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ORIGINAL PAPER

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Examining the location factors of R&D labor in the regions of Greece

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Abstract In this paper two models are developed in an attempt to elucidate the factors that influence the regional distribution of R&D labor across the regions of Greece. The first one is based on an adaptation of the [Guerrero and Seró (1997) Regional Studies 31:381–390] model to the Greek context treating the regional distribution of R&D labor as a function of the extent of agglomeration and the prevailing economic conditions. The second model extends the first one by taking into account two additional factors, viz. the production structure and infrastructure. The econometric results indicate the superior performance of the extended model in the context of Greece as well as attribute the location of R&D labor mainly on the diversification of industrial activity and the number of establishments in innovation-intensive sectors. It is therefore suggested that the stimulation of the regional production structure and infrastructure is essential for 'knowledge-lagging' regions.

JEL Classification O3 · R12

1 Introduction

The contemporary interest on knowledge-based economic growth and development approaches regions as the locations where technological innovation takes place (Rietveld and Shefer 1999). This approach emphasizes the economic transactions that focus on knowledge itself, and which lead to rapid changes in production. These in turn become incorporated into the economic processes of (a region's)

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agents. It follows, therefore, that regions, territories, or space, should not be seen as mere 'containers', in which attractive location factors may (or may not) be present, but rather as *milieus* for collective learning through intense interaction between a broad range of actors (Maskell and Malmberg 1999). A milieu is a created space that is both a result of and a precondition for learning and becomes, as Coffey and Bailly (1996) adduced, an active resource rather than a passive surface. Romer (1990) further argued that on the one hand rapid growth is strongly related to access to new technological ideas, and on the other to the diffusion of such ideas through the productive structure. In this sense, regions should not just be seen as homogenous units across geographical space, but rather as "competitive geographical units that try to obtain an economic advantage through developing or adopting technologically advanced products or processes" (Button and Pentecost 1999 p. 57).

This contrasts the traditional neo-classical and post-Keynesian approaches,[1] which rely only on the mobility of factors of production. Regional competitiveness and development can thus be seen as more related to the efficient use of endogenous resources through technological innovation; rendering such knowledge creation activities as key for the development of regions. It is thus of little surprise that such activities are examined in a growing number of regional studies (e.g. Oakey et al. 1980; Jaffe et al. 1993; Paci and Usai 2000; Kim and Knaap 2001; Sohn et al. 2003; Fischer and Varga 2003) that emphasize the role of innovative and knowledge producing sectors in promoting regional development, and/or the geography of innovation (Piergiovanni and Santarelli, 2001). Conversely, such studies draw inspiration from models of endogenous growth,[2] in which knowledge and innovation is created deliberately through the decisions of economic agents to invest in R&D and innovative sectors. As endogenous growth places emphasis on knowledge and research spillovers from the innovations produced by the R&D sectors; investments in R&D and scientific institutions cease to be mere indicators of economic growth and become producers of substantial interregional differences (Guerrero and Seró 1997).

The geographical concentration of a large number of highly educated people is therefore expected to create an appropriate environment for the rapid transfer of knowledge and ideas, which are then transformed into new products and innovative processes. Lucas (1988) for example argued that regions with a high level of innovation have become a 'destination' for highly skilled labor and a motivation for further improvements in physical and social infrastructures. Furthermore, technical progress is not an automatic outcome of investment in R&D, but requires an appropriate institutional environment, which is conductive to the adoption and assimilation of new ideas into the production system. Such an 'environment' can be considered as a 'collective learning process' within which many individuals interact and exchange ideas and information; thereby developing a 'knowledge-rich' environment that determines technical progress across space. The existing empirical literature, although placing particular emphasis on innovation as the primary force behind regional growth, it does not address explicitly the specific factors that influence the locational pattern of innovative activities across space. To remedy

[1] For a review of such approaches see Chisholm (1991).
[2] For a more detailed survey see Fine (2000).

this, an empirical model is proposed in this paper to examine the factors that affect the location of 'innovative labor'.

