of individuals to areas with less population density that are considered safe (Donthu & Gustafsson 2020; Guaralda et al., 2020; Zenkteler et al., 2021); definitively, such changes will have an impact on the regions.

The Regional Innovation System (RIS) approach is based on the literature on economic geography, learning regions, innovative means, Marshallian industrial districts, clusters, and national innovation systems (Lopes & Franco, 2019; Roman et al., 2020). RIS highlights the relevance of innovation in the development of regions (Asheim et al., 2011; Fernandes et al., 2020; Oliveira et al., 2019). From this point of view, innovation can be referred to as a consequence of the interaction between different actors, distributed by different organizations and different locations (Cooke, et al., 1997; Doloreux, 2002). The performance of RIS depends on the interactions of knowledge by part of the actors, whether outside or inside a region (Lopes & Franco, 2019).

Overall, researchers have devised the study of RIS in two lines: (1) how organizations (regional actors) interact with each other and (2) the role that each organization plays in the dissemination and production of knowledge (Doloreux & Porto Gomez, 2017; Roman et al., 2020). It is possible to affirm that actors are involved in interactive learning in this environment. Associated with RIS are the triple helix and quadruple helix models, which are often based on regional development. The triple helix model consists of the interactions between three actors (academia, industry, and government) (Etzkowitz & Leydesdorff, 2000; Lopes & Franco, 2019). On the other hand, in the quadruple helix model, a new propeller is added, the “society” (Carayannis & Campbell, 2009; Grundel & Dahlstrom, 2016). The quadruple helix model has been acutely studied as there is a need to make it operational to increase innovations and sustainable growth (Barbulescu & Constantin, 2019; Park, 2014; Yun & Liu, 2019). When the quadruple helix model is efficiently applied, it is expected that the regions’ policymakers will become more flexible, thus allowing an entrepreneurial process of discovery based on the region. Consequently, an increment in discoveries and experimentation is expected, also allowing innovation to increase (Carayannis & Grigoroudis, 2016; Carayannis et al., 2017).

The quadruple helix model was considered in the regional innovation policy implemented in 2014 — Research and Innovation Strategies for Smart Specialization (RIS3). RIS3 is a set of policies that consents to the use of European Structural and Investment Funds (ESIF) in European regions. RIS3 aims to accelerate technological development and innovation by strengthening research (Roman et al., 2020).

The RIS3 concept is based on the fact that any region, especially the least developed and in transition to generate capacities, taking into account the particularities of the region, aiming to gain competitive advantages in some market niches (Foray, 2014; Lopes et al., 2019b; Marques et al., 2020).

In this context, Science and Technology Park's (STPs) have been emerging in the last 20 years (and continuing to grow), to help in the development of regions (Khanmirzaee et al., 2021); these are widely seen as important tools for economic and technological development (Audretsch & Link, 2012; Phan et al., 2005). Since the creation of STPs, there has been an improvement in RIS performance (Cooke, 2001; Gkypali et al., 2016). On the other hand, some authors are not convinced of the actual purposes of the STPs, indicating that they are purely real businesses estates, unable to fulfil the premises for which they were created (Massey et al., 2003; Miao et al., 2015). Several reasons are pointed out for the failure of the STPs: (1) the failing promises, which did not take into account the socioeconomic context of the regions where they operate; and (2) the proponents failed to adjust the regional concept over time, making STPs inappropriate for changing political and economic contexts (van Winden et al., 2013). However, a gap remains to be explored, as STPs are often analysed in isolation, without considering the socioeconomic, industrial, and institutional dynamics of the regions where they operate. Another condition that is being neglected is that most studies analyse STPs at a specific point in time (Carvalho & Van Winden, 2017).

Within this framework, Gkypali et al. (2016) employ the regional innovation systems (RIS) concept, proposing a methodological approach that allows assessing the contribution of a Science and Technology Park's (STPs) to RIS performance in Greece. The methodological approach of Gkypali et al. (2016) encompasses (1) the RIS idiosyncrasies; (2) the intervention of government expenditures on R&D; and (3) the production and management of knowledge, taking into account the decisions of policymakers who design and implement Science, Technology and Innovation (STI) policies. Gkypali et al. (2016) recommend their model application in other contexts, which can help policymakers to formulate new policies.

This research aims to assess the contribution of STPs to the performance improvement of RIS in Portugal. That said, we intend to make a longitudinal study to evaluate the contribution of Science and Technology Parks (STPs) in the performance of RIS. To achieve this objective, the method developed by Gkypali et al. (2016) will be used in Portugal.

This research is original for applying a methodological approach, never before applied to the Portuguese context. This research contributes to the enrichment of RIS literature. From the obtained results, some suggestions are given to the regional stakeholders. These recommendations aim to contribute to the development of RIS performance in the area under analysis.

State of Art

Regional Innovation System Framework

Innovation can be defined as a persistent and ubiquitous wealth creation process that seeks to transform knowledge into solutions, whether in new technologies, products, or services (Dziallas & Blind, 2019). This interpretation allows us to embrace, from the beginning, not only a “technological front” but include in this dynamic the social process in the concrete space of an economy. An outcome of this social and, so often, elusive nature of innovation is the region; a combination of specific skills and knowledge, learning, and different actors (public and private institutions), appears as its preferred territory — importance acknowledged by several researchers (Pouder & John, 1996).

