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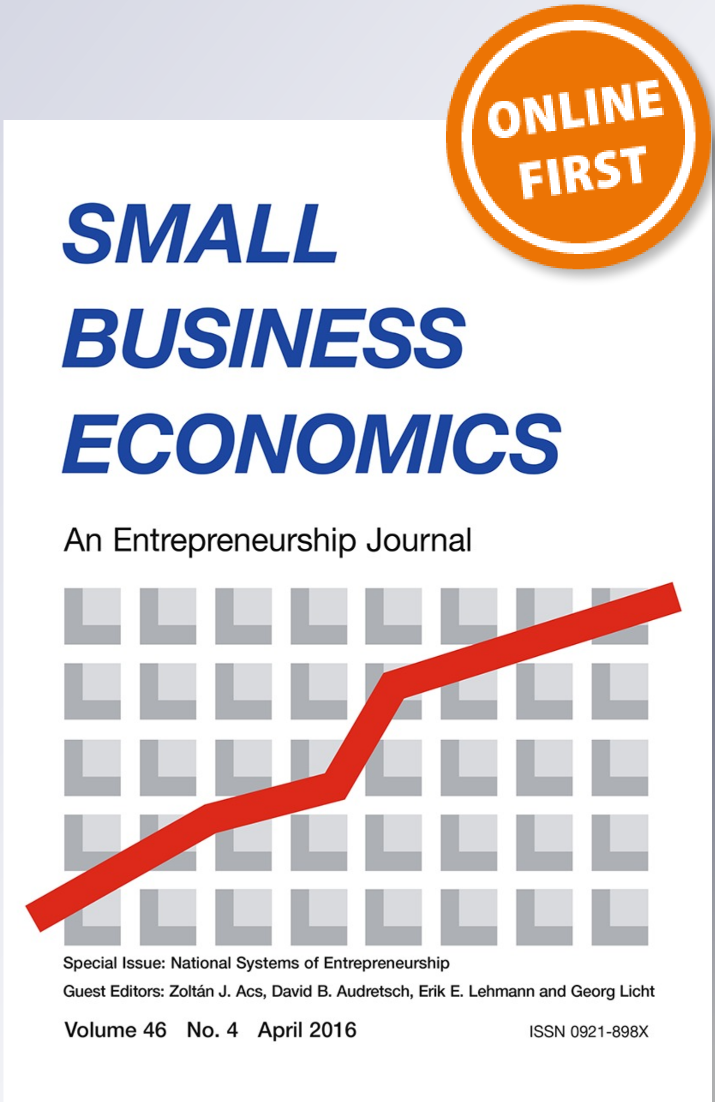

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Science parks and regional innovation performance in fiscal austerity era: Less is more?

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Abstract European financial crisis has raised questions about the sustainability and the contribution of innovation anchors especially in Southern European countries such as Greece. This paper utilizes the concept of regional innovation systems (RISs) and introduces a methodological approach that allows for evaluating an Science and Technology Park's (STP) contribution into the corresponding RIS performance, taking into consideration (1) the RIS idiosyncrasies, (2) the dominant role of government expenditures on R&D and (3) the underlying complexity of knowledge production and management, under alternative sets of restrictions imposed by fiscal consolidation on the preferences of authorities which design and implement Science, Technology and Innovation (STI) policies. Our framework relies on the estimation of a multi-input–multi-output latent knowledge production function approach and the corresponding efficiency indices. Data requirements are sourced from the Regional Innovation Scoreboard, for the four Greek regions and from a small-scale case study, with respect to the examined regional STP covering the period from 2000 to 2012. The main empirical findings highlight that the contribution of the examined STP in the corresponding RIS performance diminishes alongside with the decrease in GERD investment levels, with respect to all the efficiency indices. These findings are attributed to the structural characteristics of both the RIS and the STP under investigation, and capture their dependence on managing public financial resources for STI activities.

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1 Introduction

Financial crisis and the consecutive public debt deadlock have resulted in a significant economic and social turmoil, in most Southern European countries and especially in Greece, which is the most affected European economy. Basic statistics provide an illustration of what Europe and especially Greece have experienced the past few years; in Greece, the gross domestic product (GDP) has declined 24 % from 2009 until 2013, while it exhibits one of the lowest intensities in government and business expenditures on research and development (R&D) as a percentage of GDP among OECD countries. However, Europe has also experienced a fall of 4.5 % in R&D expenditures.

These developments have prioritized the search for new 'engines of growth' which would be compliable to the restrictions imposed by the fiscal austerities policies. At the same time, the outburst of financial crisis questioned the sustainability of innovation systems, which are mainly based on government expenditures on R&D (GERD), to maintain their dynamism; hence, the evaluation of the innovation performance in terms of efficiency and effectiveness of the innovation mechanisms that are mainly based on public funds became even more imperative. In this respect, Science and Technology Parks (STPs) have been considered, worldwide, as important tools for technological and economic development (Audretsch and Link 2012), and for that reason, the number of STPs has increased and continues to grow rapidly (Phan et al. 2005). Particular emphasis has been attributed to their role in improving the performance of regional innovation systems (RISs) as the latter have been assigned the mission to contribute significantly in terms of regional development (Cooke 2001; Audretsch 2001).

According to the latest Science and Technology and Industry Outlook (OECD 2012, p. 302), the importance of public expenditures Science, Technology and Innovation (STI) policies in the entire European context is indisputable. In Greece in particular, public expenditures on R&D are a super-dominant means for boosting innovation activities and technological development in all Greek regions. In the context of the same report, special problems are encountered since the current crisis is exerting a dampening effect on public investments on R&D. Thus, it becomes evident the necessity to investigate and evaluate the role of STPs in the context of the specific GERD dominated lagging RIS they operate, under the pressure exerted by fiscal austerity conditions.

Despite previous attempts to investigate the contribution of STPs in technological and economic development, the analysis is confined either at a rather high level of spatial and/or sectoral aggregation level (Ferguson and Olofsson 2004), or in terms of tenant firms growth and survival (Link and Link 2003; Colombo and Grilli 2005). Moreover, the findings are rather contradictory, but most importantly do not shed light on the association between the STP's performance and the corresponding unique RIS features. This shortcoming may be attributed to the lack of an underlying methodological framework which would allow the evaluation of an STP performance in the context of the corresponding RIS. Hence, the need emerges to develop an appropriate framework for the evaluation of STP's contribution in the overall performance of the system of innovation they belong to, taking into consideration (1) the RIS idiosyncrasies and (2) the dominant role of GERD.

Regarding the Greek STP's ecosystem, serious weaknesses arise with respect to policy coordination and evaluation (OECD 2012, p. 300). Bakouros et al. (2002) and Sofoulli and Vonortas (2007) present a historical overview of Greek STP's system and proceed with an informative nonquantitative illustration of their operational framework. In the present paper, we *introduce a methodological framework for evaluating an STP's contribution into the corresponding RIS performance and under alternative sets of restrictions imposed by fiscal consolidation on the preferences of authorities which design and implement Science, Technology and Innovation (STI) policies*. It is essential to point out that *STI policy authorities preferences* encompass the conditions generated by the current fiscal austerity era in Europe and especially in Greece.

The analysis is realized in two steps; firstly, the Greek RISs' transformation mechanism as a knowledge production function is analyzed in the context of a structural equation model approach which allows for taking into consideration the RIS idiosyncrasies and the dominant role of GERD in determining the regional innovation production function. In this line, we argue that the RIS mechanism that transforms innovation inputs into commercially exploitable outputs is *latent*, and thus, the subsequent estimation of innovation performance should be based on latent variables. Secondly, differential efficiency indices are estimated allowing for the presence (absence) of an STP from the corresponding RIS it operates and thus allowing for the evaluation of its contribution in RIS innovation performance. It should also be noted that the proposed methodological approach allows for the incorporation of flows between the regional and national innovation systems and the corresponding European through the measurement of all employed variables in terms of the European Innovation Scoreboard.