Moreover, in the case of Greece and although an increasing number of regional studies (cf. Alexiadis and Tomkins 2004; Christopoulos and Tsionas 2004), have paid attention to issues of regional growth and convergence, the empirical assessment of the location patterns of R&D labor have not so far received the due attention. In this paper an attempt is thus also made to remedy this by shedding some light on the factors that determine the regional distribution of R&D labor in Greece. In particular, the relation between R&D, the economic conditions, the production structure and infrastructure, as well as the extent of agglomeration of the Greek regions will be empirically established.

The remainder of this paper is organized as follows. In Section 2 descriptive statistics on the key variables are provided so to set the context for the model's specification. The model is specified in Section 3 together with some discussion of the data. The econometric application is undertaken in Section 4. The paper ends with some conclusions in Section 5.

2 The location of R&D labor in Greece

In empirical studies of innovation activities variables related to R&D expenditure or patent applications and citations are often used as proxies. Soete (1981) however, drew a distinction between two alternative measures of technology, viz. technology *input* and *output*. R&D expenditures and labor employed in R&D activities would fall under the input category, whereas patents (citations, applications, etc.) would fall under the output category. It was argued by both Soete (1981) and Fagerberg (1996) that input related measures are better proxies of innovative efforts as output related ones often conflate *innovation* and *diffusion*. Even if one wished to make use of output measures in the case of the Greek regions data on patents are unavailable. On the other hand data on R&D expenditures are either virtually non-existent or inadequate.[3] Following thus the suggestions of Soete (1981) and Fagerberg (1996) in the Greek regions raises the need for an alternative input measure. Fortunately the National Statistical Agency of Greece (NSAG) makes available annual data on the labor force engaged in the R&D sector[4] across the 51 NUTS-3 regions.[5]

Having thus satisfied the data requirements the distribution of innovative sectors across the regions of Greece can now be focused upon. To that effect Fig. 1 depicts the regional distribution of innovation activities in terms of the R&D labor force.

As it can be seen in Fig. 1 the region with the higher proportion of R&D labor force is in R_9, viz. Attiki, the capital region of Greece.[6] Relatively high proportions of R&D labor can also be found in regions $R_{2.2}$ (Thessaloniki), $R_{7.2}$ (Achaia), $R_{8.4}$

[3] Data on R&D expenditures do not cover all administrative divisions of Greece or the entire time period.
[4] According to the latest Standard Industrial Classification (SIC) system of the NSAG, established in 1991, the R&D sector corresponds to the two-digit SIC code 73.
[5] The analysis covers the period 1970–2000 as the NSAG conducts its industrial census approximately every ten years and thus data after 2000 are not available from a reliable source.
[6] Prefecture R_9 is the 'leading region' of Greece with 40% of the population, 50% of industrial activity and the highest GDP, contributes around 38% to the total national output.