In recent years, innovation and entrepreneurship have gained momentum as the main drivers for regional development and growth (Audretsch & Keilbach, 2005; Cooke et al., 1997; Cornett, 2009; Doloreux, 2011). New theories arose by placing innovation and entrepreneurship as endogenous variables, contributing to regional economic growth (Romer, 1994), highlighting the relationship between innovative and entrepreneurial appropriations, resources, capacities, knowledge and capital, and regional performance concerning their economic development and growth.

In this context, the concept of Regional Innovation System (RIS) is of particular importance as a perspective on the articulation, in different nodes; the interaction, at different levels (national, super-regional, and international); and the contribution of various elements, actors and networks to the regional success of innovation (Asheim & Coenen, 2005; Samara et al., 2020). Innovation is revealed in complex and interdependent processes on organizational capacities, of “unnegotiated interdependencies” (Christopherson & Clark, 2007; Muller & Zenker, 2001); in the capabilities and forces installed (Lau & Lo, 2015; Zhao et al., 2015); integration into open systems, i.e. in RIS institutions and how they affect actors and their interactions (Asheim et al., 2011a, b); and the potentially important influence of regional innovation policy (Carrincazeaux & Gaschet, 2015; Chung, 2002; Lengyel & Leydesdorff, 2011; Sun & Liu, 2010).

RIS is configured as an open and interconnected system with other types of Innovation Systems (IS), in constant interaction, redefined by Cooke (2005) as the interrelating knowledge generation and subsystems usage connected to international, national, and other regional systems that enhances systemic innovation at a regional level. In the absence of fluid and consistent market dynamics (Fiore et al., 2011), RIS is an instrument that has gained importance in supporting the regional development of innovation (Almeida et al., 2011; Asheim & Coenen, 2005). According to Cooke et al. (1997), three institutional components are crucial to identify the RIS capacity: (a) financial, (b) institutional learning, and (c) productive cultures that may exist.

Also, according to Cooke et al. (1997), the success of RIS is linked to (1) a culture of cooperation; (2) an associative culture; (3) the capacity and experience to carry out institutional change; (4) public/private coordination and consensus; (5) a

productive culture with sub-elements of industrial relations, cooperation at work, corporate responsibility for society, and productive specialization; and (6) existing interface mechanisms in the scientific, technological, productive, and financial fields.

Therefore, it is important to look at the performance of RIS as a valuable framework for policy evaluation in the broad field of innovation (Flanagan et al., 2011).

Integrating the Role of STPs in the RIS Framework

As we could see, it is not an easy task to evaluate the performance of a RIS since there are complex systems with various components, actors, and activities; as such, it is necessary to appraise all these factors and detect how each portion of the system works, with special attention on how the system performs as a whole (Markard & Truffer, 2008). Several authors have devoted particular attention on how to measure RIS performance and the usage of adequate metrics to review its success (Leydesdorff & Fritsch, 2006; Zabala-Iturriagoitia et al., 2007); this is an important aspect that contributes significantly to regional development (Cooke, 2002). According to Carlsson et al. (2002), the precise manner to measure the performance is complex and depends on the analysis level and RIS maturity.

A holistic reading of the innovation process, given by theories of innovation systems, reveals its great interest, incorporating the different elements and components (Flanagan et al., 2011); even more, relevant is the dynamic notion that an innovation system implies, where all components interact and influence the actual performance of innovation (Edquist, 2010).

Although Griliches (1979) suggests that a function of knowledge production can explain different patterns in innovation performance, the truth is that the process of transformation knowledge in value — in one word, “innovation” — mostly remains as an inside part of the “black box” (Rosenberg, 1982). Thus, research into evaluating the RIS performance depends on links, interactions, and processes that contribute to this process of transformation in microlevel, which is not observed directly, but they are reflected in the available innovation inputs and eventually produced outputs (Broekel, 2012; Flanagan et al., 2011).

To observe technological innovation and measure the innovation activity in the member countries, the European Commission created the European Innovation Scoreboard (EIS), which classifies 17 indicators within four groups: human capital for innovation, new knowledge development, communication, and knowledge application, and the innovation on finance, its outputs, and markets (Janger et al., 2017).

Laranja et al. (2008) highlight the importance of Science, Technology, and Innovation Policies in the treatment of nuclear vectors of intervention to accelerate the performance of innovation, although this evaluation policy perspective is recent and lacks further studies and, above all, evidence.

STPs are extended through the (a) concentration of technologies and actors, fostering the birth of new technology companies, (b) facilitating the transfer of know-how from academia to the business fabric, (c) encouraging university-based spin-offs, and (d) stimulating the development of innovative products and processes,

which can contribute decisively to improve the performance of RIS (Felsenstein, 1994; Hebllich & Slavtchev, 2014). Lindelöf and Löfsten (2003) and Vivarelli (2013) show us that STP can be catalysts or revitalizers for and of regional economic development, playing a decisive role in two fields: on the one hand, in updating business activities and, on the other, in the creation of new companies in the region in which they operate.

In the same vein, Gkypali et al. (2016), through the analysis of the Greek regions, develop a methodological approach that allows the evaluation of the STP's contribution to the corresponding RIS performance. However, the contribution and importance of STP within RIS are not always obvious and direct. For example, Westhead (1997) study is inconclusive on this topic, while Felsenstein (1994) does not even find that companies located in STP of American universities are more innovative than other local companies. A negative effect on regional economic development and innovation rates is even evidenced, which contrasts with the conclusions of Squicciarini (2008) by emphasizing the better performance of companies within STP face others in the same region.

