Innovation Efficiency and Technology Gaps in European Region: North vs. South

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Abstract

Departing from the North-South models of International Trade we test whether within European region two main technological clusters co-exist, the Northern European countries and the Southern European countries. Employing a novel non parametric meta-frontier analysis on a country level dataset for the years 2004-2006 we investigate whether there is an actual difference, in terms of innovative performance, among North and South European countries in terms of the technological frontiers under which these firms operate. We then explore the systemic factors that contribute to the existence and maintenance of these technology gaps of European among European countries, emphasizing in the role of entrepreneurship. Our empirical findings suggest that the North vs. South geographical division of countries does not apply in the case of Europe.

Keywords: *innovation efficiency, bootstrapped DEA, metafrontier analysis, technology gap*

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1. Introduction

Countries' economic growth should be perceived as a dynamic process of transformation rather than a convergence towards a steady state of growth path. Subsequently, differences in economic performance are heavily dependent on the rate of technical change which in turn is the outcome of the innovation process (Fagerberg and Verspagen, 2002). In this paper, we argue that the performance of innovation process consists of *(i)* the structural components of innovation systems, through which innovation inputs are transformed into innovation outputs and *(ii)* the efficient use of the available resources devoted to the process itself. In order to stress the difference between these two components, it seems sufficient to mention that in efficiency analysis common structural characteristics are assumed among Decision Making Units-DMUs (countries, regions, organizations etc) and they operate under a common, even unknown, production frontier (Coelli, 2005). That is, no technology heterogeneity between the analyzed DMUs is present (O' Donnell et al., 2008). Apparently, this hypothesis may be satisfied only in the case of the second component of innovation performance but it also stresses the importance of the structural components determining innovation performance.

Within the context of this paper, we shall refer to all those structural differentials that entail differences, in terms of innovation performance, as *technology gaps* of European countries, while their relative performance in terms of the efficient use of the available resources shall be referred as *innovation efficiency*. Innovation efficiency at a country level has attracted researchers' interest as it shown from the relevant literature (Taskin and Zaim, 1996; Nasierowski and Aecelus, 2003; Lee and Park, 2005; Wang and Huang, 2007; Hollanders and Esser, 2007; Sharma and Thomas, 2008; Cullmann et al., 2009). Nevertheless, technology gaps have been examined by the relevant literature only indirectly and within the framework of National Innovation Systems-NIS (Fagerberg, 1987; Verspagen; 1991; Fagerberg 1994; Lundvall et al., 2002; Balzat and Hansch, 2004).

In order to account for European countries' twofold innovation performance we adopt a novel non-parametric metafrontier approach. More specifically, taking advantage of country level data from the European Innovation Scoreboard (EIS) and Structural Indicators from Eurostat, we employ a bootstrapped DEA analysis and based on the notion of metafrontier we compute technology gaps for 32 countries situated in the European region. At a second stage, we seek to identify the factors that determine European countries' technology gaps.

Extending our methodology we have the opportunity to test for the existence of homogeneous groups of European countries in terms of structural characteristics or, in other words, to identify the similarities/dissimilarities of their NIS. Departing from the North-South models of International Trade (Krugman, 1979; Dollar, 1986), we investigate whether within European region two main technological clusters co-exist, the Northern European countries and the Southern European countries. In addition to geographical features, other dimensions are considered as possible generators of technological heterogeneity within the European innovation process referring also to countries' economic and social activities.

At this point, it must be noted that European countries' innovation performance is dependent not only on the available resources (inputs) but also and maybe most importantly on their efficient and productive use (Wennegers and Thurik, 1999). Schumpeter's notion of creative destruction (Schumpeter Mark I; 1942) is based on the idea of new businessmen 'destroying' old and established firms. Therefore, innovative performance is also interlinked with entrepreneurial activity (Audretsch and Thurik, 2001). In this paper we argue that factors related to entrepreneurship can affect innovative performance in two ways: *(i)* if they are considered as a direct input in the innovation process (Leibenstein, 1986) and *(ii)* if they are considered as a parameter determining the surrounding environment (Andre van Stel et al., 2005) which in turns determines the country specific technology gaps.

In the above framework, the main research question of this paper concerns *the estimation of technology gaps of European innovation systems and the joint estimation of their inefficiency with respect to the group frontier in which they belong to*. In the process of examining the central research question, we additionally explore two complementary issues. The first one refers to the identification *of homogeneous country groups, in terms European systems of innovation,* and the second, concerns the role *of entrepreneurship in defining and affecting technology gaps of the innovation systems.*

The rest of the paper is organized as follows: section 2 is devoted to the presentation of our methodological scheme, while in section 3 we present the data and variables used. In section 4 we present the results of the efficiency and technology gaps estimations and finally, section 5 concludes the paper.

2. Methodology

Based on recent contributions to efficiency and technology heterogeneity literature (Kounetas et al., 2009; Kontolaimou & Tsekouras, 2010) we adopt a non-parametric metafrontier approach to examine the innovative performance of European countries. The analysis is undertaken on an output-oriented basis in order to take into consideration European countries' policy objectives targeted in improving efficiently the outcomes of the innovation process rather than just increasing the available resources devoted to the innovation production process.

First, we need to define the innovation technology and metatechnology sets that are available to a sample of $i = 1, 2, ..., n$ countries. Assume that each country uses $x = (x_{1i}, x_{2i}, ..., x_{Ni}) \in R_+^N$ innovation inputs to produces $y = (y_{1i}, y_{2i}, ..., y_{Mi}) \in R_+^M$ innovation outputs under a variable returns to scale (VRS) technology S defined as $S \equiv \{(x, y): y \text{ are producible by } x\}$. In the case where multiple technologies $S^1, S^2, ..., S^k$ become applicable, each country is considered as operating under exactly one of those. The convex hull of the jointure of all technology sets determines the *metatechnology* set, formally defined as $S^M = \{(x, y : x \geq 0, y \geq 0, x$ can produce y in at least one of $S^1, S^2, ..., S^k\}$ (Rao et al., 2003).

To illustrate the above, consider the case in which there exist two separate innovation technologies S^1 and S^2 in Europe that correspond to group frontiers F^1 and F^2 respectively, as shown in Figure 1. In this context, the *metafrontier* MF which corresponds to metatechnology S^M is defined as an overall frontier that envelopes the group frontiers so that no point of these frontiers can lie above points on the metafrontier (Battese et al., 2004).

Consider a European country denoted by point A (x^1, y^1) in Figure 1. This country has access to the innovation technology S^1, as represented by the efficiency frontier F^1 and at the same time to the common to all European countries innovation technology, that is the *European metatechnology* corresponding to metafrontier MF.

The largest innovation output that this country can produce under technology S^1 is $Y^1 = y^1 / D_o(F^N; (x^1, y^1))$, where $D_o(F^N; (x^1, y^1))$ denotes the *output distance function* with respect to the group frontier F^1 as defined by Shephard (1970). However, if country A adopts the available *metatechnology*, the maximum innovation output it can produce using input quantity x^1 increases to level $Y^{M1} = y^1 / D_o(MF; (x^1, y^1))$, where $D_o(MF; (x^1, y^1))$ is the output distance function with respect to MF.

The output-oriented *technical innovation efficiency* (TE) for country A is defined as

$$TE(F^N; (x^1, y^1)) = \frac{y^1}{Y^1} = \frac{y^1}{y^1 / D_o(F^N; (x^1, y^1))} = D_o(F^N; (x^1, y^1)) \qquad (1)$$

Thus, the innovation efficiency of the country under study with reference to innovation technology S^1 can be measured by TE which refers to the distance AB, as shown in Figure 1. Still, a country can be relatively efficient with respect to a specific group frontier but inefficient with respect to the metafrontier. The innovation efficiency of country A with reference to the metafrontier MF can be measured by the output-oriented *metatechnical efficiency* (ME) which is defined as

$$ME(x^1, y^1) = \frac{y^1}{Y^{M1}} = \frac{y^1}{y^1 / D_o(MF;(x^1, y^1))} = D_o(MF;(x^1, y^1)) \tag{2}$$

Thus, the innovation efficiency of country A with reference to the metatechnology S^M can be measured by ME which refers to the distance AC, as shown in Figure 1.

Comparing the ME scores with the respective TE scores allows identifying technology differentials among the European innovation systems due to different national innovation structures. These differentials can be measured by the *technology gap ratio* (Battese et al. 2004) or the *metatechnology ratio* (O' Donnell et al. 2008) both referring to the distance between a group frontier and its respective metafrontier. Following O' Donnell et al. (2008), the metatechnology ratio (MR) is defined as

$$MR(x^1, y^1) = \frac{y^1 / Y^{M1}}{y^1 / Y^1} = \frac{ME(x^1, y^1)}{TE(x^1, y^1)} = D_o(MF;(x^1, Y^1)) \tag{3}$$

In the case of country A illustrated in Figure 1, MR refers to the distance BC and measures the innovation output expansion - given the input quantity x^1- that the country A can achieve adopting the European metatechnology, taking into account that A is among the best performers in its group. Apparently, MR takes values between zero and unity, with relatively small values indicating relatively large technology gaps. Finally, equation (3) can be written as

$$ME(x^1, y^1) = MR(x^1, y^1) \times TE(x^1, y^1) \tag{4}$$

The above equation suggests that weaknesses in innovation performance of a European country, as reflected in its distance from the European metafrontier, can be attributed to (i) its technology gap due to structural characteristics of its innovation system measured by MR and (ii) the inefficient production of innovation outputs under the group technology measured by TE.