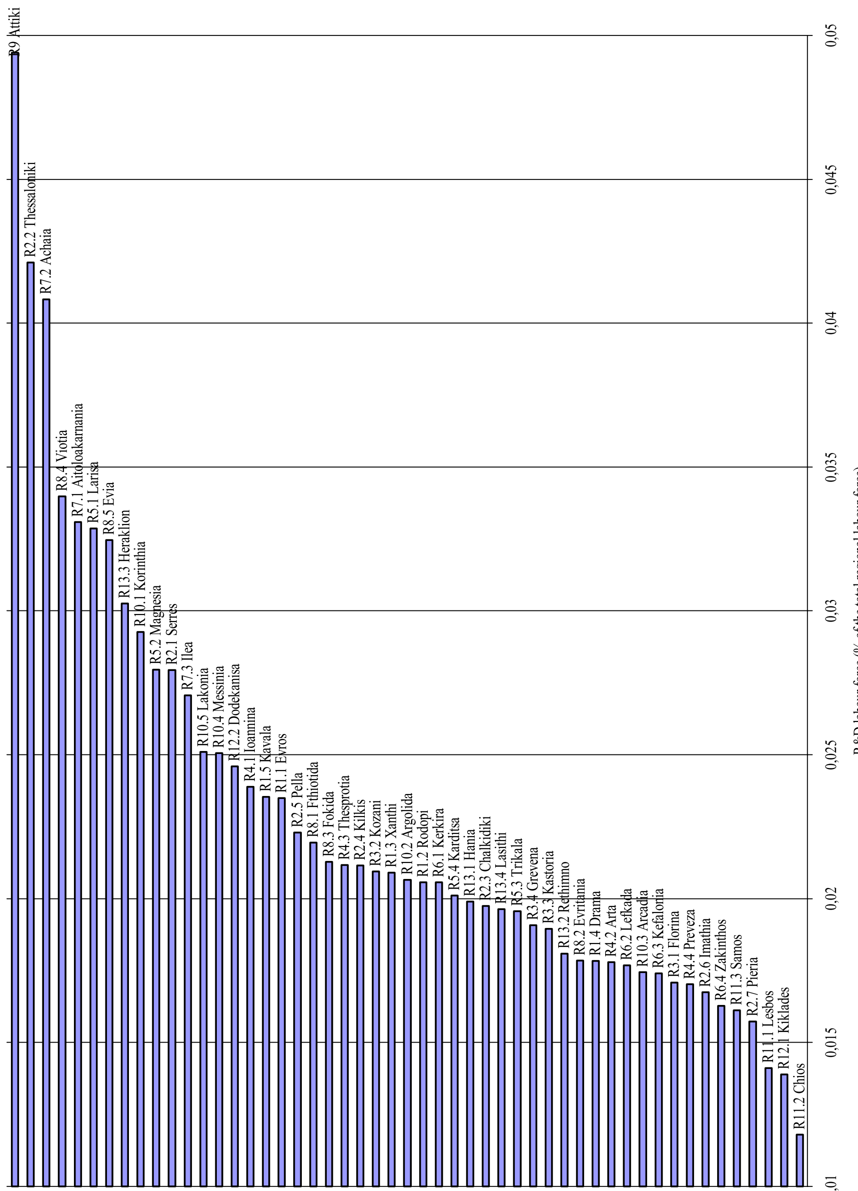

Fig. 1 Distribution of the regional R&D labor force in R&D sector as a percentage of the regional labor force (*Data source*: NSAG)

(Viotia), $R_{8.5}$ (Evia), $R_{5.2}$ (Magnesia), $R_{2.1}$(Serres), $R_{4.1}$ (Ioannina), and $R_{13.3}$ (Heraklion). It should be noted, however, that overall Greek regions are characterized by very low amounts of labor devoted to the R&D sector. The labor force employed in R&D exceeds the 0.04% of the total regional labor force only in three regions (viz. R_9, $R_{2.2}$ and $R_{7.2}$). This should not come as a surprise given that Greece