The remainder of the paper is structured as follows. In the next section, we synthesize from the existing literature the core elements upon which our analysis is based. Section 3 presents the proposed methodological, while Sect. 4 is devoted in presenting an analytical overview of the case study of the STP under examination and the corresponding RIS, along with the data employed in the empirical analysis. Section 5 discusses the empirical results, and Sect. 6 concludes the paper.

2 Theory and literature

2.1 Evaluation of the RIS performance

In principle, the design and implementation of STI policies aim at addressing key questions of whether, where and how to intervene in order to accelerate innovation performance (Laranja et al. 2008). However, the field of STI is a relatively young area of policy intervention, and as such, the evaluation practice has a much shorter history and is much less formalized. We should also acknowledge the difficulties associated with the evaluation of policy interventions in the field of STI which sometimes can be proven insurmountable (Caracostas 2007).

In this vein, *systems of innovation* set a valuable framework for evaluating policies in the broad field of innovation (Flanagan et al. 2011). Systems of innovations theories have attracted a lot of interest since they address innovation process as a whole and incorporate side components such as determinants, sources, human entrepreneurial and social capital and institutions. But what is perhaps most appealing in the notion of a system of innovation is that all these side components interact and these interactions are the actual locomotives of innovation performance (Edquist 1997; Soete et al. 2009). Nevertheless, the evaluation of the performance of innovation systems did not start until related STI policies targeted innovation as a unified system (Autio 1998). In other words, this particular subdiscipline of policy evaluation lacks an adequate history which would ensure *learning by experience*.

From a policy perspective, a transition of the traditional state-centric model of governance has occurred, shifting the focus of attention from the national level to the regional level (Tewdwr-Jones and McNeill 2000; Fritsch and Graf 2011). In this context, *a dichotomy is observed; while the central government is in charge of policy decisions on the means and allocation of resources, the evaluation of the efficacy of such policies is performed at the regional level*. The rationale behind such a dichotomy is that regional disparities attributed to institutional, social and economic conditions are reflected in the *availability* and the '*quality*' of local inputs, which in turn induce differential patterns of innovation outputs (Fritsch 2002; Fritsch and Slavtchev 2011). In order to account for such quality dimensions, efficiency analysis offers a perspective for measuring the 'quality' of RISs (Broekel 2012; Kaihua and Mingting 2014).

Conventionally, differential patterns of regional innovation performances are approximated with a knowledge production function (Griliches 1979). However, the process with which innovation inputs are transformed into innovation outputs remains for its most part a 'black box' (Rosenberg 1982). Hence, the investigation of the efficiency and effectiveness of the innovation process observed at the aggregate regional level depends on linkages, interactions and processes that contribute in this transformation process at the microlevel, which are not directly observed, but they are reflected on the available innovation inputs and eventually produced outputs (Flanagan et al. 2011; Broekel 2012).

2.2 The determining role of STPs in evaluating the RIS performance

While one-dimensional policy interventions have well-defined objectives and target groups, when it comes to RISs, few research works have been occupied with the task to explicitly investigate and evaluate the role of institutional infrastructure within the context of innovation systems (Doloreux and Parto 2005). More specifically, within a RIS, triple helix organizations are expected to collaborate and channel knowledge flows toward their commercial exploitation (Doloreux 2004). Efficient collaboration among triple helix is considered vital for achieving high levels of innovation performance (Etzkowitz and Kloftsen 2005). However, the association between a region's innovation performance and the intensity of collaboration among regional organizations does not always produce the desirable outcomes (Broekel 2012; Uzzi 1996). A series of system failures may occur for several different reasons.

In this line, it has been suggested that STPs contribute in boosting the performance of RIS because they are considered seedbeds and enclaves for technology, which nurture the development and growth of new, small, high-tech firms, facilitate the transfer of university know-how to tenant companies, encourage the development of university-based spin-offs and stimulate the development of innovative products and processes (Felsenstein 1994; Heblich and Slatchev 2014). In addition, STPs have been proven to act as catalysts for regional economic development or revitalization, thus promoting economic growth (Lindelof and Lofsten 2003; Vivarelli 2013). In this respect, STPs play a determining role in upgrading entrepreneurial activities and increasing new firm formation in the region they operate.

It should be noted, however, that entrepreneurship is a complex phenomenon that is characterized by extreme heterogeneity (Dosi et al. 1995). More specifically, the relevant literature has indicated that two distinct categories of entrepreneurs coexist which differ mainly with respect to their motives for founding a new enterprise (Baumol 1990); the first category refers to entrepreneurs who proceed in founding a new firm in an attempt to exploit a technological opportunity, while the second category entails entrepreneurs by necessity whom proceed in forming a new firm from the fear or certainty that in the contrary case they would be unemployed. Notwithstanding, it should be noted that both the driving factors that accrue to profit-making aspirations from the exploitation of a novel technological opportunity and those that are grounded on the personality, capabilities, experiences and the external environment of the entrepreneur contribute jointly in the decision of forming a new firm (Audretsch and Vivarelli 1995, 1996; Santarelli et al. 2009).

Hence, given the scarcity of available resources for funding and supporting new firm formation, any policy initiatives aiming at boosting entrepreneurship should distinguish between the two categories and take into consideration both the progressive and the regressive determinants of entrepreneurial activity. In this direction, it becomes evident that STPs operate as a beacon and a shelter for 'Schumpeterian innovative entrepreneurs' and contribute decisively in boosting the creation of new technology-based firms (NTBFs) by utilizing the local human capital (Colombo and Grilli 2010; Arvanitis and Stucki 2012; Colombo et al. 2013).

In reality however, STPs are quite heterogeneous in terms of both context and importance within the RIS (Massey et al. 1992; Uyarra 2008). More specifically, Westhead (1997) reports inconclusive evidence on the influence of the STP on tenant firms' innovative activity. Felsenstein (1994) based on empirical evidence from U.S. STPs finds no evidence that firms located on university-based STPs are more innovative than other local firms, while Wallsten (2001) finds that STPs exert a negative effect on regional economic development and rates of innovation. On the other hand, Squicciarini (2008) finds empirical evidence supporting the argument that firms located within an STP exhibit better innovation performance in contrast to firms located elsewhere in the same region. However, she finds that the presence of universities slows down the rate at which tenant firms patent and argues that this might be occurring because universities perform research activities lacking of short-term patenting objectives. Toward this direction, *we focus on the evaluation of the determining role of the existence and operation of an STP on the innovation performance of a Greek RIS taking into account the influence* of the dominant policy instrument, the restrictions imposed by financial crisis as well as regional specificities.

3 Methodological framework

3.1 A structural equation model of RIS

There is a considerable lack in the literature in developing a methodological base for delimiting the boundaries of a RIS through its main actors, investigating of their interaction and evaluating its performance (Nauwelaers and Reid 1995; Runiewicz-Wardyn 2013). We fill this gap by introducing a methodological framework which takes into account the above considerations. More specifically, the conceptual framework employed in this paper is based on the knowledge production function (Griliches 1979) adjusted for the RIS case (Jaffe 1989) where the determining role of an STP in boosting the RIS innovation performance is examined, through the adoption of the assumption that resources invested in the RIS are transformed into innovation outputs. The special features of the *transformation mechanism that is nonobservable and fuzzily defined at its largest extent determine the efficiency of the whole process* (Fritsch and Slavtchev 2011). Therefore, it is essential for the development of an appropriate conceptual framework to account for (1) the fuzzy nature of the mechanism that transforms innovation inputs into innovation outcomes, (2) the dominant role of GERD as a policy instrument, (3) the idiosyncrasies of the RIS and (4) the interactions between the above. A graphical representation of this approach is presented in Fig. 1.