In Portugal, companies based in STPs are generally small companies. On the other hand, the level of patents in Portugal is low (Rodríguez-Gulías et al., 2019). According to Rodríguez-Gulías et al. (2019), although Portugal manages to host many companies in the STPs, it would be advisable to promote the growth of companies within the STPs. This measure would allow companies to contribute more to the region's socioeconomic development in which they operate. One of the problems identified by the same author is that the characteristics of companies based in STPs in the northern region of Portugal are that companies provide few high-technology knowledge-intensive services, as well as few high or medium-high technology manufacturing activities. The STPs in Portugal promote cooperation networks, despite admitting that cooperation networks still need to work more. STPs in Portugal still point to shortcomings in terms of cooperation between STPs and higher education institutions (Lopes et al., 2018c). According to Lopes et al. (2018c), there are STPs in Portugal that have not yet implemented any process to endure knowledge and technology transfer, which certainly does not improve the RIS. The STPs also state that there is a lack of support for the commercialization of technology. Still, in Portugal, Lopes et al. (2018a) proposed the "Island Innovation Ecosystem" model to help island regions create more innovative and sustainable ecosystems. The author argues that creating external and internal networks is fundamental for the island region. In this way, island ecosystems will be able to create more value, spreading knowledge amongst the various partners they have. Island ecosystems must focus on international markets. The focus of these island ecosystems should be international markets (Lopes et al., 2018a). In this way, STPs can make an important contribution to accelerating value creation in RIS.

In this research, we intend to make a longitudinal study to evaluate the contribution of STPs in the performance of RIS, using the seven Portuguese regions within the model developed by Gkypali et al. (2016). Being so, the following hypotheses were formulated:

- H1: Policy Instrument (PI) has a negative influence on Regional Idiosyncrasies (REG).
- H2: Policy Instrument (PI) has a positive influence on Regional Innovation Inputs (INNI).
- H3: Regional Innovation Inputs (INNI) has a positive influence on Regional Innovation Outputs (INNO).
- H4: Regional Idiosyncrasies (REG) has a negative influence on Regional Innovation Inputs (INNI).

Methodological Framework

A Structural Equation Model of RIS

Since the main objective of this research is to evaluate the impact of Science and Technology Parks (STPs) in the performance stimulation of regional innovation in Portugal, this research uses the methodological framework elaborated by Gkypali et al. (2016), which assumes that the resources invested (inputs) in the Regional Innovation System (RIS) are transformed into innovation outputs. As this transformation is not directly observable (Fritsch & Slavtchev, 2011), the defined framework should allow to explain the nature of the mechanism that transforms innovation inputs into outputs, defines the primary role of public spending as a policy instrument, and verifies the existence of idiosyncrasies in the RIS and the interaction between all these aspects. The objectives adopted by the Gkypali et al. (2016) model are described in Fig. 1.

This structural model is based on a framework of the multi-input–multi–output knowledge production function, an approach to transform RIS innovation inputs into innovation outputs. It is based on four latent variables: (1) Policy Instrument (PI) measured by Government Expenditures on R&D (GERD), (2) Regional Innovation

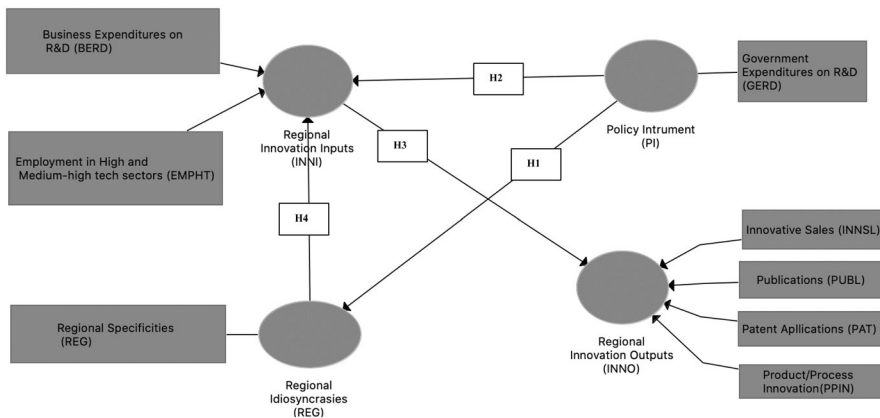


Fig. 1 Structural model

Inputs (INNI) measured by Business Expenditures on R&D (BERD), and Employment in High and Medium–high tech sectors (EMPHT); (3) Regional Innovation Outputs (INNO) measured by Innovative Sales (INNSL), Patent Applications (PAT), Product/Process Innovations (PPIN) and Publications (PUBL); and (4) Regional Idiosyncrasies (REG) measured by Regional Specificities Dummy (DR). The PI variable is an exogenous latent variable, and the other three latent variables (INNI, REG, and INNO) are endogenous.

According to Gkypali et al. (2016), PI innovation reinforces cohesion and/or convergence between regions by creating innovation inputs (INNI), and, consequently, these policies affect Regional Idiosyncrasies (REG). On the other hand, the Regional Idiosyncrasies (REG) determine the regional innovation inputs (INNI). There is an indirect influence of the IP on the regional innovation outputs (INNO) realized through the influence of the PI on the INNO, mediated by the effect primarily on the INNI and mediated by the influence of the REG through the previous influence on the INNI.