All the above measures can be computed using the DEA approach (Charnes et al., 1978). For a country i, the output-orientated efficiency estimate TE_i is derived by solving the following linear program:

$$\widehat{TE_i(x,y)} \equiv \widehat{\theta_i(x,y)} = \max\{\theta \left| \theta y \leq \sum_{i=1}^{n} \gamma_i y_i ; x \geq \sum_{i=1}^{n} \gamma_i x_i \right. \text{ for } \gamma_i \text{ such that } \sum_{i=1}^{n} \gamma_i = 1;\ \gamma_i \geq 0, i = 1, 2, ..., n\} \tag{5}$$

However, since DEA is based on the principles of linear programming, it is of deterministic nature suffering from statistical limitations. More particularly, as Simar and Wilson (1998, 1999, and 2007) note, the DEA efficiency scores are biased by construction and are affected by uncertainty due to sampling variation. To solve this problem, Simar and Wilson propose a bootstrap algorithm that enables to retrieve bias-corrected estimated of original "overstated" technical efficiency scores.

Following Simar and Wilson (2007), we adopt a bootstrap DEA approach which assumes that the original sample data is generated by "mimicking" the data generating process (DGP) described by expression (5), thus being able to re-estimate the DEA output-oriented model[1]. Repeating this process many time (Simar and Wilson suggests 2000 replications, 2007) we obtain $\widehat{TE}_i^*$ that facilitates inference procedures[2]. The bias of the output-oriented TE scores is given by:

[1] The data that is used is drawn from the sample and is characterized as "pseudo" data by simulating the GDP.

[2] To gain consistency on the empirical distribution Simar and Wilson (1998,1999) use a smooth bootstrap procedure.

$$bias_{\mathrm{B}}(\widehat{TE_{VRS}}(x_i, y_i)) \equiv \mathrm{B}^{-1}\sum_{b=1}^{B}(\widehat{TE^{*}_{VRS,b}}(x_i, y_i)) - TE_i(x_i, y_i)\,^{3},$$

where B is the number of replications. Then the bias-corrected estimator of $TE(x_i, y_i)$ is obtained by computing

$$\widehat{\widehat{TE_{VRS}}}(x_i, y_i) = 2\widehat{TE_{VRS}}(x_i, y_i) - \mathrm{B}^{-1}\sum_{b=1}^{B}(\widehat{TE^{*}_{VRS,b}}(x_i, y_i)) \tag{6}$$

The corresponding confidence intervals are constructed in a similar manner determining the quantile of the sampling distribution of $\widehat{TE^{*}_{VRS,b}} - \widehat{TE_{VRS,b}}$ through the bootstrap technique. Using the above bootstrap DEA approach both TE and ME scores are computed for each country of our sample, while the MR measures are derived from the bootsrapped TE and ME scores based on equation (3).

3. Data and Variables Definition

In order to perform our proposed analysis, we need first to identify observable measures that depict European countries' innovation performance and then construct a dataset that tracks down these measures at a country level. Our sample consists of a total of 32 countries for the years 2004 and 2006, with sixteen (16) of them to be members of the Eurozone, and the others either as candidates for entering the Eurozone (i.e Bulgaria and Romania) or for becoming EU members (i.e Turkey). The quantitative information regarding innovation inputs and outputs used in the first stage of our analysis derives from European Innovation Scoreboard (EIS; 2004, 2006), while in the second stage of our analysis, where

[3] Efron and Tibshurani (1993) propose a conservative rule for applying bootstrap DEA, that is if $\frac{bias_B(\widehat{TE_{i,VRS}}(x_i, y_i))}{\widehat{\sigma}} > \frac{1}{4}$, where $\widehat{\sigma}$ is the standard error of the biase-corrected estimator.

we investigate the drivers of technology gaps in Europe and the role of entrepreneurship, Eurostat's structural indicators database[4] is our main source of information.

At this point, it is interesting to note that when analyzing the transformation of innovation inputs to outputs a problem of time lag is present assuming that inputs do not immediately lead to innovation output (Sharma and Thomas, 2008). Thus, in order to incorporate this time lag into our analysis, we have allowed for a two year distance between the inputs and the outputs used in the first stage of our analysis. More specifically, the inputs used in the DEA models, correspond to the year 2004 whereas, outputs are assumed to be produced in 2006.

For our DEA estimations a multi-input, multi-output model is used. The inputs to innovation process are Total Expenditures on Education $(HRSPEND)$ (Nasierowski and Arcelus, 2003), Business Expenditures on R&D $(BERD)$ (Furman and Hayes, 2004) and Private Credit $(PRCREDIT)$. At this point, we have to mention that the latter seems to capture countries' entrepreneurial behavior, since it reflects firms' start up capital in order to proceed to an investment. At the same time, medium-tech and high-tech exports $(HTEXP)$ (Hollanders and Esser, 2007) and patent applications to the European Patent Office (EPO) $(PATENTS)$ (Wang and Huang, 2007; Wang, 2007) capture European countries' innovation outputs.

The second part of our empirical analysis explores the influence of environmental factors on countries' differences in structural components of their corresponding innovation systems, focusing on the potential impact of entrepreneurship. At this point, it must be noted that the right-hand variables used in the econometric estimations are constructed based on the mean value of 2004-2006 period, in order to account for potential influence of the environment during the time lag we have allowed to exist in the frontier estimations. Additionally,

[4] http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database).

differences in innovation performance are also affected by other socio-economic factors which vary from country to country and thus, several exogenous variables are taken into account in order to distinguish their effect on countries' technology gaps. Therefore, we use a dummy variable $(EURO)$ that distinguishes countries participating in Eurozone, the ratio of Government to Business Expenditures on R&D $(GOVRD)$, and the ratio of Gross Fixed Capital Formation by the private sector to the Gross Fixed Capital Formation by the government sector $(BUSINV)$. Moreover, we incorporate a competitiveness index (GCI) based on 12 pillars of competitiveness, providing a comprehensive picture of the competitiveness landscape in countries around the world at all stages of development. The pillars include Institutions, Infrastructure, Macroeconomic Stability, Health and Primary Education, Higher Education and Training, Goods Market Efficiency, Labour Market Efficiency, Financial Market Sophistication, Technological Readiness, Market Size, Business Sophistication, and Innovation (Global Competitiveness Report, 2005). Finally, the variable $(POPEDU)$ that depicts the percentage of students' enrollment in tertiary education is also incorporated (Wang and Huang, 2007). The definitions of the above mentioned variables are presented in Table 1, while basic descriptive statistics of all our variables are reported in Table 2.

4. Empirical Results and Discussion

Applying the methodology presented in section 2 on the data set presented in the previous section we measure the innovative performance for each one of the thirty two European countries under examination. More specifically, we provide estimations of the country-specific technology gaps of the innovation process as well as the innovation efficiency of European countries under study.

The estimation method, as it has been already mentioned, is the bootstrapped DEA. In the following section we consider and test a number of criterions in order to define homogenous groups in terms of structural characteristics of European countries' innovation systems. In addition, results with respect to group frontiers and the metafrontier are presented for each division criterion. Furthermore, in section 4.2 we discuss issues regarding European innovation systems' performance as it is determined by technology gaps and innovation efficiency. Finally, in section 4.3 we present the estimation results of the regression analysis regarding the environmental factors affecting structural differences among countries of European region, focusing on the role of entrepreneurship.

4.1 Technology heterogeneity Tests

For the purposes of our analysis, a crucial element needed to be addressed is the fact that European countries' technology heterogeneity of innovation process is not known *ex-ante*. For that reason and following the relevant literature we adopt a number of well known criteria. More specifically, the first criterion employed in order to define the group frontiers is based on the North vs. South models of International trade and consequently countries have been divided into groups according to their geographical position. In addition, the second criterion intends to capture country differences with respect to their economic development. More specifically, we have set the median value of the examined countries' GDP as the threshold according to which if a country exceeds it, is placed in the group of the 'developed' European countries and if otherwise, is placed in the group of the 'developing' European counties. Finally, the third grouping criterion is based on a mixture of the above two in the sense, that in order for a country to be placed in the 'North and developed' group, not only it needs to be above the GDP threshold and but also, at the same time to be geographically situated in the Northern European region, otherwise it is placed in the second group of countries.