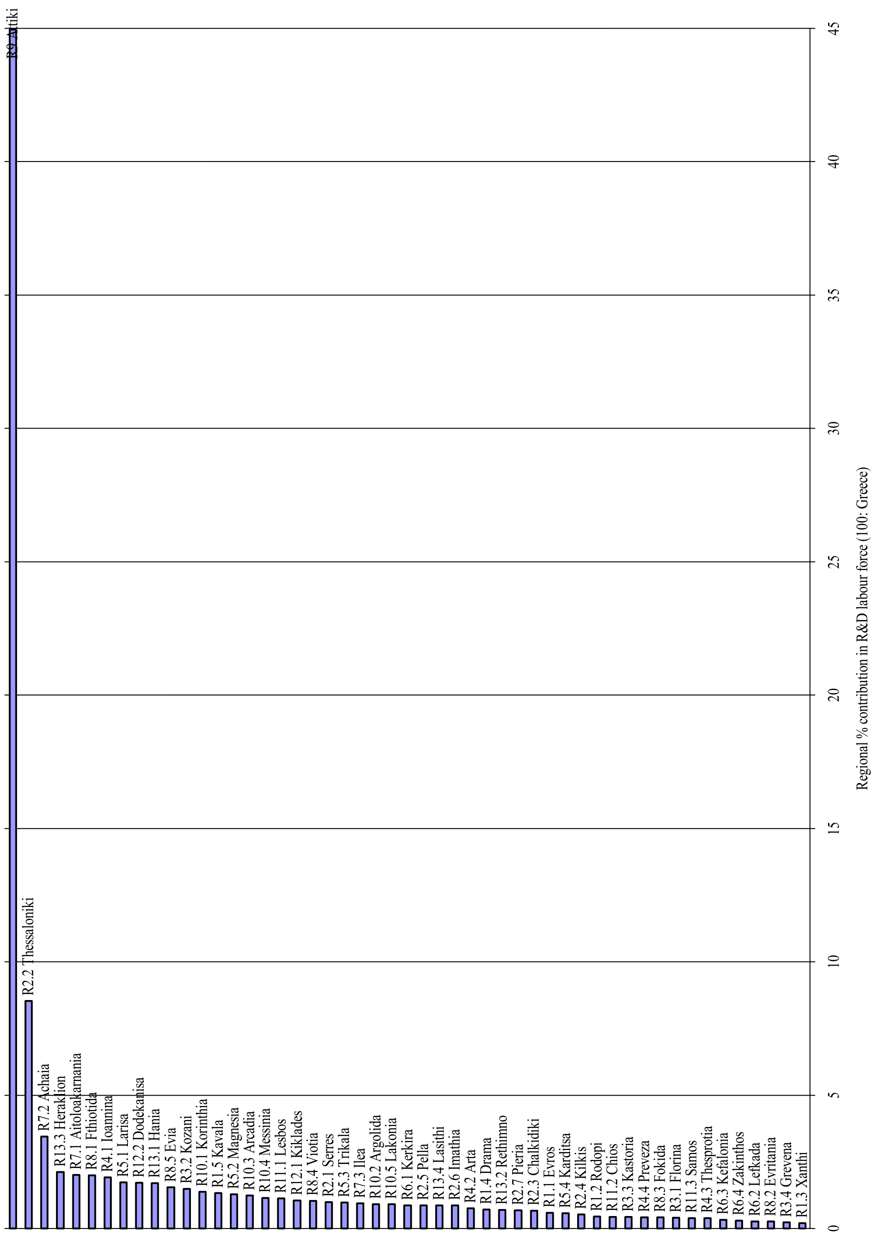

Fig. 2 Distribution of regional R&D labor as a percentage of the total R&D labor force (*Data source*: NSAG)

has the lowest level of R&D activities of all EU-15 member states (cf. Petmetzidou and Tsoulouvis 1990; Korres and Rigas, 2002).

In Fig. 1 a 'clustering' of innovation activities can thus be discerned; i.e. the R&D labor appears concentrated in relatively few regions. To obtain a better picture of the extent of this concentration, in the following figure the regional R&D labor is plotted as a percentage of the total R&D labor force in Greece (Fig. 2).

The above figure makes clear that almost half (46.4%) of the total R&D labor force is employed in firms, industries and institutions located in the Attiki region. Given this large percentage contribution of R&D labor force R_9 can be considered as the 'leader' in innovative activities. The second highest percentage of R&D labor force (8.52%) is in region $R_{2.2}$, viz. Thessaloniki, the second 'leading-region' of Greece (Fig. 2). Relatively high percentages of R&D labor force can be found in regions $R_{7.2}$ (Achaia), $R_{13.3}$ (Heraklion), and $R_{7.1}$ (Aitoloacarnania) (3.44%, 2.11%, and 2.01% respectively). For the vast majority of Greek regions the average R&D labor is in the range between 0.5% and 2%. The lowest percentages can be identified in regions $R_{1.3}$ (Xanthi), $R_{3.4}$ (Grevena), $R_{8.2}$ (Evritania) $R_{6.2}$ (Lefkada), $R_{6.4}$ (Zakinthos), $R_{6.3}$ (Kefalonia), $R_{4.3}$ (Thesprotia), $R_{11.3}$ (Samos), $R_{3.1}$ (Florina), $R_{8.3}$ (Fokida), $R_{12.1}$ (Kiklades), $R_{4.4}$ (Preveza), $R_{3.3}$ (Kastoria), $R_{11.2}$ (Chios) and $R_{1.2}$ (Rodopi) which do not exceed 0.5%. This should not be very surprising, considering that these regions belong to the poorest (in terms of GDP) areas of EU-15 (Moucque 2000; Hurst et al. 2000; Boldrin and Canova 2001).

