Revisiting the role of Incubators during Fiscal Austerity Times: The Case of PSP, Greece.

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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. Based on the concept of Regional Innovation Systems we introduce a methodological approach which allows for the evaluation of the performance of Science and Technology Parks performance under different intensity levels of Government Expenditures on R&D which is considered as the dominant a policy instrument. Our framework relies on the estimation of efficiency indices which come out of a multi input - multi output knowledge production function approach. The region under scrutiny is Western Greece and its corresponding Science Park for the period from 2000-2009. The main empirical finding suggests that, due to institutional and other factors, the contribution of PSP, as it has been formed in last decade, is negative in fostering innovation activities in the Region, when considering the conditions induced by the financial crisis.

Keywords
Science Parks, Regional Innovation System, Evaluation, Efficiency, Financial Crisis, Dominant Policy Input

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1. Introduction

Financial crisis and the consecutive public debt deadlock have resulted in significant economic and social turmoil, in most Southern European Countries and especially in Greece which is the most affected European economy. These developments have prioritized the search for new "engines of growth" which would be compliable to the restrictions imposed by the fiscal austerities policies. 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 (RIS) as the latter have been assigned the mission to contribute significantly in terms of Regional Development (Audretsch 2001; Salvador and Rolfo 2011).

According to the latest Science and Technology and Industry Outlook (OECD 2012; p.302), the importance of public expenditures in promoting Science and Technology policies in the entire European context is indisputable. In Greece in particular, including the Region of Western Greece, public expenditures on R&D are a super-dominant means for boosting innovation activities and technological development. 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[1]. Thus, it becomes evident the necessity to investigate and evaluate the role of STPs in

[1] Greek GERD has stagnated at 0.60 % of GDP and is heavily dominated by public expenditure which is far below the OECD median. Moreover the share of BERD in GDP was the second lower amongst OECD countries and Greece completely lacks large corporate investors in R&D

the context of the specific GERD dominated RIS they operate, under the pressure exerted by fiscal austerity conditions.

Despite previous attempts to investigate the role 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 (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 this task to be executed under no special requirements in terms of data and computation costs.

Regarding the Greek STPs ecosystem, serious weaknesses arise with respect to policy coordination and evaluation (OECD 2012; p. 300). Bakouros et al. (2002), and Sofouli and Vonortas (2007) present a historical overview of Greek STPs system and proceed with an informative non-quantitative illustration of their operational framework. In somewhat different line, Antonopoulos et al. (2009), focus on one particular Greek STP, namely Patras Science Park, adopt a highly deductive, non quantitative approach, and sketch some potentials for Regional Development accrued to a hypothesized operation, orientation and competencies of the examined STP.

In the present paper we *introduce a rather simple 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 and Technology (S&T) Policies*. It is essential to point out that *S&T Policy Authorities Preferences* encompass the conditions generated by the current fiscal austerity era in Europe and especially in Greece.

The analysis is realized in terms of efficiency indices which take into account the interactions of the RIS with the Greek National Innovation System and the interaction with the European Innovation System. More specifically, the proposed methodology requires information regarding the innovation performance of a specific region and can be found in the information provided by Regional Innovation Scoreboard, as well as information about the STP under investigation which in turn may be easily gathered through a small scale case study. In this context it is not worthless to mention that this methodological approach keeps computational costs at a minimum and may serve the performance evaluation of any agent in a typical RIS.

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, with respect to RIS, STPs and S&T policies. Section 3 presents the proposed methodological framework while section 4 is devoted in presenting an analytical overview of the case study of the RIS of Western Greece and Patras Science Park, along with the data employed. Section 5 discusses the empirical results and section 6 concludes the paper.

2. Theory and Literature

2.1. Regional Innovation Systems: Theoretical background

Freeman (1987; p.1) was one of the first to conceptualize the innovation process as "*the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify, and diffuse new technologies*". In this line, Kline and Rosenberg (1986) developed a theoretical model of innovation refuting the linear innovation process i.e. from research to production and sketched a complex interactive system, where feedback loops are featuring. A decade later Edquist (1997) and Lundvall (1992), systematized and formalized the notion of Systems of Innovation defining them as *"…a dynamic system, characterized both by positive feedback and by reproduction, cumulative causation, and virtuous and vicious circles…."*. The central idea in modern innovation systems theory lies in the concept that what appears as innovation at the aggregate level is in fact the result of an interactive process that involves many actors at the micro level, and that next to market forces many of these interactions are governed by nonmarket institutions (Soete et al. 2009).

Innovation systems have attracted a lot of interest since they address innovation process as a whole and do not focus separately on side components such as determinants, sources, human 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. For the investigation of Innovation Systems the relevant literature has identified three (overlapping) types, each one corresponding to a different level of analysis; the National Systems of Innovation (NIS; Edquist 1997), the Regional Innovation Systems (RIS; Cooke 2001) and Sectoral Systems of Innovation and Production (SSIP; Malerba 2002). For quite some time, economic geographers have argued that due to the tacit nature of knowledge, interactions among agents often take place at local level, that is, between organizations that are geographically close (Storper and Venables 2004; Asheim and Gertler 2005; Boschma 2005). The Regional Innovation System lies at the meso level of aggregation and is currently the focus of the current European Programming Period, the so-called Horizon 2020, as it is considered a hub between central authorities and national policies and local production and innovation performance. However, regional disparities in a series of fundamental aspects lead to the inevitable observation that there is considerable heterogeneity among European regions in terms of their structural features. Broadly speaking, the capability of regional governments in the periphery of the EU in multi-level lobbying and influence to access regional innovation funding is affected by decision-making structures that remain centralized for almost all public matters even when a wide ranging programme of regional decentralization may have been implemented (Cooke 2002; Fukugawa 2008). Therefore, in order to draw regional policy conclusions and suggestions the analysis needs to go beyond the identification of the factors that influence the innovation process (Andersson and Karlsson 2006).

2.2. STPs: Definitions and Review of Literature

The contribution of a Science Technology Park or Business Incubator into a Region's welfare has been extensively highlighted, and in this line, many attempts have been made to introduce endeavours that would welcome the set up and growth of Science and Business Parks in many Regions around the world (Bellavista and Sanz 2009). From a policy perspective, the need to establish a Science and Technology Park[2] within a particular region would serve a two-fold objective; the first one sees the operation of an STP as a seedbed and an enclave for technology, nurturing the development and growth of new, small, high-tech firms, facilitating the transfer of university know-how to tenant companies, encouraging the development of University-based spin-offs and stimulating the development of innovative products and processes (Felsenstein 1994). The second objective visualises STPs as catalysts

[2] In this paper we follow IASP definition for Science and Technology Parks as *"...an organisation managed by specialised professionals, whose main aim is to increase the wealth of its community by promoting the culture of innovation and the competitiveness of its associated businesses and knowledge-based institutions"... (http://www.iaspworld.org/information/definitions.php)*

for regional economic development or revitalization promoting thus, economic growth.