The modeling procedure is developed around the RIS innovation inputs–innovation outputs approach, which may be specified in the multi-input–multi-output knowledge production function framework when the innovation policy instrument (PI) is a distinctive latent variable which is constructed by the GERD at a regional level. The transformation mechanism of innovation inputs to innovation outputs is denoted by the path β_2. At this point, the distinctive characteristic is that both innovation inputs (INNI) and innovation outputs (INNO) are considered as latent variables due to their rather fuzzy character. We allow for the RIS innovation inputs pool to be directly influenced by the innovation PI, which in the case of Greece, as well as for the most of the European countries, is reflected on the GERD variable. The influence of PI on INNI is depicted by path γ_1. It is quite reasonable to assume that innovation PIs aim at

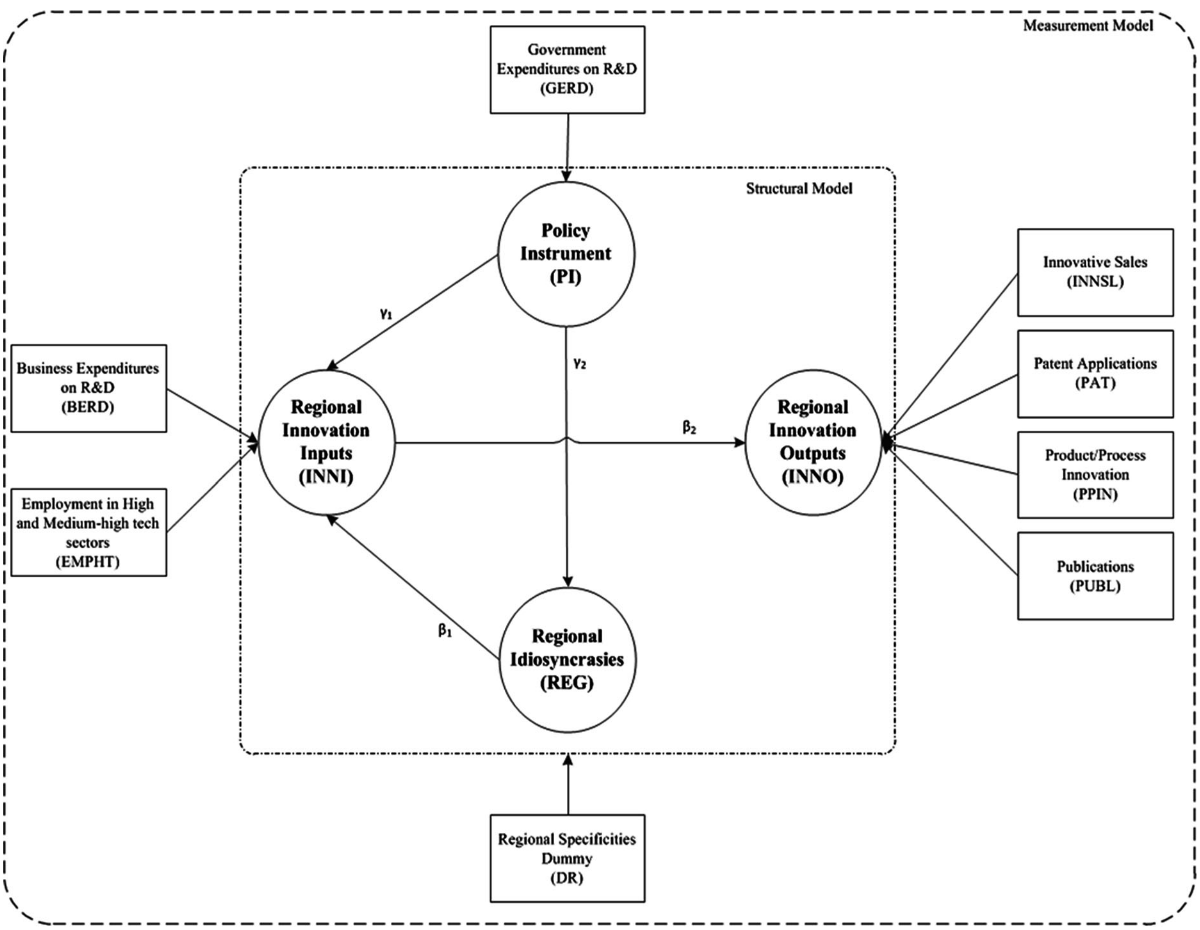

Fig. 1 Structural and measurement model

reinforcing the cohesion/convergence among regions, and hence, such policies may also affect regional idiosyncrasies. This is depicted in Fig. 1 by path γ_2. Finally, the level of regional idiosyncrasies determines the regional innovation inputs pool. This structural relationship is mirrored in path β_1 in Fig. 1.

It should be noted that according to the above-described theoretical framework, the influence of the PI on the regional innovation outputs is the sum of two distinct indirect effects. The first is the influence of the PI on INNO through its mediating effect on INNI, and the second is the influence of PI on INNO through the mediating influence on regional idiosyncrasies (REG) and INNI, respectively. The above-described theoretical framework is empirically estimated employing techniques of structural equation model (SEM), which in its general case and in matrices notation may be expressed by the following three basic equations (Bollen 1989; Wang and Wang 2012, p. 7):

$$\begin{aligned} n &= \mathbf{B}\eta + \mathbf{\Gamma}\xi + \zeta \\ Y &= \mathbf{\Lambda}_y\eta + \varepsilon \\ X &= \mathbf{\Lambda}_x\xi + \delta \end{aligned} \quad (1)$$

The first equation in the system of equations in (1) represents the structural model that establishes the structural relationships among latent variables. The components of η are endogenous latent variables, while the components of ξ are exogenous latent variables. The endogenous and exogenous latent variables are connected by a system of linear equations with coefficients matrices $\mathbf{B}$ and $\mathbf{\Gamma}$, respectively, as well as an error term vector ζ. $\mathbf{\Gamma}$ matrix represents the effects of exogenous latent variables on endogenous latent variables, and $\mathbf{B}$ matrix represents the influence of some endogenous latent variables on other endogenous latent variables.

The second and third equations in relationship (1) represent the measurement model where the latent variables are defined from the observed indicators. The second equation links the endogenous indicators—the observed y variables—to the endogenous latent variables η, while the third equation links the exogenous indicators—the observed x variables—to the exogenous latent variables ξ. The observed variables y and x are related to the corresponding latent variables η and ξ by factor loadings $\mathbf{\Lambda}_y$ and $\mathbf{\Lambda}_x$, respectively. It is assumed that:

$$\begin{aligned} &E(\zeta) = 0, \quad E(\varepsilon) = 0, \quad E(\delta) = 0, \quad \mathrm{Cov}(\zeta, \xi) = 0, \\ &\mathrm{Cov}(\varepsilon, \eta) = 0, \quad \mathrm{Cov}(\delta, \xi) = 0 \end{aligned} \quad (2)$$

but $\mathrm{Cov}(\varepsilon_i, \varepsilon_j)$ and $\mathrm{Cov}(\varepsilon_i, \varepsilon_j)$ $(i \neq j)$ might not be zero.