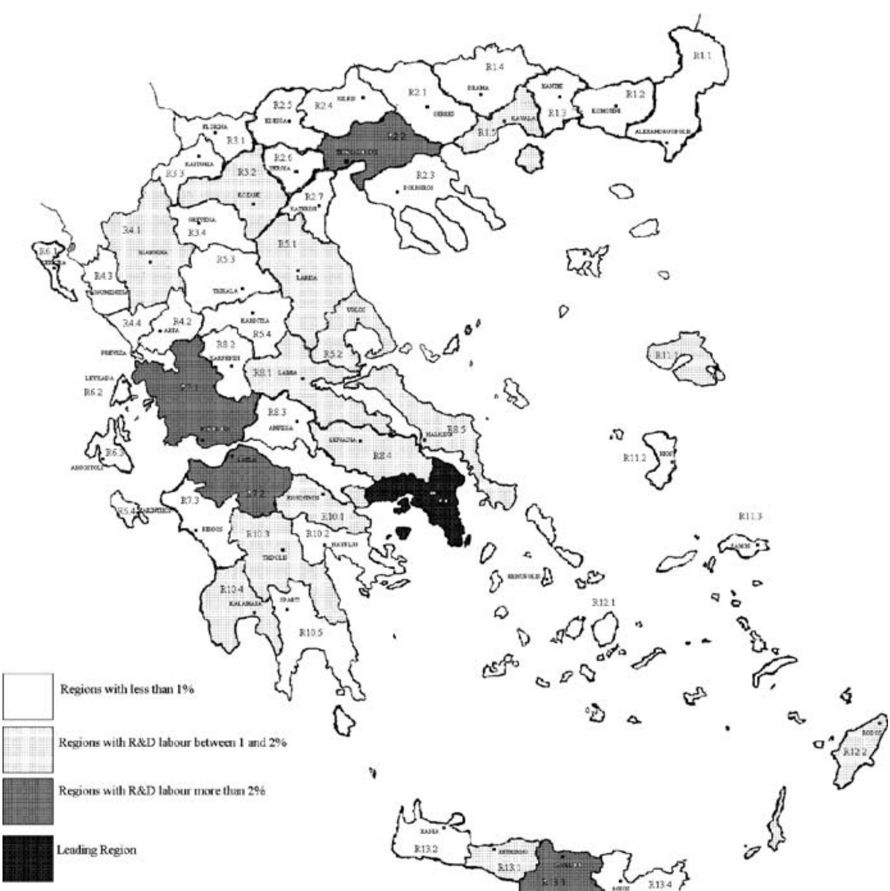

Fig. 3 The geographical pattern of R&D labor force distribution in Greece (Source: Figure 2)

Figure 3 shows the geographical pattern of the R&D labor force, expressed as percentage of the national R&D labor force.

As seen in Fig. 3, the R&D ‘lagging’ regions are located either in the northern part of the country (viz. regions $R_{1.3}$, $R_{3.4}$, $R_{4.3}$, $R_{3.1}$, $R_{4.4}$, $R_{3.3}$ and $R_{1.2}$) or in island areas (viz. regions $R_{6.2}$, $R_{6.4}$, $R_{6.3}$, $R_{11.3}$, $R_{12.1}$ and $R_{11.2}$). These will hereafter be referred to as ‘*knowledge-poor*’ regions. The map also shows that the R&D ‘leading’ regions are basically the large urban centers of Greece ($R_{2.2}$, $R_{7.2}$, $R_{7.1}$ and $R_{13.3}$). In contraposition this group of regions is deemed as ‘*knowledge-rich*’.

Having overviewed the distribution of R&D labor in the 51 Greek regions in the following section an appropriate model is constructed that fits the above context.