In reality however, STPs are quite heterogeneous both in terms of context and importance within the RIS. In order to contextually categorize STPs, Annerstedt (2006) and Haselmayer (2004) identified three generations based on the notion that STPs evolve over time; the First Generation of STPs is viewed as an extension of a University which would operate as a science-based technology zone. STPs of this generation adopt a 'linear approach' to innovation. The Second Generation of STPs Park remains an extension of a University (or other major R&D facility) into a dedicated high-tech zone but is driven from market forces to greater extent than the previous Generation of STPs This Generation is less concerned with the early exploitation of scientific results and capabilities than with the final stages of the innovation process. Finally, the Third Generation STPs is perceived as the quintessence of science-industry-government relations, increasingly functional and specialized along with its participation in local, regional and even global innovation activities. In this view, the Third Generation STPs becomes an urban catalyst for innovation that could influence also the broader culture of entrepreneurship in the city-region.

Previous research on STPs sits mainly within two broad areas of study and specifically on (i) the "institutional perspective" and on (ii) the "technology district" view originating from the field of economic geography (Koh et al. 2005). From one hand, the institutional perspective views an STP as an Institution set out to provide assistance to its tenants in various ways. Emphasis is given to incubators' operational issues, degree of spin-offs, and focuses on whether STPs contribute in the tenant firms' competitive advantages as well as the existence of any positive spillover effects to firms located in its near proximity and the regional economy. On the other hand, the perspective of economic geography views STPs and their surrounding region as *an entity,* consisting of specialized firms with an evolving structure of interfirm linkages and agglomerative effects. Of great importance is the examination of their role and contribution in the Region's development (Storper and Harrison 1991; Markusen 1996). The recent literature has encompassed both the institutional and the geographical perspectives.

Hence one quite understands the efforts of National and Regional authorities in many OECD countries to stimulate the formation of enterprise clustering via providing support for the creation of STPs. However, reality sketches a rather different picture. STPs -at least successful ones- do not exist everywhere (Wallsten 2004). In addition, and even though STPs are regarded as vital conductors in the process of technology transfer between Academia and Business Sectors, as well as a valuable regional development policy instrument, their role has been found not to be significant in pursuing many of these objectives (Massey et al. 1992; Uyarra 2008).

More specifically, Westhead (1997) and Salvador and Rolfo (2011) report lack of conclusive evidence regarding 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.

2.3. Evaluating the role of a Science Park in a Regional Innovation System

From a policy perspective, Innovation Systems are a valuable framework for evaluating policies in the broad field of innovation. However, the field of S&T, is a relative young area of policy intervention, and as such the evaluation practice has a much shorter history and is much less formalized. In particular, evaluating the performance of innovation systems did not start until related S&T policies targeted innovation as a unified system (Autio 1998). In other words, this particular sub-discipline of policy evaluation lacks an adequate history which would ensure *learning by experience*. On the other hand, we should acknowledge the difficulties associated with the evaluation of policy interventions in the field of S&T which sometimes can be proven insurmountable. Furthermore, measuring knowledge creation, diffusion and the importance of innovations introduced is a not easy task since there are “delay effects” or “time lag”, i.e. there are long time delays between the moment an innovation policy is launched and the moment the actual results of that policy are seen (Lee 2002).

Another layer of difficulty is added if one takes into account that evaluation is directed at Innovation Systems, which automatically renders it more complex than evaluating one-dimensional policy interventions. While one-dimensional policy interventions have well defined objectives and target groups, when it comes to Innovation Systems, the efficiency and effectiveness of the innovation process observed at the aggregate level depends not only on the behavior of individual actors, but also on the institutions that govern their interaction, and hence, coordination problems arise. Nevertheless, 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).

Towards this direction, in this paper, the focus is in the evaluation of the role of the existence and operation of an STP on the performance of a RIS taking into account the special characteristics, in terms of the policy dominant instrument, of RIS and restrictions imposed by financial crisis. In the next section we present some basic information about the case study of this paper and specifically, the role of Patras Science Park within the context of the RIS of Western Greece.

3. Methodological Framework

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 presenting a simple methodological framework that takes into account the above considerations. More specifically, the conceptual framework employed in this paper is based on knowledge production function (Griliches 1979) adjusted for the RIS and STPs case (Jaffe 1989), through the adoption of the assumption that resources invested in the RIS are transformed into innovation outputs. The special features of the transformation mechanism, non-observable at its largest extent, determine the efficiency of the whole process (Runiewicz-Wardyn 2013). In order to reduce the non-observabilty of this transformation mechanism, and to shed light on the role of STPs on the RIS's performance, we abandon the aggregate, but rather beclouded notion of total factor productivity, and elevate the notion of *RIS input efficiency* which accommodates situations in which an input is dominant. Furthermore, we allow for interrelationships within the RIS's input- and output-side constructs and not just for direct impacts of the inputs on outputs. Figure 1 presents the full picture of the multidimensional input-output relationships (dotted lines), as well as the intra-input (solid lines) and intra-output relationships (dashed lines).

{Insert Figure 1 around here}

Setting aside the striking complexity mirrored in this figure, some crucial basic relationships should be underlined. Extending the framework of knowledge production function (Griliches 1979) we define the abovementioned transformation mechanism of *n* inputs to *m* outputs of the multi-input multi-output type:

$$\left(y_1, \ldots, y_m \right) = f\left(x_1, .., x_n \right) \tag{1}$$

From the inputs side we consider the dominant role, in terms of policy design and implementation, of input $\left(x^* \right)$ for which it holds that:

$$x_k = x_k\left(x^*, \mathbf{z}_k \right) \quad \forall \quad k = 1, \ldots, k-1, k+1, \ldots, n \tag{2}$$

which implies that the levels of all the RIS inputs are, at some extent, determined by the dominant policy variable x^* and is grounded on the notion of "input dominance". In relationship (2), $\mathbf{z}_k$ represent exogenous drivers of x_k. Looking at the output side of the RIS we assume that for any output the following relationship may hold:

$$y_i = y_i\left(y_1, \ldots, y_{i-1}, y_{i+1} \ldots, y_m ; \mathbf{z_i} \right) \quad \forall \quad i = 1, 2, \ldots, m \tag{3}$$

where $\mathbf{z_i}$ represent exogenous drivers of y_i. Equation (3) allows for any complementarity and substitutability relationships to be accommodated in the output side of the RIS.