In the present paper and with respect to the case under examination, we consider four latent variables (η), namely the policy instrument (PI), the innovation inputs (INNI), the regional idiosyncrasies (REG) and the innovation outputs (INNO). PI is considered as exogenous. Thus, the structural model consists of the following three equations:

$$\begin{aligned} \mathrm{INNI} &= \gamma_1\mathrm{PI} + \beta_1\mathrm{REG} + \zeta_{\mathrm{INNI}} \\ \mathrm{REG} &= \gamma_2\mathrm{PI} + \zeta_{\mathrm{REG}} \\ \mathrm{INNO} &= \beta_2\mathrm{INNI} + \zeta_{\mathrm{INNO}} \end{aligned} \quad (3)$$

where γ_1 and γ_2 stand for the coefficients of the exogenous latent variable (PI) on the endogenous latent variables INNI and REG, respectively, while β_1 and β_2 denote the coefficients of the endogenous latent variables REG and INNI on the endogenous latent variable INNI and INNO, respectively. It is noticeable that all of the aforementioned four latent variables are fuzzy and not directly observed, which are of latent type. Therefore, the structural model of Eq. (3) is associated with the measurement model which consists of the following system of eight equations:

$$\begin{aligned} \mathrm{GERD} &= f_{\mathrm{G}}\mathrm{PI} + \delta_{\mathrm{GERD}} \\ \mathrm{BERD} &= \lambda_{\mathrm{BERD}}\mathrm{INNI} + \varepsilon_{\mathrm{BERD}} \\ \mathrm{EMPHT} &= \lambda_{\mathrm{EMPHT}}\mathrm{INNI} + \varepsilon_{\mathrm{EMPHT}} \\ \mathrm{DR} &= \lambda_{\mathrm{DR}}\mathrm{REG} + \varepsilon_{\mathrm{DR}} \\ \mathrm{INNSL} &= \lambda_{\mathrm{INNSL}}\mathrm{INNO} + \varepsilon_{\mathrm{INNSL}} \\ \mathrm{PAT} &= \lambda_{\mathrm{PAT}}\mathrm{INNO} + \varepsilon_{\mathrm{PAT}} \\ \mathrm{PPIN} &= \lambda_{\mathrm{PPIN}}\mathrm{INNO} + \varepsilon_{\mathrm{PPIN}} \\ \mathrm{PUBL} &= \lambda_{\mathrm{PUBL}}\mathrm{INNO} + \varepsilon_{\mathrm{PUBL}} \end{aligned} \quad (4)$$

where GERD is the government expenditures on R&D and is the indicator of the (PI) exogenous latent variable. The innovation inputs (INNI) endogenous latent variable is constructed by two observed indicators, namely BERD, the business expenditures on R&D, and EMPHT, that is, the employment on high-tech sectors of the regional economy. The regional idiosyncrasies (REG) is a single indicator latent variable constructed by a dummy variable taking the value of 1 for Western Greece region and 0 otherwise. Finally, the innovation output (INNO) is a four-indicator endogenous latent variable. The constructs of the INNO are the innovative sales of the firms in the region (INNSL), the patents associated with the firms and organizations of the region (PAT), the percentage of the regional firms that have introduced a product or process innovation (PPIN) and publications (PUBL).

3.2 The RIS' differential efficiency with respect to STP

Having devised the transformation mechanism of regional innovation inputs into innovation outputs, innovation performance may be approximated by the input–output ratios (Coelli et al. 2006, p. 52). This approach allows the RIS *efficiency* to accommodate situations in which an input is dominant. Furthermore, the above-described theoretical considerations and the resulting structural equation model consider the interrelationships within the RIS's input- and output-side constructs and not just the direct impacts of the inputs on outputs.

Extending the framework of knowledge production function (Griliches 1979; Fritsch and Slavtchev 2011), we define the abovementioned transformation mechanism of n inputs to m outputs of the multi-input–multi-output type:

$$(y_1, \ldots, y_m) = f(x_1, \ldots, x_n) \tag{5}$$

$y_1, \ldots, y_m$ are the indicators of the latent variable INNO, and $x_1, \ldots, x_n$ are the indicators of the INNI latent variable. From the inputs side, we consider the dominant role, in terms of policy design and implementation, of input (x^*) for which it holds that:

$$x_k = x_k(x^*, z_k) \quad \forall\, k = 1, \ldots, k-1, k+1, \ldots, n \tag{6}$$

which implies that the levels of all the RIS inputs are, to some extent, determined by the dominant policy variable x^* and are grounded on the notion of 'input dominance.' That is the path (γ_1) reflected in relationship (6). In relationship (6), z_k represent other determinants of x_k, which in our case involve the regional idiosyncrasies as they have been defined above.

The efficiency of the policy dominant input with respect to the ith output, under the state $s(s = 0, 1)$, is defined as the ratio of the RIS's output attained (y_i^s) to the invested resources of the policy dominant input:

$$\mathrm{Eff}_i^s = \frac{y_i^s}{x^{*,s}} \quad (i = 1, 2, \ldots, m;\ s = 0, 1) \tag{7}$$

State zero $(s = 0)$ corresponds to the transformation mechanism depicted in Eq. (5), which sketches the RIS performance when the STP is 'absent,' while state one $(s = 1)$ corresponds to the RIS's transformation mechanism when the STP is included among the key regional innovation agents. Thus, the RIS *differential efficiency* of the STP (EffSP) is defined as:

$$\mathrm{EffSP}_i^* = \mathrm{Eff}_i^{1,*} - \mathrm{Eff}_i^{0,*} = \left(\frac{y_i}{x^*}\right)^1 - \left(\frac{y_i}{x^*}\right)^0 \tag{8}$$

In other words, *the RIS differential efficiency with respect to STP of the ith output is defined as the difference between the policy dominant input efficiency for every RIS output, with and without STP*. Considering the case where the (EffSP_i^*) is not invariant with respect to the policy authorities preferences, as the latter are depicted in the level of the policy dominant input variable, but instead there are p alternative levels of the dominant policy variable, a $(p \times 1)$ vector of STP differential efficiencies arises:

$$\mathbf{EffSP}_i^* = \begin{bmatrix} \left(\frac{y_{i1}}{x_1^*}\right)^1 - \left(\frac{y_{i1}}{x_1^*}\right)^0 \\ \cdots \\ \cdots \\ \cdots \\ \left(\frac{y_{ip}}{x_p^*}\right)^1 - \left(\frac{y_{ip}}{x_p^*}\right)^0 \end{bmatrix} = \begin{bmatrix} \Delta\left(\frac{y_{i1}}{x_1^*}\right) \\ \cdots \\ \cdots \\ \cdots \\ \Delta\left(\frac{y_{ip}}{x_p^*}\right) \end{bmatrix} \tag{9}$$

Generalizing, for the case of the m RIS outputs, the RIS differential efficiency of STP with respect to the policy dominant input is given in the $(p \times m)$ matrix $\mathbf{EffSP}^*$.

$$\mathbf{EffSP}^* = [\,\mathbf{EffSP}_1^*, \quad \ldots, \quad \ldots, \quad \mathbf{EffSP}_m^*\,] \tag{10}$$

$\mathbf{EffSP}^*$ matrix encapsulates all the information regarding the efficiency of the mechanisms that transform the RIS crucial resources into innovation outputs, with and without STP, taking into account that policy authorities preferences are implemented through the intensity of the policy dominant input; such being the case, this crucial endowment heavily influences the behavior of the RIS agents. It is worth noting that relationships (9) and (10) do not take into account the interactions between European innovation system and the examined RISs. In order to address this interaction, weights should be attributed in both the input and output side of the RIS. These weights, denoted by a $(m \times m)$ block diagonal matrix $\mathbf{W}$, adjust RIS inputs and outputs in terms of their relative position within the European innovation systems. The Kronecker's product of each vector element of $\mathbf{EffSP}^{*}$ with the diagonal matrix $\mathbf{W}$ gives:

$$\mathbf{WEffSP}^{*} = \mathrm{vec}\left(\mathrm{EffSP}^{*T}\right) \otimes \mathbf{W} \tag{11}$$

where $\mathbf{WEffSP}^{*}$ is the $((p \times m) \times m^2)$ matrix of the RIS differential efficiency with respect to STP under the condition that x^{*} is the dominant input and the interactions with European innovation system have been taken into account.[1]

Combining the relationships (10), (11) with the structural and measurement model presented in relationships (3) and (4), the contribution of the examined STP in the RIS performance with respect to the jth innovation output when GERD is the dominant policy instrument is given by:

$$\begin{aligned}\mathrm{EffSP}_j &= \frac{\Delta \hat{y}_j}{\mathrm{GERD}} = \frac{\hat{y}_j^1 - \hat{y}_j^0}{\mathrm{GERD}} \\ &= k\Delta\left(\frac{\hat{\lambda}_j}{\hat{\varphi}_{\mathrm{G}}}\right)\left[\Delta(\hat{\gamma}_1 + \hat{\beta}_1 \Delta\hat{\gamma}_2)\right] \\ &\quad - \frac{1}{\mathrm{GERD}}\Delta(\hat{\varphi}_{\mathrm{G}})\left(\Delta(\hat{\lambda}_j)\sum_{i \neq j}^{k}\Delta\left(\frac{\hat{y}_i}{\hat{\lambda}_i}\right)\right),\end{aligned} \tag{12}$$

where hat (^) denotes estimated values, k is the number of innovation outputs and Δ stands for the difference in the corresponding parameters values between state $s = 1$ and $s = 0$. The analytical derivation of (12) is presented in the 'Appendix' section. In order to derive the components of the $\mathbf{WEffSP}^{*}$ matrix, the y variables in relationship (12) are transformed from their absolute values, in a scale that reflects their relative position in the European innovation system that is employing the $\mathbf{W}$ matrix according to the relationship (11).