3 Model specification

Regional endogenous-growth models (cf. Acs et al. 1994; Jaffe 1986, 1989; Guerrero and Seró 1997) make extensive use of the following knowledge-creation production function:

$$K_j = f\left(R_j, E_j, X_j\right) \tag{1}$$

where K_j is the new knowledge-production of locality’s j firms, R_j is the R&D investments in locality j, E_j is total spending in locality’s j Universities and X_j is a vector containing variables representing the characteristics of location j.

Guerrero and Seró (1997) modified Eq. 1 to include government support and business agglomerations,

$$P_{j,t} = f\left(R_{j,.t-1}, X_{j,,t-1}, U_{j,t}\right) \tag{2}$$

where $P_{j,t}$ approximates innovation-production per number of patent applications, $R_{j,t\text{-}1}$ measures the government support, $X_{j,t\text{-}1}$ includes agglomerative characteristics and $U_{j,t}$ is a random variable.

Guerrero and Seró (1997) applied Eq. 2 to the Spanish regions utilizing data that covered the 1989–1992 period. Their results indicated a spatial distribution of innovation polarized in the two large urban agglomerations of Spain (viz. Madrid and Barcelona). The descriptive statistics in Section 2 reveal a similar picture for Greece, i.e. concentration of innovative-labor in the regions of the two major urban Greek centers (viz. R_9 and $R_{2.2}$). Thus, it would be of particular interest to see if the model of regional innovation, expressed by Eq. 2 applies in the case of Greece.

However, in the case of Greek regions a straightforward application of Eq. 2 is not possible since there are no sufficient data for patents and government support. Thus, in this paper innovation-production is approximated by the labor-force employed in the R&D sector while the variable representing government support is approximated by a variable representing the overall economic conditions in a region. Starting with a variant of the Guerrero and Seró (1997) model, expressed in terms of the following regression equation:

$$RD_{i,t} = a + b_1 E_{i,t} + b_2 AGLM_{i,t} + u_{i,t} \tag{3}$$

where α is the constant term and u_t is the error term of the regression.

The E_i in the above equation is measured by the total gross value-added (hereafter GVA)[7] at the given points in time. This has been preferred in comparison to its growth rate as the latter is rather a symptom of the exploitation of a region's innovative sources over a period of time. As Richardson (1973 p. 56) pointed out:

> Innovations and technical progress do not spread evenly and rapidly over space but frequently cluster in prosperous regions; for instance, technical progress may be a function of the levels of R&D expenditures which are higher in high-income regions.

It is thus reasonable to assume that the higher the available income or economic resources (E_i) in a region, the higher the proportion devoted to innovation and, hence, the higher the R&D labor force (RD_i) in that region. Therefore the expected sign of this variable should be positive.

The literature on agglomeration (cf. Lucio et al. 2002; Rigby and Essletzbichler 2002), suggests several proxies for the AGLM variable, such as population size or density. Henderson (1997) however, argued that in the case of high-tech sectors, agglomeration is better captured through the total number of establishments in each industrial sector. As this paper focuses on innovation-intensive sectors his example has been followed and agglomeration is approximated through the diversity of the overall economic activity in a region. To that effect the *AGLM* variable measures the total number of establishments in all industrial sectors apart from the innovation-intensive ones (listed below). Thus in the spirit of Henderson (1997) one should expect that the higher the diversity the higher the innovation production; i.e. the sign of *AGLM* variable should be positive. Furthermore, a positive impact is also implied by the work of Sohn et al. (2003) in the sense of attraction effects on an urban zone.

An extended version of the model by Guerrero and Seró (1997) is given in the following general function:

$$RD_i = f(E_i, ST_i, I_i, A_i) \tag{3a}$$

According to Eq. 3a our model is extended by the introduction of a series of variables that affect the location of R&D labor (RD_i). More specifically, apart from overall economic conditions (E_i) and agglomeration (A_i), the regional distribution of innovative labor is also a function of the regional production structure (ST_i) and the available infrastructure in that region (I_i).