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

$$Eff_i^s = \frac{y_i^s}{x^{*,s}} \quad \left(i = 1, 2, \ldots, m \right) \tag{4}$$

State 0 corresponds to the transformation mechanism f depicted in equation (1) which sketches the RIS performance when the STP is "absent", while state 1 corresponds to the RIS's transformation mechanism when the STP is included among the innovation key agents. Thus, the *differential efficiency* of the Science Park $(EffSP)$, in terms of the RIS performance, may be easily defined as:

$$EffSP_i^* = Eff_i^{1,*} - Eff_i^{0,*} = \left(\frac{y_i}{x^*}\right)^1 - \left(\frac{y_i}{x^*}\right)^0 \tag{5}$$

In other words, the differential efficiency of the STP regarding the *i-th* 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 $\left(EffSP_i^*\right)$ 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 (Vonortas and Desai 2007), a $(p \times 1)$ vector of Science Park differential efficiencies arises:

$$\mathbf{EffSP_i^*} = \begin{bmatrix} \left(\frac{y_{i1}}{x_1^*}\right)^1 - \left(\frac{y_{i1}}{x_1^*}\right)^0 \\ \ldots\ldots \\ \ldots\ldots \\ \ldots\ldots \\ \left(\frac{y_{ip}}{x_p^*}\right)^1 - \left(\frac{y_{ip}}{x_p^*}\right)^0 \end{bmatrix} \tag{6}$$

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

$$\mathbf{EffSP}^* = \left[\mathbf{EffSP_1^*}, \quad \ldots., \ \ldots., \quad \mathbf{EffSP_m^*}\right] \tag{7}$$

$\mathbf{EffSP}^*$ matrix encapsulates all the information regarding the efficiency of the mechanisms which transform the RIS's crucial resources to outputs, with and without STP, taking into account that policy authorities preferences are implemented through the intensity of the policy dominant input and such being the case this crucial endowment heavily influences the behavior of the RIS agents.

It is worth noting that relationships (6) and (7) do not take into account the interactions between the National and European Innovation System and the examined Regional Innovation System as they have been depicted on the basic conceptual framework (figure 1) above. In order to address this interaction, weights should be attributed in both the input and outputs side of the RIS[3]. These weights adjust RIS's inputs and outputs in terms of their relative position within the National and European Innovation Systems. The "adjusted" values of RIS inputs and outputs are denoted as $(\hat{x})$ and $(\hat{y})$ respectively. Employing them in the context of the relationships (6) and (7), the $\widehat{\mathbf{EffSP}}_i^*$ and $\widehat{\mathbf{EffSP}}^*$ become:

$$\widehat{\mathbf{EffSP}}_i^* = \begin{bmatrix} \left(\frac{\hat{y}_{i1}}{\hat{x}_1^*}\right)^1 - \left(\frac{\hat{y}_{i1}}{\hat{x}_1^*}\right)^0 \\ \ldots\ldots \\ \ldots\ldots \\ \ldots\ldots \\ \left(\frac{\hat{y}_{ip}}{\hat{x}_p^*}\right)^1 - \left(\frac{\hat{y}_{ip}}{\hat{x}_p^*}\right)^0 \end{bmatrix} \tag{8}$$

and

$$\widehat{\mathbf{EffSP}}^* = \left[\widehat{\mathbf{EffSP}}_1^*, \quad \ldots, \ldots., \quad \widehat{\mathbf{EffSP}}_m^*\right] \tag{9}$$

where ^ denotes adjustment for interactions with the National and European Innovation Systems. Dimensions of $\widehat{\mathbf{EffSP}}_i^*$ and $\widehat{\mathbf{EffSP}}^*$ are the same with the $\mathbf{EffSP}_i^*$ and $\mathbf{EffSP}^*$ respectively.

[3] These weights are employed in the Regional Innovation Scoreboard (2006, p. 6-7), where they are analytically presented, and concern the European and National Innovation Systems' influence on Regions.

Finally, the above approach is easily extended to accommodate the evaluation of the STP, not only in terms of the dominant policy input, but also in terms of all other RIS resources. In this case, a generalized $\left((n+p) \times m \right)$ adjusted differential Science Park efficiency matrix $\left(\widetilde{\mathbf{GLEffSP}} \right)$ is obtained, with row-partitions corresponding to each input differential Science Park efficiency:

$$\widetilde{\mathbf{GLEffSP}} = \begin{bmatrix} \widetilde{\mathbf{EffSP}}_1^{\mathbf{x^*}} & \dots & \widetilde{\mathbf{EffSP}}_m^{\mathbf{x^*}} \\ \dots & \dots & \dots \\ \widetilde{\mathbf{EffSP}}_1^{\mathbf{x}_n} & \dots & \widetilde{\mathbf{EffSP}}_m^{\mathbf{x}_n} \end{bmatrix} \qquad (10)$$

4. The Region of Western Greece[4], the Patras Science Park and Data

4.1. Case Study

Western Greece Region (WGR) is the home of 6.3% of the country's population and is considered the Western Gate of Greece towards the EU, despite the inadequate transport and energy infrastructures. The tertiary sector dominates the regional economy and accounts for 75.4% of the regional GDP, while the industry and construction sector share was 17.5% and a strong primary sector accounted for 7.9% of the regions GDP in 2008. In terms of GDP per capita, in 2009, WGR is positioned 12th among the 13 Greek regions and considerably below the EU27 average (60.3%).

With respect to Expenditures on R&D, WGR accounts approximately for 6.2% of the National Government Expenditures on R&D (GERD) for the period 2000-2008 before the crisis outbreak. It could be argued that this percentage corresponds to an even worse R&D performance if the national average expenditures

[4] For a more detailed presentation of the profile of Western Greece Region one should look at Regional Innovation Monitor WGR profile in http://www.rim-europa.eu/.

on R&D are considered, which correspond to approximately 0.5% of GDP during the same period. At a regional level, Formal Institutions and Authorities excluding Higher Education Institutes (HEIs) accounted for 0.8% of the Regions GDP. However, the absorptive capacity of firms is low and the technology transfer mechanisms that could enable enterprises to exploit research results and knowledge produced in HEI and Research centre are underdeveloped and underutilized. In this context, Private Sector's contribution in R&D Expenditures (BERD) accounted only for the 0.1% of the Regions GDP over the pre-crisis period (2000-2008). A different picture emerges when the attention is shifted to the Higher Education Sector which accounts for 65.4% of the Regional GERD. In addition, there is a high concentration of Human Resources in Science and Technology (HRST) relative to the Region's size. From the above, it can be easily deduced that the dominant policy instrument for promoting innovation activities in WGR are the resources provided by Central Government.

In terms of policy initiatives in the field of S&T in WGR there is not a well defined Regional Innovation plan that is being implemented but instead the resources from Regional Operational Programmes are exploited through the co-funding of the structural funds. WGR priorities are based on establishing the Region as a hub within the National Innovation System and at the same time, strengthening public research institutions and support synergies between the main players of the RIS both Public and Private. In addition, Regional Operational Programmes are aimed at supporting the establishment of New Technology Based Firms (NTBFs), attracting investments in knowledge intensive sectors and further developing and expanding the regional infrastructures such as the Patras Science Park (PSP) for hosting firms exploiting research results.

PSP [5] is an active Incubator 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 NTBFs through incubation and spin-off processes. A number of NTBFs are operating under the auspices of PSP, most of them are inventors, adepts and users of new technologies. Thus, it aims at contributing essentially to the "innovative area" prominence. PSP is also in a close proximity with University of Patras and two major Research Centers.