Data

The necessary data to build the aforementioned structural model were collected in the reports of the Regional Innovation Scoreboard (RIS, 2012; RIS, 2014; RIS, 2016; RIS, 2017; RIS, 2019), available at https://ec.europa.eu/growth/industry/policy/innovation/regional_en for the seven Portuguese regions individually (North, Center, Lisbon, Alentejo, Algarve, and Autonomous Region of the Azores and Madeira) for the period between 2007 and 2018. The adopted period is due to the availability of existing data in these reports.

The exogenous latent variable Policy Instrument (PI) is measured by Government Expenditures on R&D (GERD), encompassing all R&D expenditures in the government and higher education sectors. The exogenous latent variable INNI measures Business Expenditures on R&D (EBRD) measured by total Business Expenditures on R&D as a percentage of GDP and by Employment in High and Medium–high tech sectors (EMPHT) measured by total Employment in High and Medium–high tech sectors as a percentage of total employment. The INNO latent variable is composed of the following indicators: (1) Innovative Sales (INNSL) defined as the percentage of turnover from new products or products with significant improvements concerning the total turnover of companies in the region; (2) Patent Applications (PAT) measured by the number of patent applications per billion GDP; (3) Product/Process Innovations (PPIN) measured by the percentage of SMEs that introduced a new product or process in one of their markets in relation to the total number of SMEs in the region; and (4) Publications (PUBL) measured by the number of public–private scientific publications with co-authorship (PUBL) per million population. Finally, the Regional Idiosyncrasies (REG) measured by dummy variable, Regional Specificities Dummy (DR), which takes the value 1 in the case of the Portuguese regions classified as strong (North, Center, and Lisbon) in the Regional Innovation Scoreboard 2019 and the value 0 in the other regions. In

Table 1 Descriptive statistics of the variables

	Mean	Standard Deviation (SD)	Min	Max
BERD	0.228	0.155	0.018	0.570
EMPHT	0.299	0.137	0.023	0.581
GERD	0.351	0.145	0.110	0.670
INNSL	0.397	0.215	0.081	0.910
PAT	0.155	0.071	0.055	0.300
PPIN	0.622	0.141	0.350	0.890
PUBL	0.160	0.095	0.029	0.319

the 2019 rank, Lisbon occupies the 94th position, the North occupies the 100th position, and the Center occupies the 105th position. The descriptive statistics of the collected variables are described in Table 1.

Methodological Approach

As referred earlier, the main objective is to evaluate the impact of Science and Technology Parks (STPs) and performance stimulation on regional innovation in Portugal, based on the structural model elaborated by Gkypali et al. (2016); this research uses a quantitative methodology; as such, it is innovative since most of the studies related to RIS and Science and Technology Parks use a qualitative methodology (Theeranattapong et al., 2021). The quantitative methodology has the advantage of allowing the validation of theories and relationships between variables through the collected data samples, generalizing the results, and it is always possible to replicate them with different samples (Ametowobla et al., 2015; Queirós et al., 2017).

The structural relationships defined in the model shown in Fig. 1, which were estimated using partial least squares (PLS) from the Smart PLS 3.0 software (Ringle et al., 2015), as used by Gkypali et al. (2016). PLS is a covariance-based structural model which is applied when estimating complex interrelations between latent variables (constructs) and observed variables, and, in recent years, this has been progressively used in empirical studies (Leguina, 2015; Ringle et al., 2020).

The use of this model has the main advantages: the permission to estimate complex models with many constructs (latent variables), indicator variables, and structural paths without imposing the assumption of data distribution; it is the indicated model to estimate small samples whose nature of the sample observations justifies; it allows to test the complexity of theoretical relationships defined by the supporting literature; and, finally, this model has a greater statistical power, that is, more likely to identify the significant relationships between the variables when in fact these relationships exist in the sample (Hair et al., 2019; Leguina, 2015).

In the estimated model, four latent variables were created (PI, INNI, INNO, and REG), and eight indicators were used (GERD, INNSL, PAT, PPIN, PUBL, DR, EMPHT, and BERD) with 49 observations each indicator. To use the PLS model, it is necessary to authenticate the sample dimension, which must be at least equal to one of the following conditions: (1) ten times larger than the number of indicators or

Table 2 Results of the model's reliability and validity measures

	INNI	INNO	PI	REG
BERD	0.952			
DR				1.000
EMPHT	0.606			
GERD			1.000	
INNSL		0.916		
PAT		0.745		
PPIN		0.561		
PUBL		0.764		
Cronbach's alpha	0.699	0.739	1.000	1.000
Composite reliability	0.769	0.839	1.000	1.000
Average variance extracted (AVE)	0.636	0.573	1.000	1.000

(2) ten times greater than the number of directed structural paths to a latent variable in the structural model (Leguina, 2015). As we can conclude, the size of our sample is 392 observations, being more than ten times the number of indicators (70), and, thus, the sample size fulfils the conditions to be used in the PLS method.

Reliability and validity measures should be addressed to confirm the estimated model, which refers to the instruments used to mediate the relationship between the latent and observed variables of the model and infers a reliability analysis of each latent variable at the indicator level and the convergent and discriminant validity. The model validation of this study is described in Table 2, which contains the indicator factor loadings, reliability, and average variance extracted (AVE) of each indicator used.

According to Ringle et al. (2020) criterion which states that the reliability coefficients of latent variables must be greater than 0.70. The values obtained in this model for reliability coefficients of latent variables are higher than the reference value (INNI > 0.769; INNO > 0.839; PI > 1,000 and REG > 1,000), and therefore, reliability coefficients are “satisfactory to good,” meaning that all latent variables are over the acceptable values for the outer loadings, reliability, and validity of the estimated model.