For empirical estimation, the function given by Eq. 3a can be written in a linear form as follows:

$$\begin{aligned} RD_{i,t} = a + b_1 E_{i,t} + b_2 AGR_{i,t} + b_3 MNF_{i,t} + b_4 SRV_{i,t} + b_5 INF_{i,t} \\ + b_6 AGLM_{i,t} + u_{i,t} \end{aligned} \tag{4}$$

Regions specialized in traditional activities (e.g. agriculture) do not appear to exhibit increasing tendencies in creating innovations. In addition, 'traditional' regions may be reluctant to adopt new innovations and in several cases even reject

[7] The NSAG provides data on GVA for the 1970 to 2000 period, deflated at 1970 current prices. Ideally, the data should have been deflated using regional price deflators. Unfortunately, as regional price indexes are not available from any official source, national deflators were used.

them (Paci and Pigliaru 1999). On the other hand, regions with modern and dynamic activities (e.g. manufacturing and services) show a tendency both in creation and adoption of the latest technology and innovation. It is thus critical to explicitly consider the regional economic structure in terms of its composition. To that effect, the regional production structure is approximated with three separate variables capturing the regional labor share of: manufacturing (MNF_i), services (SRV_i) and agricultural (AGR_i) sectors in the regional labor force. The first two variables are thus expected to return a positive sign whereas the last a negative one.

A more diversified environment in a region is also expected to lead to increases in the existing stock of knowledge in that region. This implies a positive relation between innovation production and the overall level of regional infrastructure. Thus, the expected sign for INF_i should be positive. In terms of empirical data, the level of regional infrastructure (INF_i) is approximated by the number of establishments in a series of innovation-intensive sectors. These in the case of Greece are: 'chemicals and allied products' (SIC code 24), 'office equipment and machinery' (SIC code 30), 'scientific equipment' (SIC code 33) and 'information and data processing equipment' (SIC code 72).

Having overviewed the data regarding the R&D labor across the prefectures of Greece, in the following section the estimation results are reported.

4 Estimation results

The entire time period was divided into several shorter time-spans, forming thus a 'panel-data' framework. In such a framework the main concern is the appropriate time-span lengths. Technically, it is feasible to use annual time-spans, given that the available data set provides yearly observations. However, given that the model's underlying hypothesis refers to the long-run, annual time-spans seem rather inappropriate. In estimating Eq. 3 regular non-overlapping intervals of five years were used. In particular, the entire time period was divided in six non-overlapping

Table 1 Estimation results for Eqs. 3 and 4. (Sample: 51 Greek NUTS-3 Regions, N=306)

	Basic model Eq. 3	Extended model Eq. 4
α	1.506* (10.012)	0.210* (4.201)
b_1	0.045* (2.742)	0.030* (5.871)
b_2	0.107 (1.438)	−0.001 (−0.011)
b_3		0.104 (1.121)
b_4		0.022 (1.604)
b_5		0.101* (4.350)
b_6		0.212* (6.201)
R^2 [ser]	0.202 [0.0309]	0.402 [0.0701]
AIC	24.5014	10.4022
SBC	38.3185	7.6171

Figures in brackets are the t-ratios

[*ser*] Denotes the standard error of the regression

AIC and SBC refer to the Akaike and to the Schwartz–Bayesian information criterion, respectively

*Significance at 95% level of confidence sub-periods, 1970–1974, 1975–1979, 1980–1984, 1985–1989, 1990–1994 and 1995–2000 Table 1. Using these sub-periods the error term in Eq. 4 is less likely to be influenced by business cycle fluctuations (Green 1997). Hence, the residuals are less serially correlated, compared to a yearly data set. In order to overcome the problem of heteroscedasticity, due to the presence of an 'outlier' (viz. region R_9) in which the majority of R&D labor force is concentrated, the models were estimated using the maximum likelihood method instead of the OLS.

In Table 1 the key estimation results for Eqs. 3 and 4 are reported.