In Tables 3-5 bootstrapped DEA estimation results based on the three pairs of group frontiers are presented. The first three columns of Tables 3-5, present innovation efficiency estimations of the three sets of group frontiers respectively, along with the bias and the bias corrected values of the countries original efficiency scores. Essentially, the bias corrected values are the efficiency scores obtained with the deterministic DEA, corrected by attributing to them stochastic properties bootstrapping the initial/deterministic efficiency scores. Such being the case and even though the original DEA estimates characterize a number of countries as fully efficient, after the bootstrap process their efficiency scores are reduced to the point where they no longer considered to be the most efficient relative to others. For instance, in Table 3 Latvia and Poland are both situated in the North group frontier, and while the DEA efficiency scores indicate that Poland is fully efficient, and Latvia is not, the bootstrapped efficiency scores indicate that actually, Latvia is more efficient than Poland. Finally, Table 6 presents the efficiency estimations with reference to the European metafrontier.

Based on the efficiency scores presented in Tables 3-5, we test whether efficiency scores of each pair of group frontiers have the same distribution employing a Mann Whitney U (1945) test. Results of the undertaken non parametric tests are shown in Table 7. The relevant results for the three division criteria reveal that only in the case of ‘North vs. South’ grouping no statistically significant differences in the mean efficiency between the corresponding groups are found. On the other hand, the distributions of efficiency scores exhibit statistically significant differences between the ‘developed’ and ‘developing’ countries, such being the case for the groups of ‘north and developed’ and ‘south and developing’ countries.

Based on the results with respect to the group frontiers and the European metafrontier, we compute the MR scores for each country according to section 2 (see equation (3)). The relevant results are presented in Table 8 for the 3 division criteria. In the process of computing metatechnology ratios, for some country cases, their corresponding MR score has been found to exceed unity. This may be due to the different levels of noise incorporated in the frontier estimations in relation to the noise incorporated in the metafrontier estimations. In other words, the average value of the confidence interval of the efficiency scores with respect to group frontiers (MR) is bigger than the average value of the confidence interval of the efficiency scores with reference to the metafrontier (ME) due to increased noise (and thus, 'enlarged' range of the confidence interval).

In order to *(i)* "adjust" the computed MR of each European country so as to account for noise arising in the corresponding bootstrapped estimation results and *(ii)* test the homogeneity of the technology groups we have already defined, we use a 'correction factor', that is the ratio $\left(\frac{\sigma_f}{\sigma_{mf}}\right)$. If for European country *i* holds that $\left(\frac{\sigma_f}{\sigma_{mf}}\right) \leq 1$, then the homogeneity condition is fulfilled, otherwise the country's *i* technology production system has substantial structural differences from its counterparts operating in the assumed common frontier, under which the country *i* is also placed. The underlying logic is that if on a country is assigned a lower level of noise within the group frontier compared to the corresponding level of noise of that particular country when it is placed to the European metafrontier, then the homogeneity condition is satisfied. In particular, Table 8 presents the metatechnology ratios (MR) of the bootstrapped efficiency scores based on the three pairs of group frontiers along with the correction factor and the new MR*. It becomes evident from the bottom line of table 8 that under the GDP per capita division criterion eleven (11) cases do not fulfill the homogeneity condition. In terms of the 'North vs. South' division criterion, sixteen (16) countries are misplaced, whereas under the mixed criterion seventeen (17) European countries fail to satisfy the homogeneity condition. It is interesting to note, that a number of countries and more specifically, Croatia, Ireland, Italy, Latvia, Malta, Portugal, Slovenia and Spain seem to be misplaced under all three criteria. On the contrary, Austria, Bulgaria, Denmark, Germany, Luxemburg, Sweden, Switzerland, Turkey and the United Kingdom seem to be correctly placed under all three criteria. This fact itself, may suggest that there exists such heterogeneity within the European region in terms of structural systems of technology production, that the splitting into two groups is not sufficient to treat such a degree of heterogeneity among European countries. Towards that direction, we accept as appropriate the technology grouping that entails the bigger number of countries that holds $\left(\frac{\sigma_f}{\sigma_{mf}}\right) \leq 1$. Therefore, we approve as appropriate the technology grouping that results from the GDP per capita[5]. It must be noted that even though we assume for analytic purposes that European countries operate under a common system of technology production, this is definitely not the case, since there may be some resemblances between national systems of technology production mainly due to geographic, cultural and historical reasons but the basic components of which European countries' system of technology production is comprised remain deeply heterogeneous (Freeman, 2002).

4.2. Technology Gaps and Innovation Inefficiency of the European Innovation Systems

In what follows, we adopt the 'developed vs. developing' grouping as a proper definition of technology heterogeneity based on the above discussion. Table 9 presents the estimated (MR) and (MR^*) ratios along with the corresponding ranks of European countries.

[5] The adoption of a different homogeneity condition might lead us to select another pair of group frontiers. It is possible to select the best pair of group frontiers taking the minimum sum of (σ_f / σ_{mf}). However, in this particular case, our analysis is interested in identifying the noise caused from each country individually when placed under a common technology frontier and not from the sum of countries comprising the group frontier as a whole.

In Figure 2 we present the distribution patters of the MR scores across the three grouping criteria. Moreover, in Figure 3, we present the distribution patterns of MR^* scores where it becomes evident that they are heavily affected by values of $MR^* > 1$. In order to test whether the ranks based on MR and MR^* have any significant differences across the three alternative division critertia, and thus to test for the robustness of the chosen pair of group frontiers, we use the Friedman test (1972). The relevant results in Table 10 show that among the three division criteria no significant differences in countries' ranking are present either with respect to MR or with respect to MR^*.

In Figure 4 one can gain a more holistic view of the thirty two (32) European countries' innovative performance. The horizontal axis measures countries' innovation efficiency (TE) based on estimations presented in Table 4 while the vertical axis measures the metatechnology ratios (MR) of each country as shown in Table 8 (column 5). Even though the picture is not so clear, and up to an extent this is due to the small amount of observations we can still try and create a typology with respect to European countries' innovative performance.

In order to create such a typology we set somewhat arbitrary boundaries with respect to TE and MR scores. Therefore, in terms of the horizontal axis, we set 0.60 and 0.80 as critical points and additionally, with respect to the vertical axis we set 0.80 and 0.90 as thresholds. In this way, 9 different segments are drawn in figure space indicating five (5) country types. Group A consists of Czech Republic, Hungury, Italy, Poland, Slovakia, Sweden and the Netherlands. These European countries are considered to perform excellent not only in reference to the European metafrontier but also with respect to the group frontier they belong to. Put differently, these countries are technologically 'superior' since they define the metafrontier, that is the overall system of technology production in Europe, and in addition, they exhibit superior performance in terms of the structural characteristics that define the system of technology production, with respect to the group frontier they belong to, that is the developed group frontier or the developing group frontier.

Furthermore, group B entails, Austria, Belgium, Finland, Germany, Switzerland, Luxembourrg, Spain and France. This particular country type seems to achieve very good scores with respect to the group frontier it belongs to and therefore, it seems to operate successfully within the system of technology production that defines its group frontier. In addition, this country type is able to absorb knowledge flows originating from countries that define the overall metafrontier. Apparently, knowledge flows are in operation from Group A towards Group B in relation to group specific technologies whereas appropriability conditions (Malerba and Orsenigo, 1993) seem to exist with respect to metatechnologies. Taking into account that this group is comprised only of 'developed' countries, it not groundless to assume that these countries have not yet established adequate linkages with those European countries that operate under a different structural system of technology production. These appropriability conditions seem to be even more intense for European countries belonging to Group C and in particular for Ireland, UK, Greece and Norway. Nevertheless, the intra-group flows are equally powerful as those in Group B.

Group D consists of Croatia, Lithuania, Malta, Slovenia, Cyprus, Romania, Turkey and Bulgaria. These countries seem to share common structural characteristics with the countries defining European metatechnology, but again filtering mechanisms seem to be in operation within group specific frontiers resulting in relatively low values of innovation efficiency. In other words, and taking into account that this group is comprised of countries that became official members of the European Union during the 2004 and 2007 EU enlargement, this group needs to develop such routines that will eventually allow it to develop and/or evolve structural components that define their group specific frontier. Finally and with respect to Estonia and Portugal that comprise Group E, it becomes evident that even though they belong to different group frontiers and they achieve high scores with respect to European metafrontier, filtering conditions are even more intense within their group frontiers.

4.3. Drivers of the Technology Gaps and the role of Entrepreneurship

This section is intended to explore the determinants of the European Innovation Systems' technology gaps, estimated as described above. In this direction the corrected for noise metatechnology ratios $\left(MR^*\right)$ have been regressed against a number of country-specific variables. Two criteria have guided the identification of the best model describing the factors affecting the examined countries' technology gaps with respect to their innovative performance.