4.2. Data Specificities and Variables Definition

The dataset is composed of three RIS inputs and five outputs. In particular, from the input side, Government Expenditures on R&D $(GERD)$, Private Sectors' Expenditures on R&D $(BERD)$, and Knowledge Workers (*KW*) are considered[6]. The bundle of outputs is composed of the (i) Innovative Sales variable $(INNSL)$, (ii) Patent applications (PAT), (iii) Product and/or Process Innovation $(PPIN)$, (iv) Employment in Medium and High tech Manufacturing and Knowledge Intensive Services $(EMPHT)$, and (v) public-private co-publications $(PUBL)$. This information is available for the WGR not only in absolute values but also in relative indices of the Regional Innovation Scoreboard for the period 2000-20006 and the year 2009. Simple intrapolations allowed us to construct full information time series for the period 2000-2009. This information is employed for the quantitative approach i.e. relationships (1)-(4), for the state 1.

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

[6] Input and output variables detailed definitions may be found in the Regional Innovation Scoreboard Report (2012; p. 38).

For the same period, a small scale case study has been conducted in order to gather the corresponding information for the PSP and the firms and organizations' activities located within its premises. Using this dataset adjusted time series have been constructed for the period 2000-2009 for the input-output bundle of the Western Greece RIS under the assumption that the PSP's inputs-outputs are not entailed in the corresponding Western Greece RIS. These new time series have been recalculated in terms of Regional Innovation Scoreboard indices so as to estimate the corresponding indices depicted in (1)-(4) for state 0. Basic descriptive statistics of the employed variables regarding $s = 0$ and $s = 1$ are presented in Table 1.

{Insert Table 1 around here}

5. Results and Discussion

5.1. Input - Output relationships and the policy dominant variable GERD

In the first stage of empirical analyses we have estimated the relationship between the policy dominant variable $GERD$ and the rest of the inputs that is $BERD$, KW. Alternative models have been employed, and the best, in terms of statistical fitness, has been selected. Empirical estimations are presented in Table 2.

{Insert Table 2 around here}

The statistically significant influence of $GERD$ not only on KW but also on $BERD$ provide support for the consideration of $GERD$ as a policy dominant input in the RIS of Western Greece. It is worth noting the difference with respect to the influence of this variable in the input mix. While $GERD$ exerts negative influence on $BERD$, indicating an underlying substitution effect which in turn is indicative of *crowding out* effect between these two knowledge inputs (Hussinger 2003), the corresponding influence of $GERD$ on KW is positive thus, providing empirical evidence for the existence of a complementary relationship.

Moving towards the output side of the system of innovation, the model which depicts the relationships between inputs and outputs includes two sets of relationships. On one hand the standard relationships between outputs and inputs in the knowledge production process are examined, while the other set of relationships investigates the existence of linkages among outputs. With respect to the relationships among outputs two criteria have guided the identification of the best model describing the interlinks between output variables. Firstly, we looked for a meaningful and informed set of possible output-endogenous relations, based mainly on the examined RIS's characteristics and the relevant literature. Secondly, we looked for the model with the best econometric properties among alternative models. This implies that variables with no statistically significant results may have been included in our final model, if the corresponding omitted/redundant tests of the nested model suggested doing so. Estimations have been realised for both states examined $(s = 0,1)$ as it is suggested in the methodology section. Estimation results are presented in Table 3.

{Insert Table 3 around here}

Empirical results indicate that $GERD$ exerts positive and statistically significant influence in all the RIS knowledge outputs in both states that is, with and without PSP. The same does not apply for the influence of $BERD$ and KW . More specifically, the influence of the $BERD$ variable is found to be positive and statistically significant only with respect to the co-publications $(PUBL)$ and patents (PAT) outputs under the state 0 and on the innovative sales $(INNSL)$ output under the conditions implied by state 1. Regarding the impact of knowledge workers (*KW*) input on the output mix, the empirical results reveal a positive and statistically significant contribution on the innovative sales in both states, and also a positive influence on product and process innovation $(PPIN)$ in the state that encompasses the PSP operation. In general, the empirical findings are too close to what was expected from the input-output theoretical considerations and provide ample evidence for the dominant role of the $GERD$ input in the context of the examined RIS (Taymaz and Ucdogruk, 2013).

Shifting the attention at the relationships identified in the output side of the Western Greece RIS, it is worth mentioning that product and process innovation $(PPIN)$ affects positively regional innovative sales $(INNSL)$ in both states under examination. Apparently, a robust complementary relationship between these two outputs has been established within the Western Greece RIS framework which is rather anticipated. On the other hand, innovative sales $(INNSL)$ affect positively employment in high tech sectors $(EMPHT)$, and patenting (PAT) exerts a negative influence on innovative sales only in the state where the Western Greece RIS is considered without the impact of the Science Park. While the identified relationship between $INNSL$ and $EMPHT$ is rather easily interpretable, the negative impact of patenting activities on innovative sales may be interpreted on the grounds of resource based theory (Barney 1991). In particular, patenting is considered a strategic means for protecting monopoly rents. However, the actual process of acquiring property rights is quite costly itself. Therefore, firms who possess limited amount of resources devoted in innovation processes and in order to secure appropriability conditions are incurred with a penalty in terms of the competitiveness of their product or service (Blind and Thumm 2004)

5.2. GERD dominance and Policy Authorities Preferences

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

$$GERD_{\beta} = \beta GERD_{\max} + (1-\beta) GERD_{\min} \qquad (11)$$

with $\beta \in [0,1]$. Essentially, β parameter reflects the decisions of the Regional, National and European Authorities[7] regarding the adjustment of the current level of the Public Expenditures on R&D activities dedicated in the Region $(GERD_{\beta})$ at any value of $GERD$ within an interval which is defined historically between $(GERD_{\min})$ and $(GERD_{\max})$. Authorities decision making outcomes capture their preferences but also their limitations, thus allowing us to shed some light on the impact of fiscal austerity oriented policies on PSP'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 (i) the rate in which the parameter is allowed to vary, and (ii) the margins of the interval, may be defined at any given value that either the model or policy requirements need to be satisfied.

Following the mechanism described in equation (11) a set of alternative $GERD_{\beta}$ values are generated. Next we employ the econometric relationships presented in tables 2 and 3 and produce a new spectrum of input - output values of the Western Greece RIS, which correspond to the generated $GERD_{\beta}$ values. These values are calculated for state 0 and state 1 accordingly, and permit us to estimate all the Eff_i^s ratios as they defined in relationship (4) and are presented in tables 4 and 5.

{Insert Table 4 around here}

[7] Authorities decisions making outcomes capture their preferences but also their limitations.

{Insert Table 5 around here}

It should be noted that the calculated Eff_i^s scores encompass all the inter-linkages within and between the input and output sides of the Western Greece RIS presented in figure 1. It is not worthless to mention that although the absolute values of Eff_i^s have not a direct natural interpretation, they convey valuable information for the next steps of the evaluation procedure introduced in this paper.