Latent variables (INNI, INNO, PI, and REG) have high indicator loads (greater than 0.606) and acceptable validity and convergence measured by Cronbach's alpha (all results of this indicator are greater than 0.700 — reference value — except for Cronbach's alpha of the INNI latent variable which is 0.699, which is only 0.001 below) and the average variance extracted (AVE) (all latent variables have an AVE above the reference value for this indicator which is 0.50, that is, INNI > 0.636; INNO > 0.573; PI > 1,000, and REG > 1,000).

As a measure of discriminant validity, the Fornell-Larcker criterion was also used, which allows the analysis of cross-loadings that are indicators of the discriminant validity of latent variables. As we can see in Table 3, which presents the results of the application of the Fornell-Larcker criterion, each AVE of the latent variables (elements in the main diagonal that are in bold) is greater to all the square correlations of the latent variables (elements outside the diagonal), as such creating the discriminant validity of each of the four latent variables.

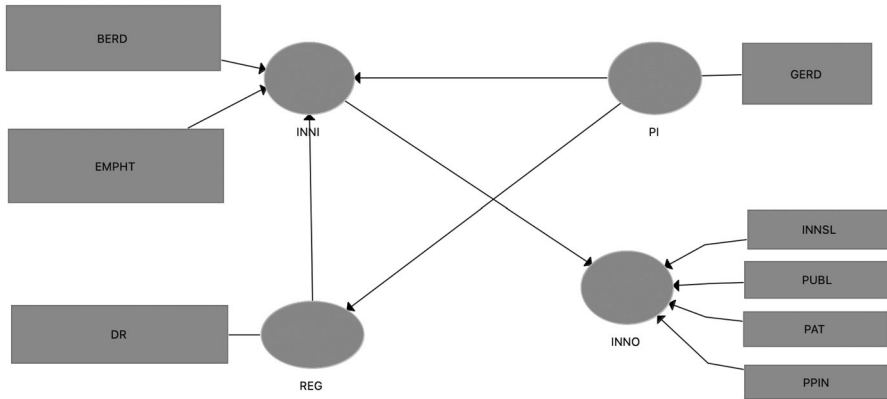


Fig. 2 Theoretical path model

We can conclude that the model is valid as it fulfils the measures of reliability and validity and discriminant validity. Based on the structural model presented in Fig. 1, the theoretical model was created in Smart PLS 3.0 with the identification of latent variables and indicators, resulting in the exhibition presented in Fig. 2.

Figure 2 shows the theoretical path model showing the eight collected indicators (represented in the rectangles), that is, GERD, BERD, EMPHT, DR, INNSL, PAT, PPIN, and PUBL, and the four latent variables created, i.e. GERD, INNI, REG, and INNO (represented in circles). Amongst the latent variables, the relationships defined by Gkypali et al. (2016) as follows:

- PI influences REG
- PI influences INNI
- PI influences INNO through INNI
- REG influences INNI
- REG influences INNO through INNI
- INNI influences INNO

Taking into account the main objective of this research to evaluate the impact of Science and Technology Parks (STP) in the performance stimulation of regional innovation in Portugal through the results found by Gkypali et al. (2016) in the Greek regions, the following hypotheses were formulated:

- H1: Policy Instrument (PI) has a negative influence on Regional Idiosyncrasies (REG).
- H2: Policy Instrument (PI) has a positive influence on Regional Innovation Inputs (INNI).
- H3: Regional Innovation Inputs (INNI) has a positive influence on Regional Innovation Outputs (INNO).
- H4: Regional Idiosyncrasies (REG) has a negative influence on Regional Innovation Inputs (INNI).

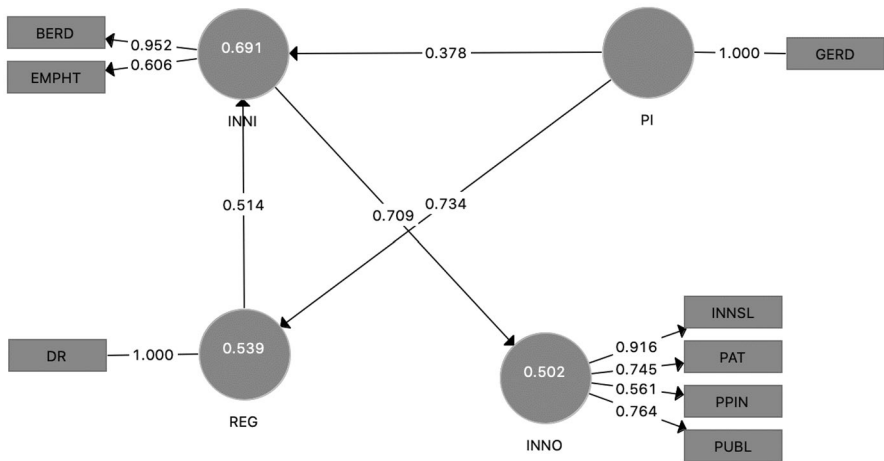


Fig. 3 PLS-SEM path model

Results and Discussion of Results

To estimate the model by PLS, it is essential to verify if the stopping criteria of the PLS algorithm is attained before the maximum number of iterations (repetition programming), which must be inferior to the settings defined in the settings for the PLS-SEM algorithm parameter (in this case 300 iterations). In this model, the algorithm converged the parameter of the PLS-SEM algorithm (of the 300 iterations) after the 7th iteration, Fig. 3 exhibits the obtained model.