Firstly, we look for a meaningful and informed set of explanatory variables among the available economic and social indicators/variables, transformations and possible interactions among variables. These variables include the country specific index of the Growth Competitiveness Index (*GCI*) and the ratio of gross fixed capital formation by the private sector to the gross fixed capital formation by the government sector (*BUSINV*). Furthermore, and taking into account that in the input-output mix on which the frontier of the innovation process is grounded, the intensity of the high-tech exporting activities has been considered as an output, we include in the set of explanatory variables the dummy variable of *EURO* in order to test for any effects of national exchange rate policies on the variable of high-tech exporting activities. Finally, in the set of explanatory variables we have included the knowledge-oriented variables of population with tertiary education (*POPEDU*) and the ratio of government's R&D expenditures to enterprises' R&D expenditures (*GOVRD*). Their definition in more detail is provided in Section 3. It can be argued, that these two knowledge-oriented variables capture, at least to some extent, the entrepreneurial dimensions of the estimated technology gap of the examined innovation processes.

Secondly, we opt for the model with the best econometric properties among alternative models. This implies that variables with no statistically significant results have been included in our final model, as they are also regarded to be an important finding. Separate tests examining the null hypothesis that individual coefficients are zero (0), and a joint test of the null hypothesis that all the parameters associated with the explanatory variables equal zero (0) have been performed. Nested models methodology has been employed to test for omitted and redundant variables. Usual tests for heteroscedasticity and multicollinearity have also been performed. OLS estimated coefficients, their t-values and the corresponding p-values, as well some measures of goodness of fit are presented in Table 11.

The monetary and exchange rate stability, ensured within the euro zone, affects positively the development of the Eurozone countries' innovation systems, resulting in superior performance of these particular countries in relation to the whole European system of innovation. It is quite interesting to note that the level of country's competitiveness, as it is captured by the *GCI* variable, does not seem to exert any significant effects on the technology gap measure. Of course several issues of endogeneity between the country competitiveness and the country's innovative performance may be present and need further research.

Unexpected as may be the first impression regarding the negative impact of *BUSINV* variable on the metatechnology ratio, on a second view it seems that indeed in countries where the private sector undertakes the greater burden of investment activities relative to the public sector the technology gap is increasing. This may be due to the fact that in European countries complex investment projects that require the development or use of cutting edge technologies, or in other words projects that are interlinked with high levels of uncertainty, are left to the public sector to be executed. Towards the same direction, it could be argued that entrepreneurial activities in European countries is not an important factor of promoting the production of knowledge and technology when compares to the public sector. It must be noted, however, that this particular variable measures the total investment activities and does not focus on knowledge intensive investments.

On the contrary, the role of knowledge-intensive entrepreneurship is approached, in the context of the present paper, incorporating in our regression model the variables of *GOVRD* and *POPEDU*. Therefore, drawing attention to actual knowledge production activities such as R&D, and according to our empirical findings, it seems that the more the public sector is involved in financing R&D activities in relation to the private sector involvement the more the technology gaps are increasing.

In an effort to combine the empirical findings with respect to *BUSINV* and *GOVRD*, in an entrepreneurial framework, it can be argued that in terms of knowledge and technology production, the European entrepreneurial performance is characterized by a duality. More specifically, European region is rather characterized by conservatism in identifying and exploiting technological opportunities. At a second stage, however, those entrepreneurs that actually get involved in knowledge/technology intensive activities, exhibits a rather satisfying performance in terms of knowledge/technology production compared to resources devoted to corresponding activities funded by the public sector. In such cases two alternative strategies exist. The first strategy involves the government sector to undertake the production of such knowledge/technology that the 'conservative' private sector does not produce, however with reduced technical efficiency. The second strategy is based on the underproduction of new knowledge/technologies and as a result, the metatechnical efficiency to be reduced, or in other words, to increase the gap of that particular innovation system.

Consequently, entrepreneurial activities that are not knowledge/technology oriented either 'force' European countries' government sector to act as a substitution with either reduced rate of returns of the resources devoted to innovation process, or to expand the technology gap of that particular country from the corresponding European metafrontier. It must be noted that the abovementioned situation signifies the falling behind of European Region in relation not only to the Global innovation frontier but also to its main competitors, US and South-East Asia.

Finally, as expected, the metatechnology ratios are greater in countries that are abundant in highly educated human capital (*POPEDU* variable). The relevant literature has well documented the link between the level of education of human capital, the entrepreneurial activities and as a consequence the production of new knowledge and technology which in turn reduces technology gaps.

5. Conclusions

While the relevant literature has investigated European countries' innovation performance within the context of systems of inputs-outputs, it has failed to address the extent to which differences in countries' innovative performance is due to differences in countries structural characteristics, or in other words due to technological heterogeneity among the national systems of innovation of countries situated in the European region.

In this direction, we examine the performance of 32 European countries' innovation systems, adopting a metafrontier approach which allows us to separate the overall innovative performance into two components. The first component concerns the efficient use of resources of each country's specific innovation system, under the condition that it operates within a relevant homogeneous group frontier. The second component to be estimated, namely the technology gap for each country concerns differentials in innovation performance that are attributed to the special structural characteristics of the European countries' innovation systems under the condition that a common European frontier, that is a metafrontier, exists.

In order to address the above issues, we employ a novel methodology based on bootstrapped DEA to measure the two components of innovative performance of 32 European innovation systems and at the same time to account for the noise of the estimation results. Furthermore, we test alternative criteria used in defining homogenous groups of European innovation systems based on the noise of the estimation results. As a starting point, we employ the ‘North vs. South’ grouping but after conducting the relevant tests we argue in favor of the ‘Developed vs. Developing’ grouping.

A quite interesting typology may be deduced if someone juxtaposes the results on the two components of the country innovation systems performance, that is innovation efficiency and technology gap estimates. Based on this typology, several patterns of knowledge flows and countries’ strategic orientations towards knowledge/technology creation process are signalized.

Exploring, at a second stage, the drivers of countries’ innovative performance with respect to the European metafrontier we identify a mixed scheme regarding the features of the entrepreneurship characteristics which affect the European countries’ technology gaps. More specifically, it seems that entrepreneurs in the European region are rather conservative and avoid getting involved in knowledge/technology oriented entrepreneurship which would promote their country’s innovation system towards the European metafrontier. On the other hand, those entrepreneurs that actually get involved in knowledge/technology intensive activities, seem to exhibit a rather satisfying performance in terms of knowledge/technology production compared to the public sector’ s relevant initiatives. Finally, the role of highly educated human capital appears to be quite significant in diminishing European countries’ technology gaps.

Most of the above issues would be of great interest to be explored using an enlarged dataset in terms of additional countries and/or time periods. In this direction, the investigation of convergence/divergence patterns referring to the innovation process of European countries in a dynamic setting may constitute interesting future research. In addition, the estimation of a global metafrontier along with group frontiers corresponding to European, South-East and US innovation systems could produce interesting results concerning the relevant position of these region-specific frontiers with respect to the global metafrontier.

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Appendix

Figure 1 Innovation performance measurement with respect to group frontiers and the metafrontier