5.3. Science Park's Evaluation within the Western Greece RIS

The estimation of the Eff_i^s, for both states, allows for the construction of the $\mathbf{EffSP}$ matrix which reflects the differential efficiency of the Western Greece RIS with and without the Science Park when the $GERD$ is the dominant policy instrument. Since Eff_i^s scores have been calculated on the basis of the information provided by the Regional Innovation Scoreboard (2006, 2008, 2012) which embody the relative ranking of the RIS both at National and European level, devising the $\mathbf{EffSP}$ matrix is equivalent to the $\mathbf{EffSP}$ matrix estimation. Since $\mathbf{EffSP}$ is defined for every input the $\mathbf{GLEffSP}$ matrix is easily constructed by juncturing all $\mathbf{EffSP}$ for every Western Greece RIS input. The estimated $\mathbf{GLEffSP}$ matrix, mirrored in Table 6, constitutes the basis for examining the main research question posed in this paper. It encompasses *(i)* all the efficiency indices for every input-output combination, *(ii)* for both states $(s = 0,1)$, that is with and without PSP, *(iii)* the crucial role of $GERD$ in determining Western Greece RIS performance in conjunction with *(iv)* the set of policy authorities' preferences and limitations (β), with respect to the policy dominant input.

{Insert Table 6 around here}

A negative value in Table 6 signifies that PSP's operation hinders the Western Greece RIS performance, while a positive value signifies that the contribution of the PSP in the Western Greece RIS performance is beneficiary. At this point it should be recalled that the state without PSP $(s = 0)$ is a counterfactual situation and has been indirectly approached via the adjustment of the Regional Innovation Scoreboard corresponding input - output indices, by subtracting inputs and outputs that are directly related to PSP and the tenant companies.

Although this approximation aids us to devise a situation where the contribution of PSP is obliterated from the 'hard performance evidence' of the Western Greece RIG, 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; (i) the indirect positive effects that the PSP exerts in the Western Greece RIS are taken into account although the PSP has been displaced, resulting in an underestimation of PSP's performance, and (ii) 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 offset each other. Keeping in mind this reservation, a graphical illustration of the $\mathbf{EffSP}$ matrix which results according to the policy authority preferences function described by equation (10) is given in figures 2a-2c.

{Insert Figures 2a-2c around here}

5.3.1. The PSP's Differential efficiency with respect to the dominant policy instrument

A series of interesting findings are identified in PSP differential efficiency with respect to $GERD$. Firstly, the PSP 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 PSP contributes positively to the Region's innovation system performance only for high levels of $GERD$. On the contrary, for low levels of the $GERD$ input, PSP seems to worsen the RIS performance in terms of all outputs.

These findings highlight the mediating role of PSP and the structural inefficiencies of Western Greece RIS. Given the fact that PSP 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 (Vonortas 2000). 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 re-orientation 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 towards open innovation principles (Hansson et al.

2005; Barbero et al. 2012) which would result in the regional innovation actors to share common objectives and risks and not just resources.

The positive contribution of PSP in the performance of Western Greece RIS is revealed for different $GERD$ levels depending on the output under examination. A closer look in figure 2a reveals that PSP 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 PSP to contribute positively in Western Greece RIS performance, S&T policy makers at regional and central level need to design policies and direct the available funding at individual output targets (Etzkowitz 2006). Only for the value of β parameter exceeding 0.8 all the differential efficiency indices become positive except for the co-publications case. In other words, only during periods of great spending when $GERD$ investments exceeded the 80% of the historical maximum, did the PSP contribute positively in all differential efficiency indices, but the co-publications.

5.3.2. The PSP's Differential efficiency with respect to BERD *and* KW *inputs*

The reader should recall that $BERD$ and KW levels are not determined exogenously but they are products of decision making processes which take into account the policy authorities preferences regarding the $GERD$ levels. Therefore, the values of $BERD$ and KW are determined through the estimated relationships presented in Table 2 and of course the policy authority preferences reflected in equation (11). The ratios of $BERD, KW$ to $GERD$ for both states are presented in figure 3 depending on the scenario of β parameter.

{Insert Figure 3 around here}

In figures 2b and 2c the differential efficiency indices with respect to $BERD$ and KW are presented for different levels of the β parameter. It is evident that PSP differential efficiency indices both with respect to $BERD$ and KW namely, $\mathbf{EffSP_i^{BERD}}$, $\mathbf{EffSP_i^{KW}}$, are negative in their sum regardless of the level of the β parameter. Especially with respect to $BERD$, it is interesting to note that three patterns emerge from figure 2b. PSP's inefficiency is increasing for $PUBL$ and $EMPHT$ as the level of $GERD$ investments increases. On the contrary, inefficiencies with respect to patenting and innovative sales decrease as policy authorities intensify their $GERD$ investments. Finally, PSP inefficiency with respect to $PPIN$ remains constant for all $GERD$ scenarios. Turning to the KW differential efficiency indices, it is interesting to note that even for high levels of $GERD$, only an extremely weak contribution of PSP is identified, in the case of patenting activities and innovative sales.

In terms of the overall differential efficiency indices with respect to $BERD$, their interpretation should be based on PSP's idiosyncratic features. More specifically, and following Sofouli and Vonortas (2007) in their review of Science Parks in Greece, PSP has been described as "supported extensively by public funds" while up until today no evaluation of performance has been undertaken either by central or regional authorities. A study from Bakouros et al. (2002) confirms that PSP along with two other Greek Science Parks has been underperforming due to lack of linkages with the tenant companies and the nearby University and Institutes. More importantly, several factors are reported as determinants of PSP underperformance including, *".....inadequate private funding (no seed capital, only occasional links to limited venture capital), lack of managerial expertise running the facilities and very limited reliance on experienced external business managers to provide services to tenant* *firms, confusion between research and commercial needs and requirements, ineffective infrastructure offered to prospective tenant*s" (Bakouros et al. 2002).

However, the most important issue detected that contributes majorly in the situation depicted in figure 2b is that PSP, from its creation, has been run by government employees as public enterprise, and has been linked organizationally to (owned by) central government agency owned by the Greek Ministry of Finance. As a result, PSP has not developed links to the regional government and is not being oriented to operate as a financially sustainable private enterprise. In other words PSP, from its birth has been oriented towards 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 approach which allows for the evaluation of STPs performance under different intensity levels of government expenditures on R&D 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 which come out of a multi input - multi output knowledge production function (KPF) approach, in which however, the dominant role of $GERD$ and the specificities of knowledge output mix are included. Data requirements are sourced from the Regional Innovation Scoreboard, as far as the Greek RIS is concerned, and from a small scale case study, with respect to the examined regional STP, namely Patras Science Park (PSP) covering the period from 2000-2009.

The contribution of PSP in the Western Greece RIS performance diminishes alongside with the decrease in $GERD$ investment levels, with respect to all the efficiency indices. In this line, examining the performance of PSP in the context of Western Greece RIS, efficiency indices with respect to KW and $BERD$ indicate that PSP's contribution is always negative even though it improves for very high levels of $GERD$ investments. These findings are attributed to the structural characteristics of both the Western Greece RIS and PSP, and capture their dependence on managing public financial resources for S&T activities. These empirical findings are in accordance with the corresponding empirical findings of Wallsten (2001; 2004) for the U.S. STPs, and confirms, in quantative terms, the concerns expressed by Bakouros et al. (2002) and Sofouli and Vonortas (2007) for the case of Greek STPs.