As it can be seen, in Eq. 3 above, although the constant term is highly significant only one of the remaining two explanatory variables has turned out to be so, viz. E_i, which indicates that the prevailing economic conditions in a region affect positively its R&D labor force. In other words, the higher the income in a region, the higher the amount of labor employed in R&D and vice versa. Although the two explanatory variables have the expected signs, the econometric performance of the Eq. 3 model cannot be considered as satisfactory, given the low value of the R^2. Thus, attention is turned to the extended version of the model, i.e. Eq. 4 in which the value of the R^2 (0.40) has almost doubled, implying that half of the variation of the dependent variable is explained by the additional variables. Moreover, all the explanatory variables have the expected signs. In particular, the regional agglomeration and infrastructure affect crucially the location of R&D labor in Greece. A 1% increase in these variables leads to an increase in R&D labor by 21% and 10% respectively. Based on these results it could be argued that the Greek R&D labor is concentrated in regions with highly diversified industrial activities and with a large number of establishments in innovation-intensive sectors. Much to one's surprise the regional economic conditions contribute only 3% to an increase in regional R&D labor. This suggests that in the case of Greece diversification of industrial activity and the number of establishments in innovation-intensive sectors is a far more important factor, for R&D labor, than pure economic conditions (measured by the level of GVA).[8]

As indicated by the descriptive statistics in Section 2, R&D labor in Greece is concentrated mainly in the R_9 and $R_{2.2}$ urban, high-income regions. What is clarified by the econometric results is that R&D labor in Greece is concentrated on regions with highly diversified environments, which are coincidental to urbanization effects.

The three variables describing the production structure, although having the expected signs are nevertheless statistically insignificant. This can be attributed to the fact that the production structure in most of the Greek regions is oriented in traditional activities while dynamic sectors are located in relatively few regions.

The *Akaike* (AIC) and the *Schwartz-Bayesian* (SBC) information criteria have been used for the model selection. According to the AIC and SBC criteria,[9] the extended model is superior from the basic model in Eq. 3; especially as the values of both criteria are minimized. Moreover, the superior SBC criterion indicates that the

[8] It is worthy informing here that Capello (2002) also reported similar findings for the case of Italy; and in particular for the localization and urbanization economies' high spatial concentration, viz. of the high-tech sector in the metropolitan area of Milan.

[9] As a rule of thumb, the best fitting model is the one that yields the minimum values for the AIC or the SBC criterion, calculated as $AIC = T\ln(RSS) + 2n$ and $SBC = T\ln(RSS) + n\ln(T)$, where RSS is the residual sum of squares, T is the number of observations and n stands for the number of parameters estimated. The SBC test has superior properties and is asymptotically consistent, whereas the AIC is biased towards selecting an overparameterized model (Enders 1995).

inclusion of the additional variables in the extended model, i.e. Eq. 4, explains the distribution of R&D labor in Greece to a more satisfactory degree.

5 Conclusions

In this paper two models were developed to explore the regional distribution of R&D labor force in Greece. The first model simply considered the distribution of R&D labor as a function of the prevailing regional economic and agglomeration conditions. The second one considered in addition the regional production structure and infrastructure. The two models were empirically tested and the second one was found superior in explaining the location patterns of R&D labor in the regions of Greece. In that sense a theoretical advancement has been accomplished through the establishment of a superior model in the context of Greece.

As perhaps expected, the descriptive statistics in Section 3 showed that the majority of R&D labor in Greece is concentrated in a few high-income regions. The econometric results, however, refute this simplistic view by linking the location of R&D labor to the regional diversification of industrial activity and infrastructure. In that sense, an empirical advancement has been accomplished through the clarification of the specific 'non-income' factors that influence the location of R&D labor in Greece.

Obviously, although the model proposed in this paper explains satisfactory the locational pattern of R&D labor in Greece, more empirical studies in other countries are necessary to establish its underlying relations. It is though hoped that the model's form in Eq. 4 will aid such applications in countries with the requisite data.

Finally, the main implication of the findings is that regional and industrial policies aiming at the reorientation of R&D labor towards the 'knowledge-lagging' regions should focus on the stimulation of the regional production structure and infrastructure.

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