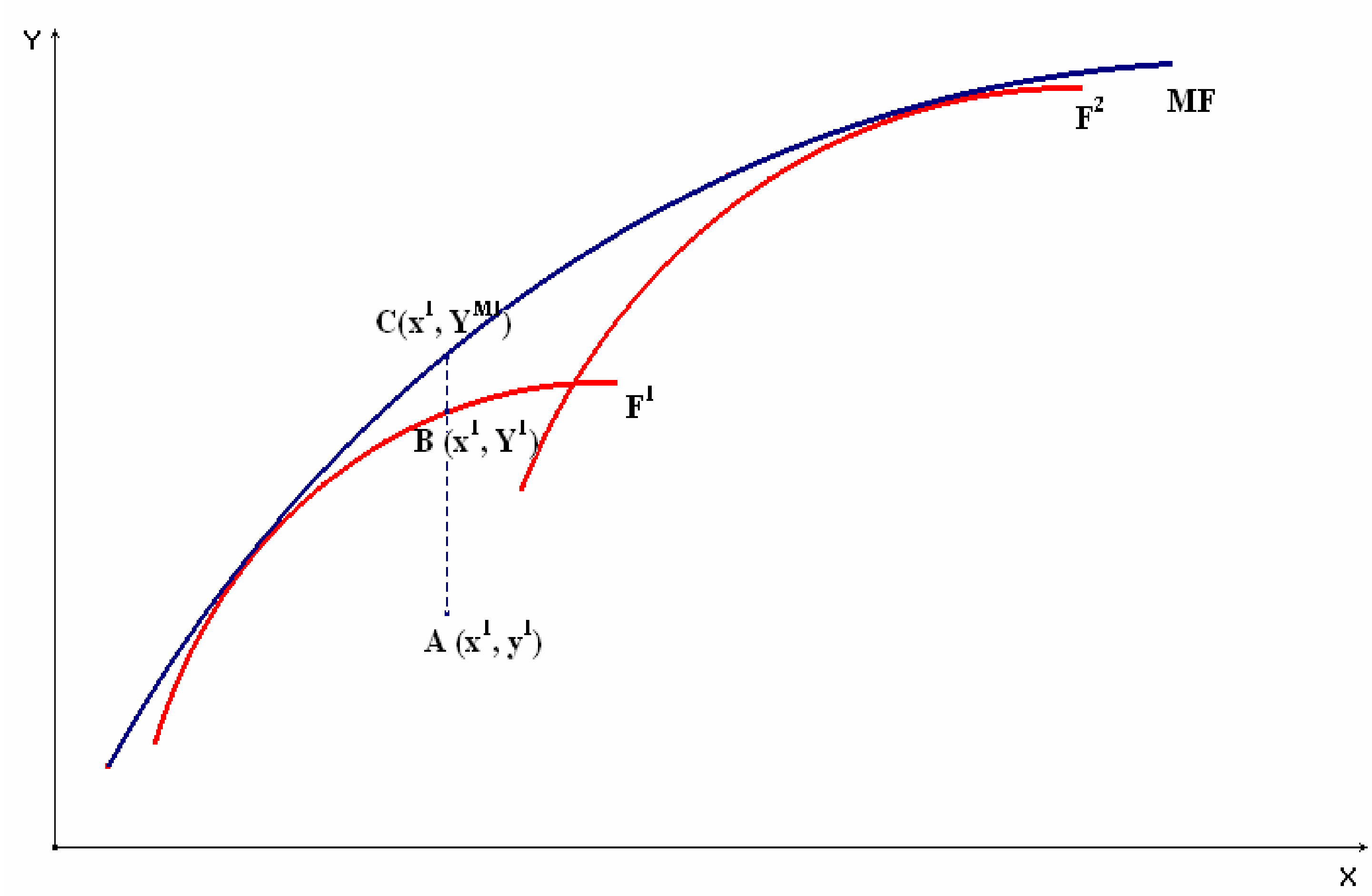

Figure 2 Kernel densities of bootstrapped MR scores

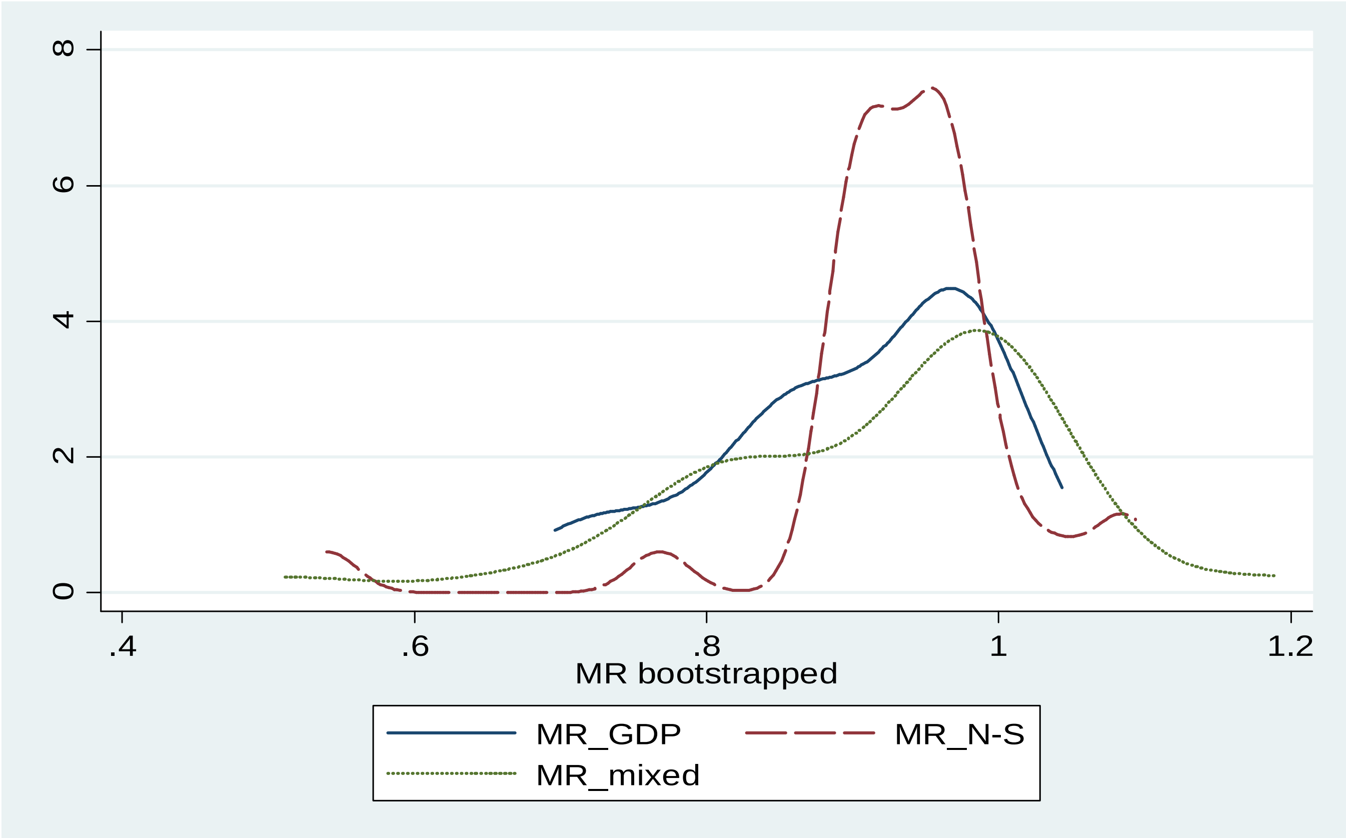

Figure 3 Kernel densities of bootstrapped MR* scores

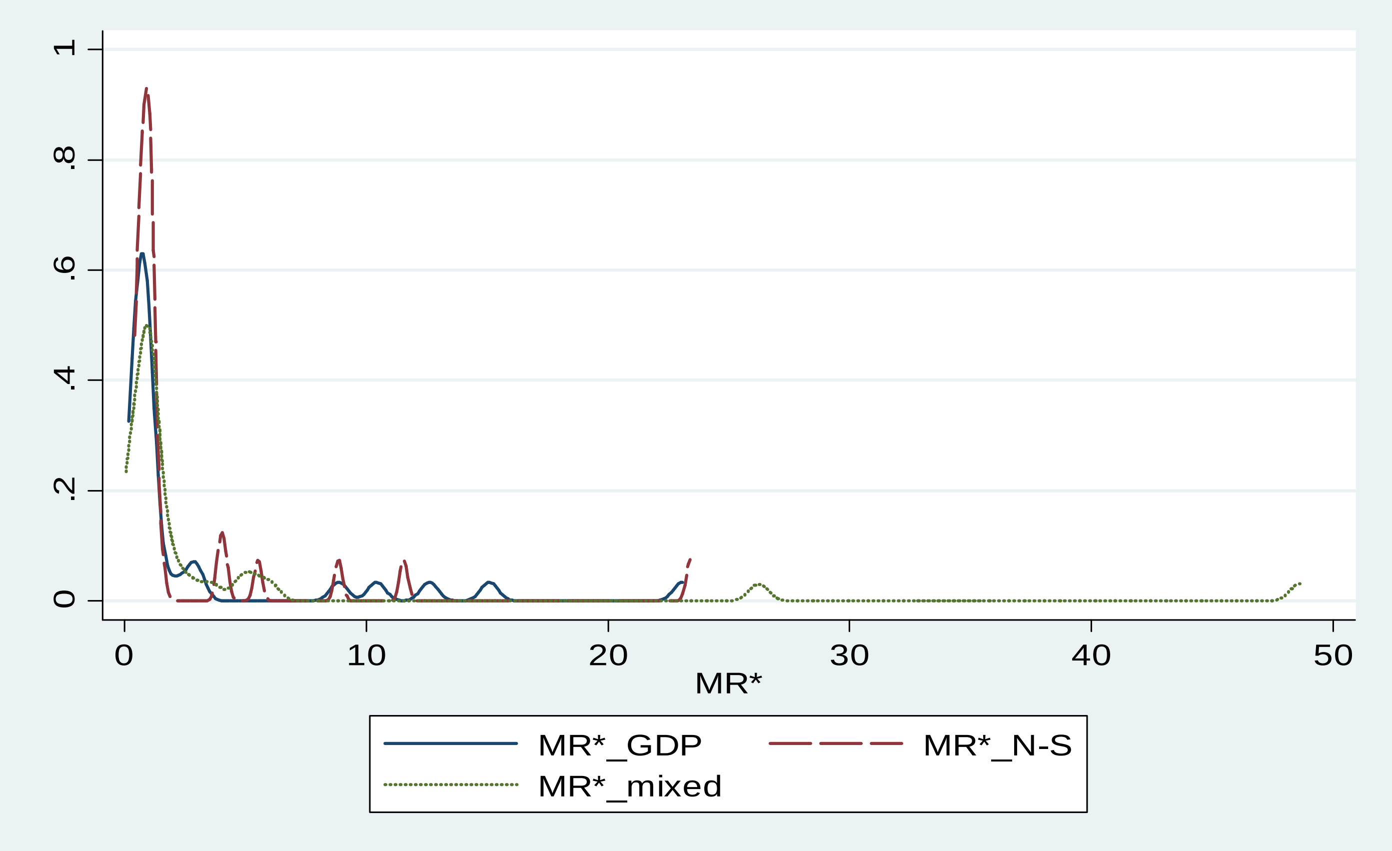

Figure 4 Typology of European innovation systems

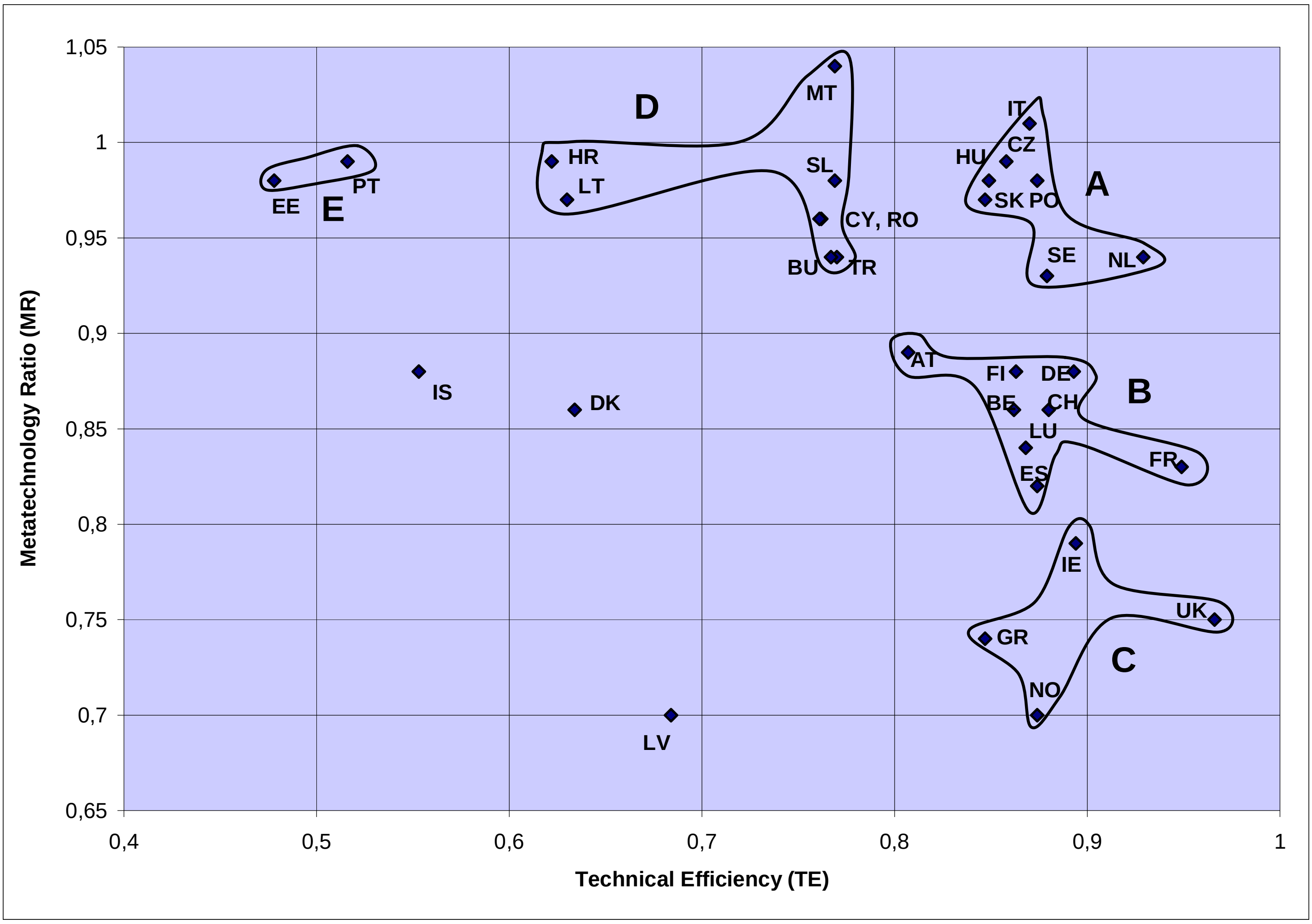

Table 1 Variables Definition

Variable	Definition
Innovation Performance Inputs-Outputs	
HRSPEND	Total public expenditure on education (αs a percentage of GDP)
PRCREDIT	Private credit (relative to GDP)
BERD	Business R&D expenditures (αs a percentage of GDP)
PATENTS	Patent applications to the European Patent Office (EPO) (Measured as number of applications per million inhabitants)
HTEXP	Medium-tech and high-tech exports (Measured as a percentage of total exports)
Second Stage Explanatory Variables	
EURO	A dummy variable that takes the value of 1 if the country has adopted the official currency of the European Union and 0 otherwise
GCI	Growth Competitiveness Index
GOVRD	The ratio of government to business expenditures on R&D.
BUSINV	The ratio of Gross fixed capital formation by the private sector to the Gross fixed capital formation by the government sector.
POPEDU	Population with tertiary education per 100 population aged 25-64

Table 2 Descriptive statistics of the used variables

	Mean	St. Deviation	Min	Max
Inputs				
HRSPEND	5.712	1.223	3.770	8.330
PRCREDIT	0.947	0.515	0.281	1.664
BERD	1.088	0.765	0.160	2.670
Outputs				
HTEXP	0.462	0.162	0.114	0.692
PATENTS	1.308	1.229	0.032	4.306
Second Stage Variables				
GCI	4.817	0.572	3.85	5.883
EURO	0:50.00%	0.508		
	1:50.00%			
GOVRD	1.082	0.770	0.208	3.829
BUSINV	9.200	11.528	3.800	67.951
POPEDU	22.915	7.733	9.400	34.600

Table 3 Bootstrapped efficiency results with respect to group frontiers, North vs. South

	Efficiency Score	Bias corrected	Bias	Standard error	LB	UB
North						