Combining thus, the differential efficiency of PSP with the conditions imposed by the current economic crisis, it becomes evident that PSP needs to re-orientate its position within the Western Greece RIS. More specifically, PSP needs to tighten the links with the Western Greece RIS and take up a coordinating role not of managing funds but of managing and creating linkages between innovation anchors within the Western Greece RIS. In doing so, PSP needs to set its priorities in supporting S&T based youth entrepreneurship, promoting the commercialization of the significant research output of the HEIs of the Region and developing relationships among the high-tech startups and the incumbent firms of the Region. In a few words a more Schumpeterian approach of both PSP and Western Greece S&T policy authorities should be adopted.

Last but not least, it is worth mentioning that the generalibility of this methodological framework comes at a cost. In particular, the data employed in this context are limited in time period covered and the robustness of the empirical results is principally supported by previous findings in the relevant literature. In this sense, this framework could be applicable to many other contexts and may be useful for policy making purposes. One should keep in mind that the investigation of any RIS and the corresponding attempts of evaluation of any innovation actors is associated with high degrees of unobserved heterogeneity and thus, the methodological approaches should be adjusted in order to accomodate each Region's special characteristics.

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Appendix

Table 1. Descriptive Statistics of the employed variables.

Variables		Average (Std. Dev.)		Max (Min)	
		s=0	**s=1**	**s=0**	**s=1**
Knowledge Inputs	GERD	0.065 (0.003)	0.069 (0.003)	0.070 (0.061)	0.072 (0.064)
	BERD	0.019 (0.005)	0.022 (0.003)	0.025 (0.010)	0.025 (0.016)
	KW	0.030 (0.023)	0.044 (0.013)	0.061 (0.000)	0.070 (0.031)
Knowledge Outputs	INSAL	0.321 (0.072)	0.362 (0.044)	0.440 (0.195)	0.440 (0.300)
	PPINN	0.318 (0.038)	0.333 (0.040)	0.380 (0.280)	0.384 (0.266)
	PAT	0.216 (0.035)	0.237 (0.036)	0.274 (0.187)	0.287 (0.187)
	PUBL	0.229 (0.016)	0.229 (0.016)	0.240 (0.200)	0.240 (0.200)
	EMPHT	0.561 (0.064)	0.572 (0.059)	0.662 (0.498)	0.662 (0.506)

Table 2. GERD domination in the input side.

Variable	BERD		KW	
	s=0	s=1	s=0	s=1
Constant	0.051	0.048*	0.076	-0.171
	(0.019)	(0.017)	(0.074)	(0.125)
GERD	-	-	-	3.132*
				(1.156)
log(GERD)	-0.025*	-0.027*	0.027*	-
	(0.014)	(0.013)	(0.015)	
R^2	0.503	0.577	0.272	0.296
F-statistic	14.125*	16.218*	7.544*	8.222*

Numbers in parentheses are the corresponding standard errors

* Denotes statistical significance at 5% level

Table 3. Transformation of Knowledge Inputs to Knowledge Outputs and Outputs Substitutability/Complementarity.

Variable	PPIN		PUB		PAT		INNSL		EMPHT	
	s=0	s=1	s=0	s=1	s=0	s=1	s=0	s=1	s=0	s=1
Constant	0.769*	0.949*	0.074	0.015	0.320	0.340	-0.376	0.537	-1.063	-0.119
	(0.347)	(0.314)	(0.242)	(0.212)	(0.846)	(0.546)	(0.790)	(0.329)	(1.131)	(1.101)
GERD	3.447*	6.825*	2.249*	2.100*	4.542*	3.530*	31.046*	4.698*	30.687*	15.120*
	(1.501)	(3.029)	(0.887)	(0.464)	(0.651)	(0.719)	(7.113)	(1.685)	(11.106)	(5.125)
BERD	2.516	-1.610	2.947*	3.892	4.229**	9.075	13.132	6.377**	21.623	12.273
	(6.725)	(5.114)	(0.875)	(2.864)	(2.712)	(8.895)	(10.372)	(3.008)	(16.131)	(16.294)
KW	-1.051	1.689*	0.023	-0.159	-0.406	1.621	5.685*	3.422*	4.705	2.748
	(0.986)	(0.800)	(0.874)	(0.536)	(1.865)	(1.392)	(3.354)	(0.595)	(2.500)	(2.350)
PPIN	-	-	-	-	-	-	2.592*	1.614*	-	-
							(0.693)	(0.257)		
PUBL	-2.235	-1.350	-	-	-1.144	0.352	-	-	-	-
	(1.314)	(0.738)			(1.729)	(1.274)				
INNSL	-	-	-	-	-	-	-	-	0.691*	1.011
									(0.245)	(0.280)
PAT	-	-					-1.339**	-0.120	-	-
							(0.592)	(0.207)		
R^2	0.878	0.898	0.744	0.672	0.650	0.614	0.942	0.984	0.789	0.651
F-statistic	7.394*	9.414*	7.221*	6.188	8.818*	7.955*	14.962	16.885	8.333*	7.886*
DW-statistic	1.486	2.019	2.022	1.855	2.287	2.033	2.371	2.417	2.573	2.151

Numbers in parentheses are the corresponding standard errors
One and two asterisks denote statistical significance at 5% and 10% level respectively

Table 4. Efficiency indices without Science Park (s=0) under different levels of the Dominant Policy Variable.

	PAT	PPIN	PUBL	INNSL	EMPHT	PAT	PPIN	PUBL	INNSL	EMPHT
			β=0,0					*β=0,6*		
BERD	10.383	17.970	10.295	15.402	29.419	11.705	17.409	12.631	17.462	29.630
GERD	3.523	6.097	3.493	5.226	9.982	3.263	4.854	3.522	4.868	8.261
KW	16.954	29.341	16.810	25.149	48.036	6.103	9.077	6.586	9.105	15.449
			β=0,1					*β=0,7*		
BERD	10.590	17.888	10.658	15.686	29.445	11.946	17.299	13.061	17.894	29.679
GERD	3.476	5.872	3.499	5.149	9.666	3.225	4.669	3.525	4.830	8.011
KW	12.948	21.871	13.031	19.179	36.001	5.547	8.032	6.064	8.308	13.780
			β=0,2					*β=0,8*		
BERD	10.802	17.802	11.031	15.993	29.475	12.194	17.182	13.503	18.353	29.732
GERD	3.431	5.655	3.504	5.080	9.362	3.187	4.490	3.529	4.796	7.770
KW	10.508	17.318	10.731	15.558	28.673	5.090	7.173	5.637	7.661	12.412
			β=0,3					*β=0,9*		
BERD	11.019	17.711	11.415	16.324	29.508	12.448	17.060	13.957	18.840	29.789
GERD	3.387	5.444	3.509	5.018	9.071	3.150	4.317	3.532	4.768	7.538
KW	8.866	14.251	9.185	13.135	23.743	4.709	6.454	5.280	7.128	11.270
			β=0,4					*β=1,0*		
BERD	11.242	17.616	11.809	16.678	29.545	12.709	16.932	14.426	19.357	29.851
GERD	3.345	5.241	3.513	4.962	8.790	3.114	4.149	3.535	4.744	7.315
KW	7.686	12.044	8.074	11.403	20.200	4.387	5.844	4.979	6.681	10.303
			β=0,5							
BERD	11.471	17.515	12.214	17.057	29.586					
GERD	3.303	5.044	3.518	4.912	8.520					
KW	6.797	10.379	7.238	10.108	17.532					