4 Data and variables definition

4.1 The construction of the dataset for both states

The empirical estimation of the above-presented methodological framework requires data on regional innovation inputs and innovation outputs. In this direction, we follow closely the relevant literature about the efficiency of the RISs as well as the approach adopted in the framework of the EU Regional Innovation Scoreboard.[2] The information on regional innovation inputs and outputs concerns all four Greek regions at the NUTS 2 level.

Of particular interest is the Western Greece region because it hosts the STP under examination. More specifically, Patras Science Park[3] was established in 1998. As an Incubator it seeks to provide, create and develop the appropriate infrastructures, conditions, mechanisms and added-value services that support and promote the creation, operation and growth of new technology-based firms (NTBFs) through incubation and spin-off processes (Antonopoulos et al. 2009). A number of NTBFs are operating under the auspices of this STP; most of them are inventors, adopters and modificators of new technologies. Thus, it aims at contributing essentially to the region's innovative performance. An additional advantage of the STP under examination is its close proximity with the regions' oldest and biggest university and two major research centers.

A panel dataset is constructed for the period 2002–2012 for both states $s = 0$ and $s = 1$ for the four Greek regions in order to identify RIS idiosyncrasies. Regarding $s = 1$, all the indices of innovation inputs and innovation outputs, as well as the GERD index, follow the scaling of the Regional Innovation Scoreboard.[4] In other words, the data employed have

[1] This approach may straightforwardly be extended in the case of all RIS inputs and not just the dominant one. In this case, the $\mathbf{WEffSP}$ is a $((n+p)m \times m^2)$ matrix.

[2] Input and output variables detailed definitions, rationale and sources may be found in the Regional Innovation Union Reports (2010, 2011, 2013, 2014) and Regional Innovation Scoreboard Reports (2009, 2012, 2014).

[3] Due to space limitations, Patras Science Park case study is presented quite briefly. For a more detailed presentation of Patras Science Park, see Bakouros et al. (2002), Sofoulli and Vonortas (2007), Antonopoulos et al. (2009).

[4] All data have been transformed to normalized values that are equal to the difference between the real value and the lowest value across all European regions divided by the difference between the highest and lowest value across all European

been adjusted for interaction with the European innovation system according to the transformation described in Eq. (11). Although the weight matrix (**W**) is not a priori known, it is employed via the measurement scale of the innovation inputs and outputs variables. The descriptive statistics of the employed variables are presented in the right part of the Table 1 both for the four Greek regions (upper right part) and for the case of the innovation system of the Western Greece region (lower right part).

In order to device the dataset that corresponds to a RIS without the existence of an STP ($s = 0$), we have employed information from two sources; firstly, the absolute values for each employed indicator/variable (g^1) were drawn from the Planning Directorate of the Western Greece Region which provides these data to the Greek Statistical Authority, which in turn provides them to Eurostat. Secondly, and for the same period, a small-scale case study has been conducted in order to gather the corresponding information pertaining to the STP, including firms' and organizations' activities located within its premises. The amount of innovation inputs and outputs attributed in the STP's enterprises and organizations were subtracted from g^1, and thus, the corresponding innovation inputs and outputs of the counterfactual case, the RIS without the STP operation, were calculated (g^0). Using this information, yearly adjustment coefficients (α_{it}) have been calculated for each input and output that correspond in state zero ($s = 0$) according to $\alpha_{\text{it}} = 1 - (g^0_{\text{it}}/g^1_{\text{it}})$. Basic descriptive statistics of the adjustment coefficients α_{it}, in an average period base, are presented in Table 2.

Thus, for each indicator θ_{it} approximating the latent variables, we have calculated the corresponding values on the basis of $\theta^0_{\text{it}} = \alpha_{\text{it}}\theta^1_{\text{it}}$, where θ^1_{it} are the weighted values of the regional innovation inputs and outputs as they are provided by the Regional Innovation Scoreboard Reports. Basic descriptive statistics of input–output variables as well as the policy instrument variable of the measurement model for state $s = 0$ are

Footnote 4 continued
regions. These values are first transformed using a power root transformation in order to take into account that they are not normally distributed (Hollanders et al. 2009, p. 23).

Table 1 Descriptive statistics of the employed variables

State	$s = 0$							$s = 1$						
	PI	INNI		INNO				PI	INNI		INNO			
	GERD	EMPHT	BERD	PUBL	PAT	PPIN	INNSL	GERD	EMPHT	BERD	PUBL	PAT	PPIN	INNSL
National Innovation System (all four regions)														
Average	0.322	0.168	0.161	0.218	0.245	0.342	0.439	0.325	0.171	0.164	0.221	0.249	0.347	0.444
(SD)	(0.059)	(0.150)	(0.098)	(0.087)	(0.051)	(0.078)	(0.166)	(0.056)	(0.148)	(0.096)	(0.087)	(0.049)	(0.076)	(0.161)
Min	0.250	0.040	0.040	0.120	0.180	0.252	0.240	0.250	0.047	0.040	0.120	0.180	0.263	0.270
(Max)	(0.410)	(0.480)	(0.350)	(0.370)	(0.360)	(0.690)	(0.890)	(0.410)	(0.480)	(0.350)	(0.370)	(0.360)	(0.690)	(0.890)
Regional Innovation System (region of Western Greece)														
Average	0.237	0.055	0.090	0.215	0.155	0.232	0.259	0.272	0.059	0.115	0.228	0.227	0.308	0.328
(SD)	(0.017)	(0.007)	(0.039)	(0.228)	(0.014)	(0.029)	(0.061)	(0.018)	(0.008)	(0.036)	(0.013)	(0.023)	(0.034)	(0.059)
Min	0.250	0.040	0.050	0.200	0.180	0.252	0.240	0.250	0.047	0.080	0.210	0.180	0.263	0.270
(Max)	(0.300)	(0.160)	(0.180)	(0.230)	(0.230)	(0.350)	(0.410)	(0.300)	(0.070)	(0.200)	(0.240)	(0.260)	(0.380)	(0.440)

Table 2 Descriptive of the employed adjustment coefficients in two states ($s = 1$ to $s = 0$)

	Average (SD)	Max	Min
GERD	0.871 (0.052)	0.912	0.818
BERD	0.785 (0.071)	0.844	0.749
EMPHT	0.920 (0.044)	0.941	0.905
PUBL	0.945 (0.046)	0.967	0.921
INNSL	0.77 (0.06)	0.824	0.738
PAT	0.680 (0.11)	0.792	0.63
PPIN	0.742 (0.13)	0.831	0.685

provided in the left part of Table 1 both for the four Greek regions (upper right part) and for the case of the innovation system of the Western Greece region (lower right part). Obviously, adjustment coefficients have been applied only with respect to the Western Greece region innovation data.