Austria	0.802	0.744	0.058	0.002	0.692	0.798
Belgium	0.825	0.758	0.067	0.002	0.711	0.819
Czech Republic	1.000	0.876	0.124	0.012	0.757	0.995
Denmark	0.639	0.581	0.058	0.002	0.518	0.636
Estonia	0.557	0.502	0.055	0.002	0.456	0.554
Finland	1.000	0.796	0.204	0.041	0.710	0.994
Germany	1.000	0.828	0.172	0.021	0.750	0.994
Hungary	1.000	0.858	0.142	0.010	0.789	0.995
Iceland	0.577	0.536	0.042	0.001	0.500	0.576
Ireland	0.877	0.795	0.083	0.004	0.719	0.872
Latvia	0.950	0.882	0.068	0.002	0.828	0.945
Lithuania	1.000	0.798	0.202	0.045	0.694	0.996
Luxembourg	1.000	0.793	0.207	0.047	0.693	0.995
Netherlands	1.000	0.875	0.125	0.008	0.803	0.996
Norway	0.709	0.648	0.060	0.002	0.596	0.706
Poland	1.000	0.785	0.215	0.049	0.694	0.994
Slovakia	1.000	0.794	0.206	0.045	0.695	0.994
Sweden	0.926	0.847	0.079	0.003	0.783	0.921
Switzerland	1.000	0.799	0.201	0.037	0.716	0.995
United Kingdom	0.868	0.805	0.063	0.001	0.762	0.863
average	0.886	0.765	0.122	0.017	0.693	0.882
std deviation	0.153	0.111	0.065	0.019	0.101	0.152
min	0.557	0.502	0.042	0.001	0.456	0.554
max	1.000	0.882	0.215	0.049	0.828	0.996
South						
Bulgaria	1.000	0.810	0.190	0.029	0.712	0.992
Croatia	0.737	0.669	0.068	0.002	0.616	0.733
Cyprus	1.000	0.810	0.190	0.030	0.711	0.994
France	1.000	0.812	0.188	0.029	0.717	0.993
Greece	0.761	0.676	0.085	0.004	0.612	0.757
Italy	1.000	0.813	0.187	0.029	0.715	0.992
Malta	1.000	0.830	0.170	0.019	0.751	0.994
Portugal	0.577	0.518	0.059	0.002	0.464	0.573
Romania	1.000	0.809	0.191	0.031	0.709	0.995
Slovenia	1.000	0.848	0.152	0.011	0.787	0.994
Spain	0.875	0.790	0.085	0.003	0.728	0.870
Turkey	1.000	0.809	0.191	0.031	0.712	0.992
average	0.876	0.736	0.148	0.021	0.662	0.871
std deviation	0.190	0.141	0.053	0.015	0.119	0.188
min	0.443	0.380	0.059	0.002	0.372	0.442
max	1.000	0.848	0.191	0.049	0.787	0.995

Table 4 Bootstrapped efficiency results with respect to group frontiers, Developed vs. Developing