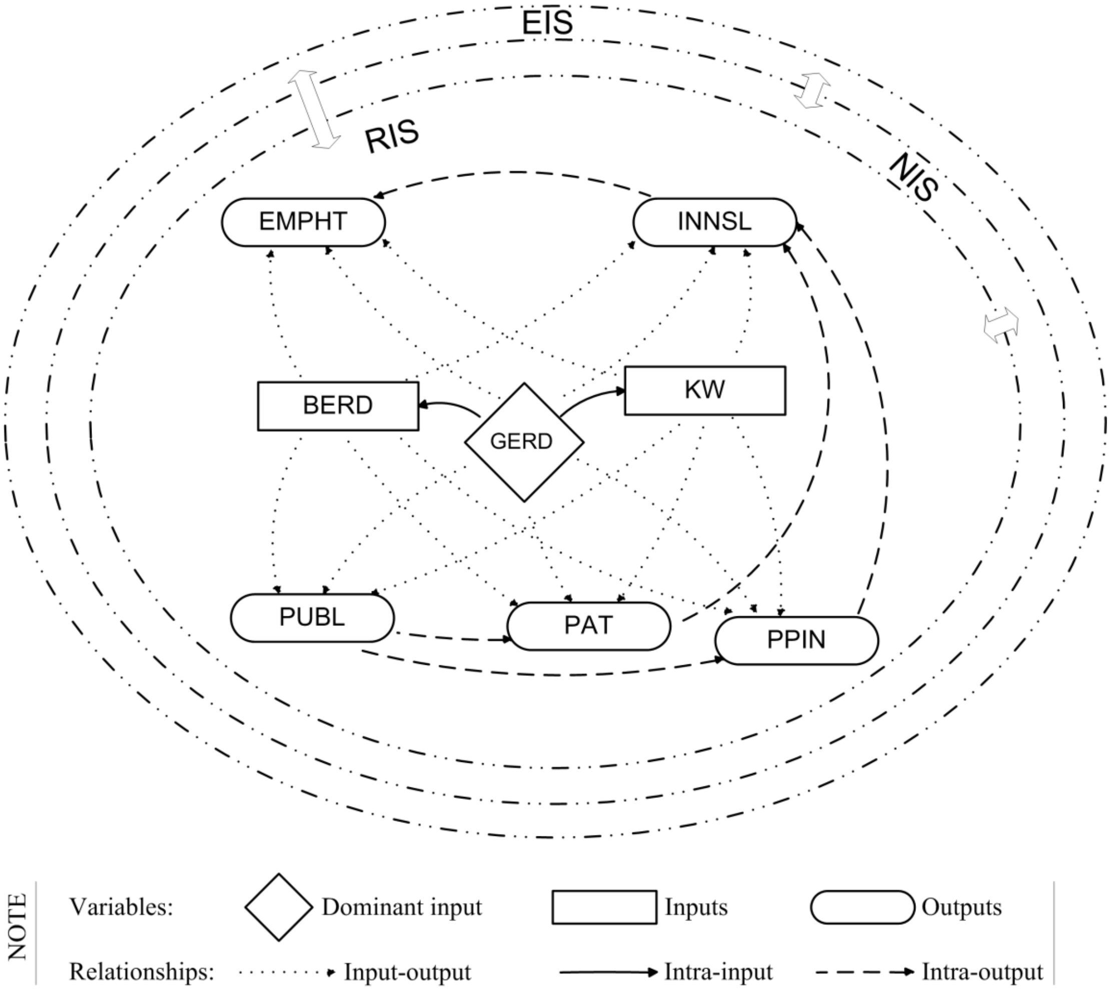
Table 5. Efficiency indices with Science Park (s=1) under different levels of the Dominant Policy Variable.

	PAT	PPIN	PUBL	INNSL	EMPHT	PAT	PPIN	PUBL	INNSL	EMPHT
			β=0,0					*β=0,6*		
BERD	8.428	15.558	8.559	13.260	25.788	10.724	15.024	10.362	16.406	25.822
GERD	3.202	5.910	3.252	5.037	9.797	3.446	4.827	3.329	5.271	8.297
KW	6.950	12.829	7.058	10.934	21.266	5.343	7.486	5.163	8.174	12.865
			β=0,1					*β=0,7*		
BERD	8.786	15.484	8.841	13.745	25.804	11.143	14.912	10.689	16.989	25.813
GERD	3.245	5.720	3.266	5.077	9.531	3.483	4.661	3.341	5.310	8.068
KW	6.579	11.595	6.620	10.293	19.322	5.174	6.924	4.963	7.888	11.985
			β=0,2					*β=0,8*		
BERD	9.154	15.405	9.131	14.245	25.815	11.573	14.793	11.025	17.589	25.800
GERD	3.288	5.533	3.279	5.116	9.272	3.518	4.497	3.352	5.347	7.844
KW	6.262	10.538	6.246	9.744	17.658	5.021	6.418	4.783	7.631	11.193
			β=0,3					*β=0,9*		
BERD	9.532	15.320	9.427	14.761	25.822	12.014	14.666	11.370	18.208	25.783
GERD	3.329	5.351	3.292	5.156	9.019	3.553	4.338	3.363	5.385	7.625
KW	5.987	9.622	5.921	9.271	16.218	4.882	5.960	4.620	7.399	10.478
			β=0,4					*β=1,0*		
BERD	9.919	15.228	9.731	15.293	25.826	12.467	14.532	11.724	18.847	25.761
GERD	3.369	5.172	3.305	5.194	8.772	3.587	4.181	3.373	5.422	7.412
KW	5.746	8.820	5.636	8.858	14.959	4.756	5.544	4.472	7.190	9.828
			β=0,5							
BERD	10.317	15.129	10.042	15.841	25.826					
GERD	3.408	4.998	3.317	5.233	8.531					
KW	5.533	8.114	5.386	8.495	13.850					

Table 6. The estimated **GLEffSP** Matrix.