4.2 Variables definition

Two observed variables are the indicators of the innovation inputs latent variable (INNI). More specifically, we consider the BERD and the EMPHT as they are defined in the Frascati Manual. All R&D expenditures in the government sector (GOVERD) and the higher education sector (HERD), as defined in the Frascati Manual, are represented by the GERD variable that forms the single indicator exogenous latent variable of the PI. The endogenous latent variable of the regional innovation outputs (INNO) is composed of the (1) INNSL variable, which is defined as the turnover of new or significantly improved products as a percentage of the total turnover of the firm in the region; (2) the number of patent applications (PAT); (3) the percentage of the number of SMEs who introduced a new product or a process to one of their markets as a percentage of the total number of SMEs in the region (PPIN); and (4) the number of public–private coauthored research publications (PUBL). Finally, the regional idiosyncrasies that may exert an influence on RIS efficiency (Quatraro 2009) is captured by a dummy variable DR which is reflected by the single indicator latent variable REG. The DR variable takes the value of 1 in the case that the observation corresponds to the Western Greece region and 0 for the rest three Greek regions included in the dataset.

5 Results and discussion

5.1 The RIS structural model

In the first stage of our empirical analysis, we have estimated the structural equation model along with the measurement model presented in relationships (3) and (4) employing partial least-squares structural equation modeling (PLS-SEM) techniques. PLS is a soft causal modeling approach to SEM, aimed at maximizing the explained variance of the dependent latent constructs, with no assumptions about data distribution (Esposito Vinzi et al. 2010). PLS becomes a powerful estimation tool when (1) the sample size is small; (2) the applications have little available theory; (3) the predictive accuracy is paramount and the correct model specification cannot be ensured (Hwang et al. 2010; Wong 2013). All of the above situations are in operation in the context of the present research; especially with respect to the rather small size of our sample $s = 0$ ($N = 44$), we should note that in the context of the adopted PLS-SEM estimation methodology, the minimum required sample size should be at least equal to the largest of the (1) ten times the largest number of indicators or (2) ten times the largest number of structural paths directed at a particular latent construct in the structural model (Hair et al. 2011). In our case, both of these rules of thumb are satisfied.

Empirical estimations of the structural model are presented in the upper part of Table 3 and the corresponding estimation results of the measurement model in the middle part of the same table for states $s = 1$ and $s = 0$, respectively. The lower part of Table 3 mirrors the fit and reliability indices.[5] It becomes evident from the beginning that the estimation results for the state $s = 1$ are differentiated from the corresponding empirical results of state $s = 0$ only with respect to the magnitude of the coefficients. The signs of the structural paths and the loadings in all the cases, as well as the level of statistical significance in the huge majority of cases, remain unaltered. Based on the above, it could be argued that the operation of the STP in the RIS *does not* reshape the basic relationships of the transformation mechanism of the regional inputs to regional outputs.

[5] Estimations have been made using the Smart-PLS (v.3.1.3) software developed by Ringle et al (2014).

Table 3 Structural and measurement model estimation results

Latent variables	Structural model—path coefficients β_i							
	INNI		REG		INNO		PI	
	$s = 0$	$s = 1$	$s = 0$	$s = 1$	$s = 0$	$s = 1$	$s = 0$	$s = 1$
PI	0.512***	0.498***	−0.604***	−0.518***	–	–	–	–
	(0.118)	(0.112)	(0.083)	(0.093)				
INNI	–	–	–	–	0.964***	0.935***	–	–
					(0.008)	(0.121)		
REG	−0.102*	−0.111**	–	–	–	–	–	–
	(0.068)	(0.063)						
Indicators	**Measurement model—loadings λ_i**							
GERD	–	–	–	–	–	–	1.000	1.000
							(–)	(–)
BERD	0.972***	0.959***	–	–	–	–	–	–
	(0.011)	(0.012)						
EMPHT	0.976***	0.964***	–	–	–	–	–	–
	(0.009)	(0.011)						
PUBL	–	–	–	–	0.895***	0.912***	–	–
					(0.027)	(0.023)		
INNSL	–	–	–	–	0.942***	0.922***	–	–
					(0.016)	(0.021)		
PAT	–	–	–	–	0.975***	0.954***	–	–
					(0.008)	(0.100)		
PPIN	–	–	–	–	0.700***	0.655***	–	–
					(0.108)	(0.131)		
REGD	–	–	1.000	1.000			–	–
			(–)	(–)				
Statistic	**Fit and reliability statistics**							
R^2	0.336	0.319	0.465	0.401	0.928	0.910	–	–
AVE	0.949***	0.946	–	–	0.782***	0.768***	–	–
	(0.019)	(0.022)			(0.039)	(0.046)		
CRI	0.974***	0.972***	–	–	0.934***	0.929***	–	–
	(0.010)	(0.021)			(0.016)	(0.021)		
Cronbach's α	0.946***	0.942***	–	–	0.903***	0.894***	–	–
	(0.021)	(0.025)			(0.039)	(0.038)		

***, ** and * denote a statistical significance at 1, 5 and 10 % level, respectively

Bootstrapped standard errors are reported in parentheses

According to the estimation results, the PI latent variable exerts a positive influence on the regional innovation inputs latent variable (path γ_1). As it was expected, the relationship between regional innovation inputs and regional innovation outputs is positive (path β_2).Hence, basic assumptions of the knowledge production function are valid. On the other hand, it is rather interesting to note that the PI latent variable exerts a negative influence on the REG latent construct (γ_2 path), which captures the regional idiosyncrasies. It seems that although high levels of GERD facilitate the Western Greece RIS convergence with the national innovation system, the operation of the STP within the examined RIS slows down this convergence process. Regarding the β_1 path, empirical results showcase that regional idiosyncrasies negatively influence regional innovation inputs inducing therefore a 'leakage' of innovation resources from the regional innovation system. This leakage becomes more intensive in the case where the STP is included as a regional innovation anchor[6].

As it has already been mentioned, besides the estimated *direct* structural paths, the employed modeling approach allows us to estimate three *indirect* effects of PI on the regional innovation outputs. The relationship between PI and INNO is partially mediated by INNI, while the relationship between PI and INNI is fully mediated by REG. The indirect and total effects are presented in Table 4 for both the examined states.

Further evidence on a seemingly offset effect of regional idiosyncrasies is provided if we consider the indirect effects of PI on INNI through REG as they are presented in the upper part of Table 4. Taken together, the empirical findings suggest that the national innovation system (NIS) dominates over the RIS for high levels of government investments in R&D. Such a homogenization process though eventually balances the decrease in regional innovation inputs, which is induced by the regional specificities. Notwithstanding, such an offset effect is slightly less strong in the case where the STP is included as an innovation anchor. The same picture emerges if one considers the indirect effects of PI and REG on regional innovation outputs through regional innovation inputs. It is apparent that the inclusion of the STP in the regional innovation system (1) downplays the positive role of PI and (2) amplifies the negative impact of regional idiosyncrasies on regional innovation outputs.

Surprisingly enough, the total effects estimation results also suggest that the positive influence of PI latent construct on both the regional innovation inputs and regional innovation outputs latent constructs *is greater in the case where the STP is not included in the RIS than in the case where Science Park is among the regional innovation anchors.* Therefore, the empirical evidence suggests that the role of STP in boosting the innovation performance of the region needs to further explore the nature of regional specificities that hinder the role and operation of the STP in the region. Such kind of analysis is presented and discussed in the following two sections on the basis of the estimated RIS differential efficiencies with respect to the STP.

[6] This argument disregards the different levels of statistical significance of the estimated coefficients in each one of the two states.

5.2 GERD dominance, policy authorities preferences and STP performance

Recalling that GERD is considered as the policy dominant input variable, we devise the following policy authority 'preferences' function with respect to the GERD level.

$$\mathrm{GERD}_\beta = \beta\mathrm{GERD}_{\max} + (1-\beta)\mathrm{GERD}_{\min} \qquad (13)$$

with $\beta \in [0,1]$. Essentially, the β parameter reflects the decisions of the regional, national and European authorities regarding the adjustment of the current level of the public expenditures on R&D activities dedicated in the region (GERD_β) at any value of GERD within an interval, which is defined historically between $(\mathrm{GERD}_{\min})$ and $(\mathrm{GERD}_{\max})$. Decision-making outcomes of authorities capture their preferences, but also their limitations, thus allowing us to shed some light on the impact of fiscal austerity-oriented policies on STP's performance within the Western Greece RIS. For the purposes of the paper at hand, we define each step for the parameter β to be equal of 0.1. It should be noted that (1) the rate in which the parameter is allowed to vary and (2) the margins of the interval which may be defined at any given value that either the model or policy requirements need to be satisfied.