	Efficiency Score	Bias corrected	Bias	Standard error	LB	UB
Developed						
Austria	0.844	0.807	0.036	0.001	0.756	0.841
Belgium	1.000	0.862	0.138	0.035	0.706	0.996
Denmark	0.666	0.634	0.032	0.001	0.594	0.664
Finland	1.000	0.863	0.137	0.037	0.706	0.997
France	1.000	0.949	0.051	0.001	0.909	0.997
Germany	1.000	0.893	0.107	0.016	0.763	0.997
Iceland	0.580	0.553	0.027	0.000	0.518	0.578
Ireland	0.943	0.894	0.049	0.003	0.812	0.940
Italy	1.000	0.870	0.130	0.034	0.707	0.997
Luxembourg	1.000	0.868	0.132	0.035	0.706	0.997
Netherlands	1.000	0.929	0.071	0.003	0.849	0.997
Norway	1.000	0.874	0.126	0.033	0.705	0.998
Spain	1.000	0.874	0.126	0.033	0.707	0.998
Sweden	0.926	0.879	0.047	0.001	0.817	0.923
Switzerland	1.000	0.880	0.120	0.024	0.739	0.997
United Kingdom	1.000	0.966	0.034	0.000	0.931	0.997
average	0.935	0.850	0.085	0.016	0.745	0.932
std deviation	0.130	0.108	0.045	0.016	0.105	0.130
min	0.580	0.553	0.027	0.000	0.518	0.578
max	1.000	0.966	0.138	0.037	0.931	0.998
Developing						
Bulgaria	1.000	0.770	0.230	0.054	0.685	0.994
Croatia	0.695	0.622	0.074	0.002	0.573	0.691
Cyprus	1.000	0.762	0.238	0.057	0.682	0.994
Czech Republic	1.000	0.858	0.142	0.009	0.791	0.993
Estonia	0.532	0.478	0.054	0.001	0.438	0.529
Greece	1.000	0.847	0.153	0.013	0.762	0.994
Hungary	1.000	0.849	0.151	0.009	0.789	0.992
Latvia	0.768	0.684	0.085	0.004	0.618	0.763
Lithuania	0.706	0.630	0.076	0.003	0.579	0.703
Malta	1.000	0.769	0.231	0.045	0.699	0.992
Poland	1.000	0.874	0.126	0.007	0.801	0.993
Portugal	0.577	0.516	0.061	0.002	0.464	0.573
Romania	1.000	0.761	0.239	0.057	0.682	0.994
Slovakia	1.000	0.847	0.153	0.010	0.791	0.994
Slovenia	1.000	0.769	0.231	0.056	0.681	0.994
Turkey	1.000	0.767	0.233	0.055	0.684	0.994
average	0.892	0.738	0.155	0.024	0.670	0.887
std deviation	0.172	0.121	0.071	0.024	0.112	0.171
min	0.532	0.478	0.054	0.001	0.438	0.529
max	1.000	0.874	0.239	0.057	0.801	0.994

Table 5 Bootstrapped efficiency results with respect to group frontiers, North & Developed vs. South & Developing

	Efficiency Score	Bias corrected	Bias	Standard error	LB	UB
North & Developed						
Austria	0.878	0.849	0.029	0.001	0.803	0.876
Belgium	1.000	0.921	0.079	0.013	0.757	0.998
Denmark	0.674	0.652	0.022	0.000	0.622	0.672
Finland	1.000	0.921	0.079	0.014	0.754	0.999
Germany	1.000	0.932	0.068	0.009	0.770	0.998
Iceland	1.000	0.949	0.051	0.002	0.889	0.998
Ireland	1.000	0.917	0.083	0.014	0.756	0.998
Luxembourg	1.000	0.920	0.080	0.014	0.755	0.998
Netherlands	1.000	0.921	0.079	0.014	0.755	0.998
Norway	1.000	0.920	0.080	0.014	0.756	0.998
Sweden	0.926	0.894	0.032	0.001	0.849	0.924
Switzerland	1.000	0.920	0.080	0.014	0.757	0.999
United Kingdom	1.000	0.952	0.048	0.001	0.893	0.998
average	0.960	0.897	0.062	0.008	0.778	0.958
std deviation	0.094	0.078	0.023	0.006	0.070	0.094
min	0.674	0.652	0.022	0.000	0.622	0.672
max	1.000	0.952	0.083	0.014	0.893	0.999
South & Developing						
Bulgaria	1.000	0.739	0.261	0.058	0.682	0.991
Croatia	0.695	0.619	0.076	0.002	0.576	0.691
Cyprus	1.000	0.733	0.267	0.062	0.681	0.991
Czech Republic	1.000	0.847	0.153	0.010	0.786	0.992
Estonia	0.532	0.471	0.061	0.001	0.437	0.528
France	1.000	0.744	0.256	0.055	0.689	0.992
Greece	0.761	0.649	0.113	0.008	0.576	0.755
Hungary	1.000	0.838	0.162	0.010	0.786	0.993
Italy	1.000	0.737	0.263	0.060	0.685	0.992
Latvia	0.541	0.469	0.072	0.002	0.427	0.537
Lithuania	0.699	0.615	0.084	0.004	0.560	0.692
Malta	1.000	0.803	0.197	0.021	0.753	0.993
Poland	1.000	0.860	0.140	0.010	0.789	0.991
Portugal	0.577	0.512	0.065	0.002	0.471	0.572
Romania	1.000	0.720	0.280	0.068	0.677	0.992
Slovakia	1.000	0.829	0.171	0.011	0.783	0.992
Slovenia	1.000	0.834	0.166	0.016	0.749	0.993
Spain	0.875	0.776	0.099	0.004	0.716	0.870
Turkey	1.000	0.746	0.254	0.061	0.681	0.994
average	0.878	0.713	0.165	0.024	0.658	0.871
std deviation	0.180	0.125	0.079	0.026	0.118	0.178
min	0.532	0.469	0.061	0.001	0.427	0.528
max	1.000	0.860	0.280	0.068	0.789	0.994

Table 6 Bootstrapped efficiency results with respect to metafrontier

	Efficiency Score	Bias corrected	Bias	Standard error	LB	UB
Austria	0.791	0.716	0.075	0.003	0.656	0.785
Belgium	0.825	0.741	0.084	0.002	0.701	0.817
Bulgaria	1.000	0.724	0.276	0.063	0.679	0.992
Croatia	0.695	0.616	0.079	0.002	0.580	0.689
Cyprus	1.000	0.734	0.266	0.061	0.675	0.993
Czech Republic	1.000	0.848	0.152	0.010	0.785	0.992
Denmark	0.627	0.547	0.081	0.004	0.497	0.622
Estonia	0.532	0.469	0.063	0.002	0.436	0.527
Finland	1.000	0.757	0.243	0.038	0.712	0.993
France	0.857	0.789	0.068	0.001	0.748	0.849
Germany	1.000	0.789	0.211	0.022	0.744	0.993
Greece	0.720	0.625	0.095	0.005	0.566	0.715
Hungary	1.000	0.831	0.169	0.010	0.789	0.991
Iceland	0.534	0.486	0.048	0.001	0.447	0.530
Ireland	0.786	0.705	0.081	0.002	0.659	0.779
Italy	0.976	0.876	0.100	0.003	0.827	0.968
Latvia	0.532	0.476	0.056	0.001	0.448	0.528
Lithuania	0.697	0.613	0.085	0.004	0.554	0.692
Luxembourg	1.000	0.729	0.271	0.055	0.687	0.991
Malta	1.000	0.802	0.198	0.017	0.764	0.993
Netherlands	1.000	0.877	0.123	0.006	0.817	0.993
Norway	0.687	0.616	0.072	0.003	0.566	0.683
Poland	1.000	0.858	0.142	0.010	0.779	0.993
Portugal	0.577	0.509	0.068	0.002	0.472	0.572
Romania	1.000	0.727	0.273	0.061	0.680	0.990
Slovakia	1.000	0.823	0.177	0.012	0.780	0.991
Slovenia	0.844	0.756	0.088	0.002	0.708	0.837
Spain	0.805	0.719	0.086	0.003	0.671	0.798
Sweden	0.926	0.819	0.107	0.005	0.755	0.919
Switzerland	1.000	0.753	0.247	0.040	0.708	0.990
Turkey	1.000	0.724	0.276	0.063	0.678	0.992
United Kingdom	0.804	0.729	0.075	0.002	0.689	0.799
average	0.851	0.712	0.139	0.016	0.664	0.844
std deviation	0.167	0.118	0.079	0.022	0.113	0.166
min	0.532	0.469	0.048	0.001	0.436	0.527
max	1.000	0.877	0.276	0.063	0.827	0.993

Table 7 Comparison of efficiency scores distributions between the groups for each grouping criterion

	Average efficiency	Null Hypothesis (Ho)	Value of Criterion	p-value	Decision with respect to Ho
Criterion 1					
North (N)	0.886	N=S	-0.428	0.669	accepted
South (S)	0.876				
Criterion 2					
Developed (Dd)	0.935	Dd= Dg	3.430	0.001	not accepted
Developing (Dg)	0.892				
Criterion 3					
North & Developed (NDd)	0.960	NDd= SDg	4.202	0.000	not accepted
South & Developing (SDg)	0.878				

Notes: The null hypothesis that the two groups come from the same population (i.e. they have the same distributions) is tested using the Wilcoxon rank sum (Mann Whitney) test.