	PAT	PPIN	PUBL	INNSL	EMPHT	PAT	PPIN	PUBL	INNSL	EMPHT
			β=0,0					*β=0,6*		
BERD	-1.956	-2.412	-1.736	-2.142	-3.631	-0.981	-2.385	-2.270	-1.056	-3.809
GERD	-0.321	-0.187	-0.242	-0.188	-0.185	0.182	-0.026	-0.192	0.403	0.036
KW	-10.004	-16.512	-9.752	-14.214	-26.770	-0.760	-1.592	-1.424	-0.931	-2.584
			β=0,1					*β=0,7*		
BERD	-1.804	-2.404	-1.817	-1.941	-3.642	-0.803	-2.386	-2.371	-0.905	-3.866
GERD	-0.231	-0.153	-0.233	-0.072	-0.135	0.258	-0.009	-0.185	0.480	0.057
KW	-6.368	-10.276	-6.411	-8.886	-16.679	-0.373	-1.108	-1.101	-0.421	-1.795
			β=0,2					*β=0,8*		
BERD	-1.647	-2.397	-1.901	-1.748	-3.660	-0.621	-2.389	-2.477	-0.764	-3.932
GERD	-0.143	-0.122	-0.225	0.036	-0.091	0.332	0.007	-0.177	0.551	0.073
KW	-4.246	-6.780	-4.486	-5.814	-11.015	-0.070	-0.755	-0.853	-0.031	-1.218
			β=0,3					*β=0,9*		
BERD	-1.487	-2.392	-1.988	-1.563	-3.686	-0.434	-2.394	-2.587	-0.632	-4.006
GERD	-0.058	-0.094	-0.216	0.138	-0.052	0.403	0.020	-0.169	0.617	0.087
KW	-2.880	-4.629	-3.264	-3.864	-7.525	0.173	-0.494	-0.660	0.272	-0.792
			β=0,4					*β=1,0*		
BERD	-1.323	-2.388	-2.078	-1.385	-3.719	-0.242	-2.400	-2.702	-0.510	-4.090
GERD	0.024	-0.069	-0.208	0.232	-0.018	0.472	0.032	-0.162	0.679	0.097
KW	-1.941	-3.224	-2.437	-2.545	-5.241	0.369	-0.300	-0.507	0.509	-0.475
			β=0,5							
BERD	-1.154	-2.386	-2.172	-1.216	-3.760					
GERD	0.105	-0.046	-0.200	0.321	0.011					
KW	-1.265	-2.265	-1.852	-1.612	-3.682					

Figure 1. Multidimensional relationships among inputs and outputs and interactions between the different levels of innovation systems



Figures 2a-c. Differential Efficiency performance for different levels of β parameter

Figure 2a. PSP's differential efficiency with respect to the policy dominant variable ($GERD$)

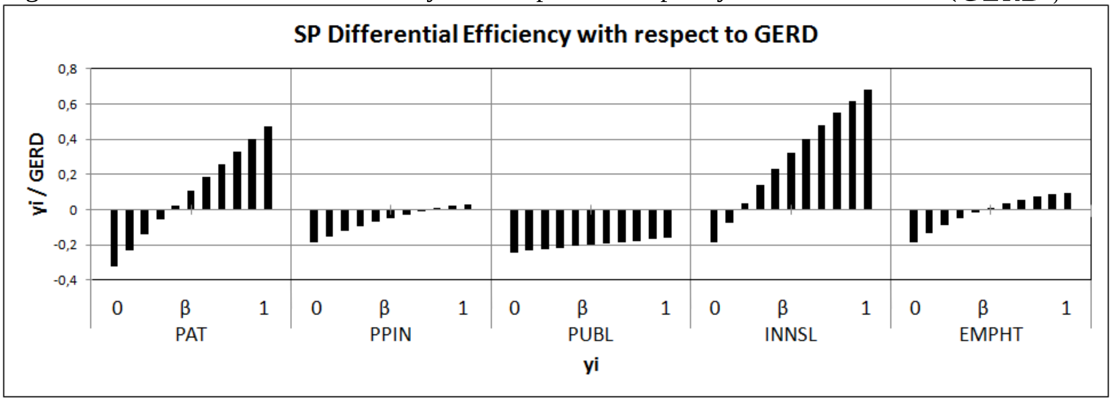


Figure 2b. PSP's Differential efficiency performance with respect to $BERD$ input

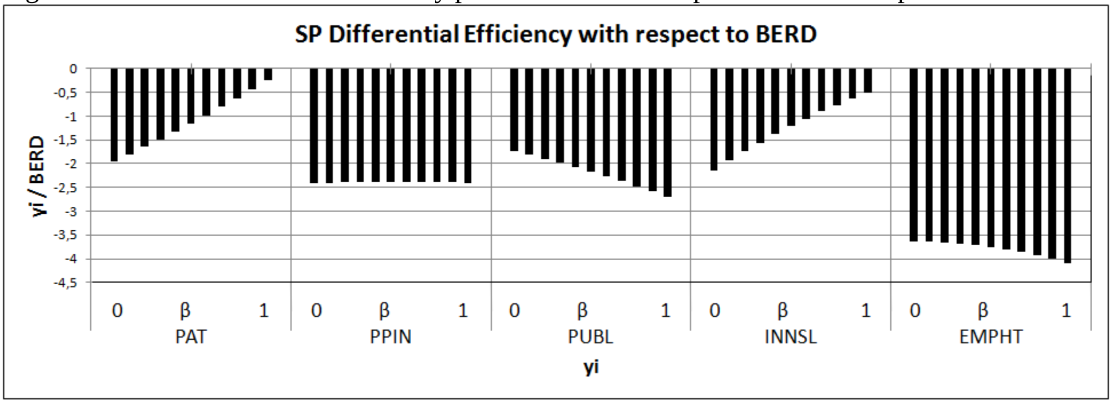


Figure 2c. PSP's Differential efficiency performance with respect to KW input

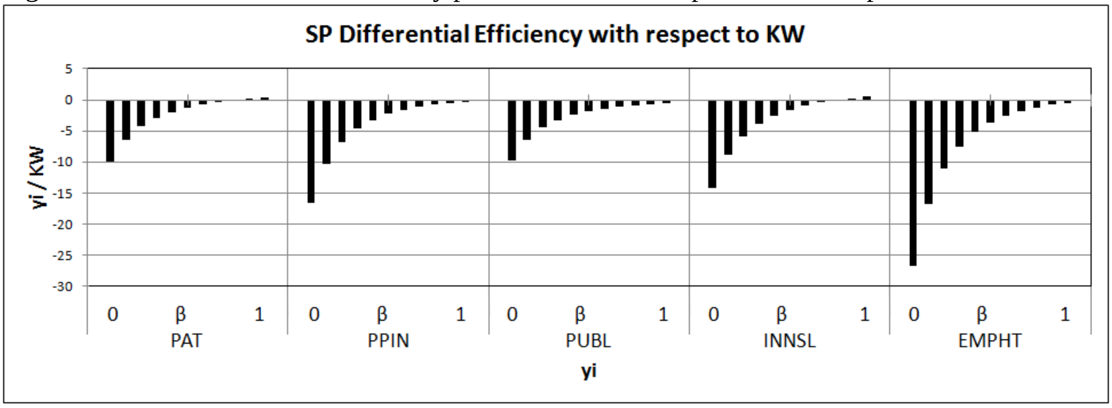


Figure 3. BERD, KW ratios to GERD for different levels of the dominant policy variable in both states (s=0,1)