To assess the predictive precision of the model, we need to analyse the R^2 values of the endogenous (dependent) latent variables, that is, the INNI, INNO, and REG, as shown in Table 4. There are different authors' opinions on the reference values for R^2 , and its evaluation must consider the specified model and the study area. Leguina (2015) considered that, in general, the reference R^2 values are 0.75, 0.50, and 0.25; consequently, the endogenous latent variables are, respectively, described as substantial, moderate, and weak. Nonetheless, Ritchey (2008) concluded that, in the social sciences, R^2 reference values from 0.04 to 0.16 are considered moderately weak and moderately strong from 0.20 to 0.49. As stated by the Leguina (2015) criterion, the PLS algorithm calculated a moderate R^2 for all variables and a strong R^2 according to the R^2 Ritchey (2008); the results are exhibited in Table 4.

Table 3 Results of the application of the Fornell-Larcker criterion

	INI	IINO	PI	REG
INI	0.798			
IINO	0.709	0.757		
PI	0.755	0.580	1.000	
REG	0.751	0.569	0.734	1.000

Table 4 Variance explained

	R square	R square adjusted
INNI	0.691	0.678
INNO	0.502	0.491
REG	0.539	0.529

According to Leguina (2015), when path coefficients are greater than 0.20, they are considered to be establishing significant relationships between latent variables. From the path coefficients estimates (Fig. 3), we can conclude that the variation of 1% in the latent variable PI has an impact of 37.8% of the latent variable INNI and 73.4% of the latent variable REG; the 1% variation in the REG latent variable has an impact of 51.4% of the INNI latent variable and the 1% variation in the INNI latent variable has an impact of 70.9% of the INNO latent variable.

As soon as the path coefficients were calculated, a bootstrap analysis was performed to assess their statistical significance (95%). Table 5 exhibits the outcomes of this significance test. Being so, it is concluded that all latent variables are very significant for $p < 0.05$, and the relationships between $INNI > INNO$ and $PI > INNI$ are very significant with $p = 0.000$.

We can conclude that PI has a positive influence on Regional Idiosyncrasies (REG), rejecting hypothesis 1. Thus, our results are different from those indicated by Gkypali et al. (2016) for Greece. According to the authors, the inclusion of STP in the RIS minimizes the positive role of the PI, as well as increases the negative impact of REG on the innovation results of the regions. Tamásy (2007) states that STPs should be managed as private organizations without government funding. The author also states that business incubation is an expensive political instrument because incubators have a low impact on the motivation of individuals to start a business, in addition to not increasing the survival, growth, and innovation of companies. On the other hand, the greater the financing granted to incubators, the greater their costs.

Another conclusion of this research is that PI positively influences INNI, confirming hypothesis 2. Our results align with that indicated by Gkypali et al. (2016). The authors state that the national innovation system has a positive and fundamental impact on RIS when there are high government investments in R&D. This finding is opposed to the one indicated by Tamásy (2007). On the other hand, government expenditures on R&D are widely recognized as a political instrument capable of stimulating regional innovation policy (Zhao et al., 2019). This political instrument can also stimulate companies to invest in R&D, which in turn will positively influence regional innovation inputs (Guellec & Potterie, 2003; Lopes João et al., 2021).

The results also point out that the INNI has a positive influence on the INNO, also confirming hypothesis 3. Our findings are in line with those indicated by Ning and Mengzhou (2008) and Gkypali et al. (2016). The results of the authors' studies show a positive relationship between INNO and INNI. According to Li et al. (2019),

properly designed regulations improve the innovation production of companies and consequently the production of regional innovation. When regulation increases, the operating cost of private SMEs increases, which in turn reduces SMEs' ability to remain in the market. If there are fewer companies in the market in a region, it can make it difficult for STPs to incubate new companies, which can result in reduced production of regional innovation (Gray & Shadbegian, 1998; Li et al., 2019; Simpson & Bradford, 1996).

Finally, the results indicate that REG has a positive influence on INNI, rejecting hypothesis 4. Our results then aligned with those of Gkypali et al. (2016). The authors claim that REG negatively influences INNI, which indicates that there are resources that are being wasted. This waste is most notorious when we include STPs as an anchor and catalyst for regional innovation. This waste will affect the efficiency of innovation in the regions, which leads to the receipt of lower revenues by regional governments (Hsieh & Klenow, 2009; Li et al., 2017).

According to RIS (2019) and as seen in Fig. 4, three Portuguese regions are classified as strong (North (PT11), Center (PT16), and Lisbon (PT17)), and four regions

Fig. 4 Regional innovation performance — Portugal. Source: RIS (2019)