Employing the mechanism described in Eq. (13), a set of alternative GERD_β values are generated. In the next step, we estimate the RIS differential efficiencies with respect to the STP EffSP_j for all the alternative GERD_β values. The estimated values of RIS differential efficiencies with respect to the STP for the whole spectrum of the policy authorities preferences regarding the level of GERD are presented in Table 5.

A negative value in Table 5 signifies that STP's operation hinders the Western Greece RIS performance, while a positive value signifies that the contribution of the STP in the Western Greece RIS performance is beneficiary. At this point, it should be recalled that the state without PSP $(s = 0)$ is a

Table 4 Indirect and total effects estimation results

	Source	Mediator	Outcome	$s = 0$	$s = 1$
Indirect effects	PI	REG	INNI	0.062**	0.059*
				(0.036)	(0.035)
	PI	INNI	INNO	0.553***	0.531***
				(0.035)	(0.100)
	REG	INNI	INNO	−0.062*	−0.104**
				(0.044)	(0.067)
Total effects	INNI	–	INNO	0.964***	0.935***
				(0.080)	(0.121)
	PI	–	INNI	0.574***	0.557***
				(0.098)	(0.0102)
	PI	–	INNO	0.491***	0.427***
				(0.042)	(0.055)
	PI	–	REG	−0.604***	−0.518***
				(0.083)	(0.093)
	REG	–	INNI	−0.102*	−0.111**
				(0.068)	(0.063)
	REG	–	INNO	−0.098*	−0.104**
				(0.066)	(0.067)

***, ** and * denote statistical significance at 1, 5 and 10 % level, respectively

Bootstrapped standard errors are reported in parentheses

Table 5 Differential efficiencies with respect to GERD

β	(PAT/GERD)	(PPIN/GERD)	(PUBL/GERD)	(INNSL/GERD)
0.0	−0.010	−0.066	−0.059	−0.015
0.1	−0.007	−0.058	−0.055	−0.012
0.2	−0.005	−0.050	−0.050	−0.010
0.3	−0.003	−0.042	−0.046	−0.007
0.4	−0.001	−0.034	−0.042	−0.004
0.5	0.001	−0.026	−0.038	−0.002
0.6	0.003	−0.018	−0.035	0.000
0.7	0.005	−0.010	−0.031	0.003
0.8	0.007	−0.002	−0.028	0.005
0.9	0.009	0.007	−0.024	0.007
1.0	0.011	0.015	−0.021	0.009

counterfactual situation and has been indirectly approached via the adjustment of the Regional Innovation Scoreboard corresponding innovation input–output indices, by subtracting inputs and outputs that are directly related to STP and the tenant companies.

Although this approximation aids us to devise a situation where the contribution of STP is obliterated from the 'hard performance evidence' of the Western Greece RIS, it should be acknowledged that there are unobservable factors that influence the innovation profile of Western Greece and are not directly measured and thus not depicted. Hence, the counterfactual situation suffers from two weaknesses: (1) The indirect positive effects that the STP exerts in the Western Greece RIS are taken into account although the STP has been displaced, resulting in an underestimation of STP's performance, and (2) the input–output bundles of the hosted companies are totally deducted from the RIS, ignoring the possibility that the tenant firms might still exist and operate at different locations within the region. Therefore, it is not unrealistic to assume that the two above opposite bias

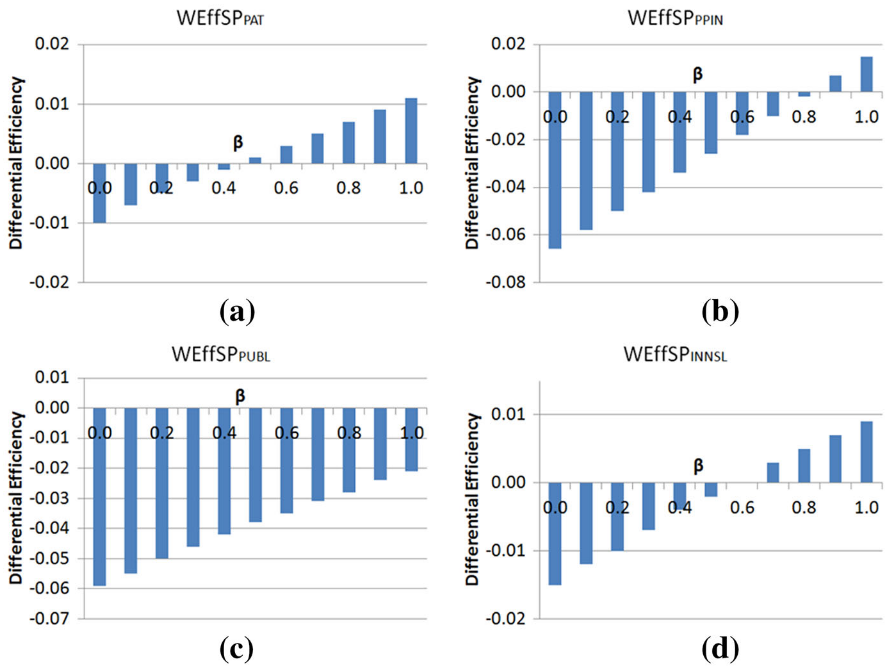

Fig. 2 Differential efficiencies with respect to GERD for: **a** PAT, **b** PPIN, **c** PUBL and **d** INSL

offset each other. Keeping in mind this reservation, a graphical illustration of the **WEffSP*** matrix which results according to the policy authority preferences function described by Eq. (13) is given in Fig. 2.

A series of interesting findings are identified in RIS differential efficiency with respect to STP for various levels of GERD. Firstly, the STP differential efficiency with respect to GERD is an increasing function of the β parameter, as the latter conveys the level of the policy dominant variable GERD. Except for the case of publications (PUBL), *it seems that the STP contributes positively to the region's innovation system performance only for high levels of GERD. On the contrary, for low levels of the GERD, the examined STP seems to worsen the RIS performance in terms of all outputs.*

More specifically, a closer look in Fig. 2a reveals that the STP exhibits significant capabilities in boosting innovative sales (INNSL) and patenting activity (PAT) when GERD investments are relatively low. In this direction, and in order for the STP to contribute positively in Western Greece RIS performance, STI policy makers at regional and national level need to design policies and direct the available funding at individual output targets. Only for the value of β parameter exceeding 0.8, all the differential efficiency indices become positive except for the copublications case. In other words, only during periods of great spending when GERD investments exceeded the 80 % of the historical maximum, did the STP contribute positively in all differential efficiency indices, but the copublications.

These findings highlight the mediating role of the STP and the structural inefficiencies of Western Greece RIS. Given the fact that the examined STP is an independent organization that sets and implements its own policies and more importantly manages its own resources, its coordinating role is hampered by the fact that the organizations that PSP is called to coordinate are both autonomous and distant in cultural, psychic and institutional terms (Hansson et al. 2005). This fact in turn results in structural coordination issues that when government spending in the production of new knowledge is low are highlighted. Such kind of detuning is further decomposed in inadequate scale and scope economies, lack of critical mass of agents and resources to be coordinated and exceedingly high transaction and search costs. The situation sketched above reflects the conditions induced by the current financial crisis that WGR and Greece in general are undergoing. Structural reforms and major reorientation are demanded for all agents involved in the regional knowledge production process. The emphasis should be placed in shaping common organizational principles and a new innovation process targeting at establishing a new regional paradigm oriented toward open innovation principles (Hansson et al. 2005; Barbero et al. 2012; Taymaz and Ucdogruk 2013), which would result in the regional innovation actors to share common objectives and risks and not just resources.