Table 8 Correction of bootstrapped MR scores for noise

	Criterion 1-North vs South			Criterion 2-Developed vs Developing			Criterion 3-Mixed		
	MR	Correction factor[1]	MR*[2]	MR	Correction factor	MR*	MR	Correction factor	MR*
Austria	0.963	0.600	0.578	0.887	0.320	0.284	0.844	0.240	0.203
Belgium	0.978	0.750	0.734	0.860	17.550	15.091	0.805	6.550	5.272
Bulgaria	0.895	0.467	0.418	0.940	0.868	0.816	0.980	0.920	0.902
Croatia	0.921	1.105	1.018	0.991	1.263	1.252	0.996	1.105	1.100
Cyprus	0.906	0.498	0.452	0.963	0.934	0.900	1.002	1.023	1.025
Czech Republic	0.968	1.237	1.198	0.989	0.907	0.897	1.001	1.031	1.032
Denmark	0.941	0.657	0.618	0.862	0.171	0.148	0.839	0.057	0.048
Estonia	0.934	1.067	0.996	0.980	0.867	0.850	0.994	0.933	0.928
Finland	0.951	1.077	1.024	0.876	0.979	0.858	0.821	0.369	0.303
France	0.972	24.083	23.404	0.831	0.750	0.623	1.061	45.833	48.619
Germany	0.953	0.981	0.935	0.883	0.745	0.658	0.847	0.431	0.365
Greece	0.924	0.867	0.801	0.738	2.844	2.099	0.963	1.844	1.777
Hungary	0.968	1.000	0.968	0.978	0.939	0.919	0.992	1.040	1.032
Iceland	0.907	0.900	0.816	0.879	0.400	0.351	0.512	1.600	0.819
Ireland	0.887	1.696	1.504	0.789	1.217	0.960	0.769	6.217	4.781
Italy	1.079	10.704	11.544	1.007	12.519	12.603	1.189	22.074	26.236
Latvia	0.540	1.889	1.020	0.696	4.222	2.939	1.014	2.667	2.705
Lithuania	0.768	11.513	8.841	0.972	0.692	0.673	0.996	0.949	0.945
Luxembourg	0.920	0.852	0.784	0.840	0.626	0.526	0.793	0.245	0.195
Malta	0.966	1.145	1.107	1.043	2.745	2.864	0.999	1.255	1.253
Netherlands	1.002	1.226	1.228	0.944	0.468	0.442	0.952	2.177	2.072
Norway	0.949	0.808	0.767	0.704	12.577	8.855	0.669	5.346	3.579
Poland	1.094	5.041	5.514	0.981	0.735	0.721	0.997	0.980	0.977
Portugal	0.983	1.200	1.180	0.987	1.150	1.135	0.995	1.000	0.995
Romania	0.898	0.515	0.462	0.955	0.942	0.900	1.010	1.124	1.135
Slovakia	1.036	3.782	3.919	0.971	0.840	0.816	0.993	0.924	0.917
Slovenia	0.891	4.625	4.121	0.984	23.458	23.074	0.906	6.625	6.002
Spain	0.911	1.231	1.121	0.823	12.654	10.417	0.928	1.577	1.463
Sweden	0.967	0.609	0.589	0.932	0.283	0.263	0.916	0.130	0.119
Switzerland	0.942	0.929	0.876	0.856	0.609	0.521	0.819	0.354	0.290
Turkey	0.895	0.487	0.436	0.943	0.869	0.820	0.971	0.964	0.935
United Kingdom	0.906	0.765	0.693	0.755	0.235	0.178	0.766	0.824	0.631
average	0.932	2.635	2.490	0.901	3.324	2.952	0.917	3.700	3.708
std deviation	0.093	4.726	4.560	0.093	5.760	5.272	0.129	8.686	9.407
min	0.540	0.467	0.418	0.696	0.171	0.148	0.512	0.057	0.048
max	1.094	24.083	23.404	1.043	23.458	23.074	1.189	45.833	48.619
>1	4	16	15	2	11	10	6	17	16

Notes: [1] Correction factor has been computed as the ratio of the st. error estimate from the bootstrapped process with respect to frontier to the st. error estimate with respect to metafrontier, i.e. σ_f / σ_{mf}

[2] MR* has been computed as the product of the bootstrapped MR score and the correction factor

Table 9 Ranking of European innovation systems based on MR and MR* scores

	Criterion 1-North vs South				Criterion 2-Developed vs Developing				Criterion 3-Mixed			
	MR	**Rank1**	**MR***	**Rank1***	**MR**	**Rank2**	**MR***	**Rank2***	**MR**	**Rank3**	**MR***	**Rank3***
Austria	0.963	12	0.578	28	0.887	18	0.284	29	0.844	23	0.203	29
Belgium	0.978	6	0.734	24	0.860	23	15.091	2	0.805	27	5.272	4
Bulgaria	0.895	28	0.418	32	0.940	16	0.816	20	0.980	15	0.902	23
Croatia	0.921	20	1.018	15	0.991	3	1.252	9	0.996	10	1.100	13
Cyprus	0.906	25	0.452	30	0.963	12	0.900	14	1.002	5	1.025	16
Czech Republic	0.968	8	1.198	9	0.989	4	0.897	15	1.001	6	1.032	14
Denmark	0.941	17	0.618	26	0.862	22	0.148	32	0.839	24	0.048	32
Estonia	0.934	18	0.996	16	0.980	8	0.850	17	0.994	12	0.928	21
Finland	0.951	14	1.024	13	0.876	21	0.858	16	0.821	25	0.303	27
France	0.972	7	23.404	1	0.831	26	0.623	24	1.061	2	48.619	1
Germany	0.953	13	0.935	18	0.883	19	0.658	23	0.847	22	0.365	26
Greece	0.924	19	0.801	21	0.738	30	2.099	8	0.963	17	1.777	9
Hungary	0.968	9	0.968	17	0.978	9	0.919	12	0.992	14	1.032	15
Iceland	0.907	23	0.816	20	0.879	20	0.351	28	0.512	32	0.819	24
Ireland	0.887	30	1.504	7	0.789	28	0.960	11	0.769	29	4.781	5
Italy	1.079	2	11.544	2	1.007	2	12.603	3	1.189	1	26.236	2
Latvia	0.540	32	1.020	14	0.696	32	2.939	6	1.014	3	2.705	7
Lithuania	0.768	31	8.841	3	0.972	10	0.673	22	0.996	9	0.945	19
Luxembourg	0.920	21	0.784	22	0.840	25	0.526	25	0.793	28	0.195	30
Malta	0.966	11	1.107	12	1.043	1	2.864	7	0.999	7	1.253	11
Netherlands	1.002	4	1.228	8	0.944	14	0.442	27	0.952	18	2.072	8
Norway	0.949	15	0.767	23	0.704	31	8.855	5	0.669	31	3.579	6
Poland	1.094	1	5.514	4	0.981	7	0.721	21	0.997	8	0.977	18
Portugal	0.983	5	1.180	10	0.987	5	1.135	10	0.995	11	0.995	17
Romania	0.898	26	0.462	29	0.955	13	0.900	13	1.010	4	1.135	12
Slovakia	1.036	3	3.919	6	0.971	11	0.816	19	0.993	13	0.917	22
Slovenia	0.891	29	4.121	5	0.984	6	23.074	1	0.906	21	6.002	3
Spain	0.911	22	1.121	11	0.823	27	10.417	4	0.928	19	1.463	10
Sweden	0.967	10	0.589	27	0.932	17	0.263	30	0.916	20	0.119	31
Switzerland	0.942	16	0.876	19	0.856	24	0.521	26	0.819	26	0.290	28
Turkey	0.895	27	0.436	31	0.943	15	0.820	18	0.971	16	0.935	20
United Kingdom	0.906	24	0.693	25	0.755	29	0.178	31	0.766	30	0.631	25

Table 10 Comparison of ranks based on MR and MR* scores across the grouping criterions

Null Hypothesis (Ho)	Value of Criterion	p-value	Decision with respect to Ho
Rank1=Rank2=Rank3	2.163	0.339	accepted
Rank*1=Rank*2=Rank*3	1.488	0.475	accepted

Notes: The null hypotheses that the mean ranks based on MR and MR* scores do not differ across the three grouping criterions are tested using the Friedman nonparametric test

Table 11. Regression results

Variable	Estimated Parameter	Standard Error	*t*-value	Pr(>|*t*|)
EURO	1.683	0.358	4.706	0.000
BUSINV	-0.047	0.015	-3.099	0.005
GOVTRD	-1.136	0.304	-3.734	0.001
POPEDU	0.112	0.036	3.091	0.005
GCI	2.359	5.524	0.427	0.674
GCI^2	-0.528	0.559	-0.945	0.355
Constant	0.173	13.497	0.013	0.990
Number of Obs	29			
R^2	0.671			
Adjusted R^2	0.581			