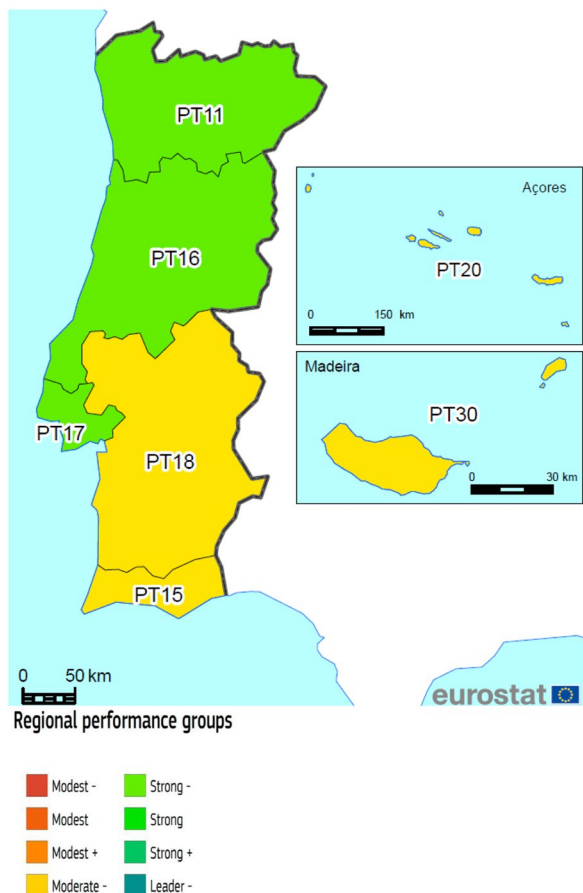


Table 5 Significance testing results of the structural model

	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	<i>t</i> statistics (IO/STDEV)	<i>p</i> values
INNI—> INNO	0.709	0.714	0.077	9.239	0.000*
PI—> INNI	0.378	0.375	0.151	2.495	0.013**
PI—> REG	0.734	0.727	0.060	12.227	0.000*
REG—> INNI	0.514	0.520	0.152	3.370	0.001*

Authors' calculations

* $p < 0.01$ e; ** $p < 0.05$

are classified as moderate (Algarve (PT15), Alentejo (PT18), Autonomous Region of Madeira (PT30), and Autonomous Region of Azores (PT20)), that is, there are no clearly significant differences in terms of innovation (strong vs moderate).

It was found that in 2016, the regions in Portugal were all classified as moderate innovators, except for the Autonomous Region of Madeira and Azores, which were classified as modest innovators (Lopes et al., 2018b, 2019, 2021). Compared to 2019, all regions improved their innovative performance, except for Alentejo and Algarve.

As mentioned earlier, in addition to the direct path coefficients, the model also allows estimating three indirect paths of the effects of PI on the outputs of regional innovation (INNO), that is, PI—> REG—> INNI—> INNO; REG—> INNI—> INNO; PI—> INNI—> INNO and an indirect effect of PI on INNI (PI—> REG—> INNI), as shown in Table 6. On the obtained values, as

Table 6 Indirect and total effects estimation results

	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	<i>t</i> statistics (IO/STDEV)	<i>p</i> values
Indirect effects					
PI—> REG—> INNI	0.377	0.373	0.102	3.685	0.000*
PI—> REG—> INNI—> INNO	0.267	0.266	0.077	3.469	0.001*
REG—> INNI—> INNO	0.364	0.369	0.112	3.260	0.001*
PI—> INNI—> INNO	0.268	0.269	0.116	2.300	0.022*
Total effects					
INNI—> INNO	0.709	0.714	0.077	9.239	0.000*
PI—> INNI	0.755	0.748	0.069	10.903	0.000*
PI—> INNO	0.535	0.535	0.081	6.609	0.000*
PI—> REG	0.734	0.727	0.060	12.227	0.000*
REG—> INNI	0.514	0.520	0.152	3.370	0.001*
REG—> INNO	0.364	0.369	0.112	3.260	0.001*

Authors' calculations

* $p < 0.05$ and the 95% bootstrap

Table 7 Synthesis of the hypotheses

Hypothesis	Supported/not supported
H1: Policy Instrument (PI) has a negative influence on Regional Idiosyncrasies (REG)	Not supported
H2: Policy Instrument (PI) has a positive influence on Regional Innovation Inputs (INNI)	Supported
H3: Regional Innovation Inputs (INNI) has a positive influence on Regional Innovation Outputs (INNO)	Supported
H4: Regional Idiosyncrasies (REG) has a negative influence on Regional Innovation Inputs (INNI)	Not supported

an example, for $PI \rightarrow REG \rightarrow INNI$ (0.377), making the product between the $PI \rightarrow REG$ influence (0.734) and the $REG \rightarrow INNI$ influence (0.514). A variation of 1% in the PI has an indirect impact of 37.7% in the INNI. As we can see in Table 6, all indirect effects are statistically significant with $p = 0.000 < 0.05$ for 95% bootstrap.

Table 6 also shows the total effects of influences on the endogenous latent variables (INNI, INNO, and REG), with the most expressive total effects being verified in the influence of $INNI \rightarrow INNO$ (0.709), $PI \rightarrow INNI$ (0.755), and $PI \rightarrow REG$ (0.734). All total effects are also statistically significant with $p = 0.000 < 0.01$ for 95% bootstrap.

The indirect effects and the total effects confirm the results obtained in the significance test (Table 5), that is, there is a direct, indirect, and total positive influence of the PI on INNI and REG, a positive influence of INNI on INNO, and a positive influence of REG on INNI, reinforcing the confirmation of hypotheses 2 and 3 and rejecting the hypotheses of the influence of regional innovation idiosyncrasies (hypotheses 1 and 4) (Table 7).

Conclusions

Concluding Remark

This research is aimed to evaluate the impact of STPs and performance stimulation on regional innovation in Portugal. The structural model is based on a framework of the multi-input–multi-output knowledge production function, consequently an approach to transform RIS innovation inputs into innovation outputs.