However, the most important issue detected that contributes majorly in the situation depicted in Fig. 2 is that the STP, from its establishment, has been managed as public enterprise and has been linked organizationally to national government via the Greek Ministry of Finance. Hence, the adopted routines and the resulting organizational memory have led the STP not to develop effective links with the regional governance system and not being oriented to operate as a financially sustainable private enterprise. In other words, this particular STP has been always oriented toward managing significant amounts of GERD investments and has developed over the years corresponding capabilities overlooking the needs to develop market capabilities and linkages with local and international business actors.

6 Conclusions

Financial crisis has raised questions about the sustainability and the contribution of innovation actors across Europe and especially in Southern European countries such as Greece. In this paper, we introduce a methodological framework that allows for the evaluation of STP's performance under different intensity levels of GERD activities in the context of a Greek RIS. We argue on the idiosyncratic character of the investigated Western Greece RIS, on the basis of the dominant role of the GERD as a policy instrument capable of stirring the regional innovation policy.

Our framework relies on the estimation of efficiency indices that come out of an extended multi-input–multi-output knowledge production function approach, in which, however, the dominant role of GERD and the specificities of innovation output mix are included. In this direction, we argue on the rather latent nature of the transformation mechanism of innovation inputs into outputs and a structural equation system is devised in order to take into account the unknown a priori regional knowledge production function, the dominant character of the GERD policies as well as the regional idiosyncrasies. Data are employed from the regional innovation, as far as the Greek RISs are concerned, and from a small-scale case study, with respect to the examined regional STP, covering the period from 2002 to 2012.

The contribution of the examined STP in the Western Greece RIS performance diminishes alongside with the decrease in GERD investment levels, with respect to all the efficiency indices. These findings are attributed to the structural characteristics of both the Western Greece RIS and the STP under investigation and capture their dependence on managing public financial resources for STI activities.

Combining thus the differential efficiency of the STP with the conditions imposed by the current economic crisis, it becomes evident that the STP needs to reorientate its position within the corresponding RIS. More specifically, the examined STP needs to tighten the links with the region and take up a coordinating role not of managing funds, but of managing and creating linkages between innovation anchors within the RIS. In doing so, STP needs to set its priorities in supporting STI policies based on youth entrepreneurship, promoting the commercialization of the significant research output of the higher education institutions of the region and developing relationships among the high-tech startups and the incumbent firms of the region. In other words, we argue *that during the fiscal austerity times, Science and Technology Parks should primarily change their orientation from the technology transfer mechanisms toward institutions that aim at boosting entrepreneurial capital and especially changing society's perception of entrepreneurship.*

Last but not least, this framework could be applicable to many other contexts and may be useful for policy-making purposes. However, one should keep in mind that the investigation of any RIS and the corresponding attempts of evaluation of any innovation actors are associated with high degrees of unobserved heterogeneity, and thus, the methodological approaches should be adjusted in order to accommodate each region's special characteristics.

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Appendix

The structural equations of the system (1) and taking into account that $E(\zeta) = 0, E(\varepsilon) = 0$ and $E(\delta) = 0$ may be written as:

$$E(\text{INNO}) = \hat{\beta}_2 E(\text{INNI}) \tag{14}$$

$$E(\text{INNI}) = \hat{\gamma}_1 E(\text{PI}) + \hat{\beta}_1 E(\text{REG}) \tag{15}$$

$$E(\text{REG}) = \hat{\gamma}_2 E(\text{PI}) \tag{16}$$

where hats (^) denote estimated values. The reduced form of Eq. (14), with respect to the exogenous latent of policy instrument (PI), is:

$$E(\text{INNI}) = (\hat{\gamma}_1 + \hat{\beta}_1 \hat{\gamma}_2) E(\text{PI}) \tag{17}$$

From the measurement Eq. (2), it holds that $E(\text{PI}) = \frac{\text{GERD}}{\hat{\varphi}_\text{G}}$. Combining this with Eq. (17), it becomes that:

$$E(\text{INNI}) = (\hat{\gamma}_1 + \hat{\beta}_1 \hat{\gamma}_2) \frac{\text{GERD}}{\hat{\varphi}_\text{G}} \tag{18}$$

Replacing equation (18) in equation (14), it results in:

$$E(\text{INNO}) = \frac{\hat{\beta}_2}{\hat{\varphi}_G} \left[\hat{\gamma}_1 + (\hat{\beta}_1 \hat{\gamma}_2) \right] \text{GERD} \tag{19}$$

The term $\left(\hat{\beta}_2 \hat{\gamma}_1 / \hat{\varphi}_\text{G} \right)$ is the indirect effect of GERD on INNO through the INNI, and the term $\left(\hat{\beta}_2 \hat{\beta}_1 \hat{\gamma}_2 / \hat{\varphi}_\text{G} \right)$ is the indirect effect of GERD on INNO through REG and INNI.

Moving to the measurement equation of INNO, as it is formulated in relationship (2), it is apparent that for the k constructs $\hat{y}_i$, $(i = 1, \ldots, k)$ of the latent variable, INNO holds that[7]:

$$E(\text{INNO}) = \frac{\hat{y}_i}{\hat{\lambda}_i}, \quad i = 1, \ldots, k$$

Summing up for all k constructs of the knowledge output latent variable, it results that:

$$E(\text{INNO}) = \frac{1}{k} \left(\sum_{i=1}^{k} \frac{y_i}{\hat{\lambda}_i} \right) \tag{20}$$

By replacing the second part of Eq. (20) in Eq. (19):

$$\hat{y}_j = \frac{k \hat{\lambda}_j}{\hat{\varphi}_G} \left[\hat{\beta}_2 \left(\hat{\gamma}_1 + \hat{\beta}_1 \hat{\gamma}_2 \right) \right] \text{GERD} - \hat{\lambda}_j \sum_{i \neq j}^{k} \frac{\hat{y}_i}{\hat{\lambda}_i} \tag{21}$$

Hence, the efficiency of the regional innovation system regarding the $\hat{y}_j$ innovation output with respect to GERD is defined as:

$$\begin{aligned} \text{Eff}_j &= \frac{\hat{y}_j}{\text{GERD}} \\ &= \frac{k \hat{\lambda}_j}{\hat{\varphi}_\text{G}} \left[\hat{\beta}_2 \left(\hat{\gamma}_1 + \hat{\beta}_1 \hat{\gamma}_2 \right) \right] - \frac{\hat{\varphi}_\text{G}}{\text{GERD}} \left(\hat{\lambda}_j \sum_{i \neq j}^{k} \frac{\hat{y}_i}{\hat{\lambda}_i} \right) \end{aligned} \tag{22}$$

The differential RIS efficiency of the Science Park, with respect to the GERD, as it is defined in Eq. (8) of the main text, is the difference in Eff_j between states s = 0 and s = 1. Denoting with Δ, these differences form Eq. (8) and it arises that:

$$\begin{aligned} \text{EffSP}_j &= \frac{\Delta \hat{y}_j}{\text{GERD}} = \frac{\hat{y}_j^1 - \hat{y}_j^0}{\text{GERD}} \\ &= k \Delta \left(\frac{\hat{\lambda}_j}{\hat{\varphi}_\text{G}} \right) \left[\Delta \left(\hat{\gamma}_1 + \hat{\beta}_1 \Delta \hat{\gamma}_2 \right) \right] \\ &\quad - \frac{1}{\text{GERD}} \Delta (\hat{\varphi}_\text{G}) \left(\Delta \left(\hat{\lambda}_j \right) \sum_{i \neq j}^{k} \frac{\Delta(\hat{y}_i)}{\Delta \left(\hat{\lambda}_i \right)} \right) \end{aligned} \tag{23}$$

Considering p-different levels of GERD variable, the $\mathbf{EffSP}_j$ vector is composed as it is depicted in Eq. (9) of the main text. The generalization of the above procedure in the case of additional constructs of policy instrument and/or in the case of different components of knowledge inputs and outputs variables is straightforward and results in the generalized $((n \times p) \times m)$ matrix.

[7] In our case $k = 4$, that is, PAT, INNSL, PUBL, PPIN.

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