The findings lead us to conclude that PI has a positive influence on REG. Another conclusion of this research is that PI has a positive influence on INNI. The results also point out that the INNI has a positive influence on the INNO. Furthermore, the results show that the INNI has a positive influence on the INNO. Finally, the results indicate that REG has a positive influence on INNI.

When looking at the 2019 regional innovation in Portugal, it is possible to observe a clear innovation delimitation; the North, Center, and Lisbon zones are the areas that have a strong innovation, and the rest of the country has a moderate

innovation, including the islands. Nonetheless, there was an improvement between 2016 and 2019 in all regions except Alentejo and Algarve. This is in line with the Policy Instrument's positive influence on the Regional Innovation inputs, which positively influences the Regional Innovation Outputs, which is also aligned with the findings of Ning and Mengzhou (2008) and Gkypali et al. (2016). This also shows that the Policy Instrument is an important factor influencing regional innovation. Consequently, it is expected that science parks will bring a positive impact on the population's lives.

Research Implications

When looking at STPs and RIS, the models usually described in the literature are the type of "one model fits all regions." As our results indicate, this approach is inadequate for all regions under study. As seen earlier, the evolution between 2016 and 2019 resulted in improvement in all regions except two (Alentejo and Algarve); in this case, we are dealing with an inland region (Alentejo) and a region with a single type of industry, tourism (Algarve); both regions have a deficit of STPs. As such, it is recommended to policymakers the adoption of operation models combining the local characteristics of the region and industry, thus stimulating the regional economy and acting as an innovation drive (Dorocki et al., 2017). Since the geography of innovation is complex, innovation patterns should be followed for each region (Camagni & Capello, 2015). Policymakers can also use the knowledge produced in this research to create the necessary instruments to strengthen the cooperation with the most prominent actors within STPs, including the strengthening of university cooperation (Chen & Liu, 2021). This may help to overcome the complexity of geographically related incentives, as sometimes science parks are compared to impulsive agglomerations (Huang et al., 2012).

Complementing regional innovation, science parks also deliver resources and encourage entrepreneurial fields; besides the usual services such as counselling and training, they deliver facilities for successful practising, allowing professionalism to be improved (Chen & Liu, 2021); this will help the local actors to further advance on innovation. Any encouragement for local innovative activities should be accompanied by the strengthening of local funding in terms of knowledge, education, and skills to assure the best results in terms of innovation policies (Rodríguez-Pose & Crescenzi, 2008), as the performance of RIS depends on the interactions of actors knowledge, whether outside or inside a region (Lopes & Franco, 2019). This is important in terms of helping the development of regions, as these are widely seen as important tools for economic and technological development (Audretsch & Link, 2012; Phan et al., 2005).

Another aspect to take into consideration with practical implication on the managerial side of STPs is the changing nature of globalization which pressures regions to act as innovative organizations, forcing the actors to search for the following attributes (Gust-Bardon, 2014): (1) qualified human resources; (2) structures to ease the stream of knowledge and its learning process; (3) capability to learn from failures and successes; (4) partnership and dialogue amongst regional actors to achieve

a common vision of the necessary development path and the construction of social capital; and (5) availability to the external environment and its effort.

In summary, this research contributed to theory by further enrichment of the current literature on STPs and their influence on RIS. On the practical side, and as mentioned before, some suggestions are given to the regional stakeholders from the obtained results. These recommendations aim to contribute to the development of RIS performance in the area under analysis. It also demonstrates the dynamics of the knowledge-based economy with STPs playing an important role in the creation, diffusion, and application of regional knowledge, with consequences at the level of organizations, nations, and regions. Also, the framework can be applied to other contexts, thus being useful for policy-making purposes. Nonetheless, care should be taken as the investigation of any RIS and the efforts to assess the innovation actors are related to high levels of disregarded heterogeneity; thus, the methodological approaches should be adjusted to accommodate the characteristics of each region.

This research is original as it uses a methodological approach never before applied to the Portuguese context. This research contributes to the enrichment of the RIS literature. Some suggestions were made to regional actors to increase the contribution of STPs in improving the performance of RIS in Portugal.

Research Limitations and Future Lines of Investigation

One of the limitations found in this research is related to data used, as it is restricted to the reports of the Regional Innovation Scoreboard (RIS, 2012, 2014, 2016, 2017, 2019) and available for the seven Portuguese regions and the period between 2007 and 2018. Along this timeline, some variables could have been changed, added, or removed, limiting the comparison between regions (for example, the EMPHT variable is not available for the autonomous region of Madeira and Azores in 2016 and 2018, and there is no data available for the PUB variable in 2013 and 2015). Other primary sources on this data type could be useful for data crossing.

As for future lines of investigation, this research and its context can be useful to make broader longitudinal studies involving more regions, i.e. EU Peripheral Regions, EU Ultraperipheral Regions, or even all EU countries, with the application of this study model with the application of this study model and including new variables in terms of innovation to enrich the framework used. It will also be interesting to develop a study focused on the levels of innovation of the Portuguese regions under analysis, using a wider temporal sample.

Acknowledgements NECE-UBI, Research Centre for Business Sciences, Research Centre and this work are funded by FCT – Fundação para a Ciência e a Tecnologia, IP, project UIDB/04630/2020.

Author Contribution All authors contributed equally in all parts of the study. All authors read and approved the final manuscript.

Data Availability The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics Approval All authors agreement with Ethical Responsibilities of the journal.

Consent to Participate Not applicable.

Consent for Publication All authors consent the publication.

Conflict of Interest The authors declare no competing interests.

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