8. PERFORMANCE MEASUREMENT IN PUBLIC SPENDING: EVIDENCE FROM A NON-PARAMETRIC APPROACH

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Abstract

This paper employs the data envelopment analysis (DEA) method to evaluate the performance of public spending and to show how productivity has changed over time for 18 selected OECD countries during 1995 to 2002. Our analysis shows that 14 countries exhibit variable returns to scale, meaning that they could reduce technical inefficiency through internal scale economies. The patterns of changes in efficiency for the countries are further analyzed using the Malmquist productivity index approach. The result shows that total factor productivity is higher in the first sub-period, 1995-1999, which could be attributed to the increased competition and internationalization of the banking system, which took place in this sub-period due to the accelerated liberalization and deregulation of the financial system. Finally, the Tobit model results of the random effects show that population density, energy production, and corruption have negative effects on efficiency scores, while energy use and creditor have positive effects on them.

Keywords: public spending, data envelopment analysis, efficiency, productivity, OECD countries
JEL Classification: H50, E62, C14

1. Introduction

The relationship between public spending and economic growth has been a popular issue in economic development, yet a consensus has been lacking regarding the performance of public spending, as well as its productivity. This paper employs the data envelopment analysis (DEA) method to evaluate the performance of public spending among 18 selected Organization for Economic Co-operation and Development (OECD) countries. First developed by Charnes *et al*. (1978), the DEA

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model evaluates the relative efficiency of several best-practice decision making units (DMUs), considered as coherent and complete groups that permit a quantity of outputs to be produced using a vector of inputs. Using the data of these vectors, the DEA constructs an "efficiency frontier", which then serves as a base from which to calculate the relative effectiveness of the selected organizational units. In other words, DEA is a linear programming technique that enables management to benchmark the DMU. The DEA method allows us to develop a neutral evaluation, unbiased a priori by any type of criteria, of the proportions in which the goal of productive spending is pursued, for any expenditures classified by function.

The main purpose of this paper is that by using a two-stage procedure to apply programming techniques to a country-level panel data for 18 OECD countries among 1995-2002. In the first stage, DEA is used to compute efficiency and we use the shares obtained by DEA models to calculate the Malmquist productivity index.[3] Next, a panel Tobit regression is used to analyze the external factors or operating environments which might explain the variation in efficiencies. Performance measures encourage government service providers to improve their efficiency and effectiveness, because this information makes them more accountable to parliament. They also promote yardstick competition in the provision of government services that face little competition (Carrington *et al*., 1997).

There is an abundant amount of studies to date measuring the productive efficiency of diverse types of DMUs,[4] but few papers analyze the functional disaggregation of consolidated government expenditure (COFOG, Classification of the Functions of the Government) efficiency using cross-country data. Ventelou and Bry (2006) provide an entire review of recent studies covering the task which is to reveal exactly what proportion of public spending is used for "productive" purposes and what proportion is used for other purposes. This new breakdown simply consists in supposing that inefficiency is not "pure inefficiency" associated with wasted resources, but rather it results from seeking another "output" that had been overlooked at the time of the evaluation.[5] Early papers show that there is a strong possibility that public spending is

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[3] *The advantages of the Malmquist productivity index are that it does not make assumptions about the optimizing behavior of the producers and it allows for inefficiency (Fare* et al*., 1994). Furthermore, the Malmquist index does not rely on econometric estimation, but instead it uses a non-parametric approach similar to that used by DEA.*

[4] *DEA is a popular tool to analyze efficiency in many fields, such as banking (Blass and Grossman, 2001; Hauner, 2005); financial services (Fiordelisi and Molyneux, 2004); hospitals (Cellini* et al*., 2000; Dervaux* et al*., 2004); agriculture (Schimmelpfennig, D. and Thirtle, C., 1999; Latruffe* et al*., 2004); regional development (Leonida* et al*., 2004; Price and Weyman Jones, 1996); and school performance evaluation (Coates and Lamdin, 2002).*

[5] *Drake and Simper (2005) presents a critique of the performance radar technique proposed by Home Office in the United Kingdom as a new public policy objective to assess police force performance. Afonso and Fernandes (2006) analysis the public expenditure efficiency of Portuguese municipal governments by interpreting public sector activities as production processes that transform inputs such as labour and capital into outputs/outcomes. DEA is used to compute input and output Farrell efficiency measures (efficiency scores) for 51 Portuguese municipalities located in the region of Lisbon and Vale do Tejo (RLVT) for 2001. This paper contributes to the literature by providing new evidence concerning the efficiency analysis of local government.*

efficient, such as Ardagna and Silvia (2004). Their paper shows that stabilizations implemented by cutting public spending could lead to higher gross domestic product (GDP) growth rates. However, we also call attention to studies conducted by Aschauer (1988, 1989), Lynde (1992), or Devarajan *et al*. (1996) that are like Ventelou and Bry (2006), in which public spending is considered as an input of the macroeconomic production function. For *y*, the real GDP per unit of labor, we have $y = f(k, g)$ with *k*, the private capital stock by unit of labor input, and g, a "productive public spending per capita".[6]

The large number of studies in this area starts from an investigation of public spending (g) which has an infrastructural objective (such as "public capital") and speculates that this part of the public spending quests, entirely and simply, the objective of production (or economic growth).[7] As can be seen in Ventelou and Bry (2006), the only study to break from this hypothesis (see Bleaney *et al*., 2001) does so by using a rather subjective *ad hoc* classification made along with the different public expenditures classified by function (such as defense, education, health care spending, etc.). Hansson and Henrekson (1994) apply a production function approach to examine the effect of different kinds of government expenditure on productivity growth in the private sector for 14 OECD countries and 14 industries during the period 1970-87. Afonso and Aubyn (2005) apply DEA and FDH (Free Disposable Hull) analysis to evaluate efficiency in health and education expenditures. The results strongly suggest that efficiency in spending in these two economic sectors, where public provision is usually very important, is not an issue to be neglected.[8]

The subject of this paper lies within the limits of research initiated by econometric studies on the relationship between public spending. Interestingly, we focus not only on the overall public spending, but now on its composition. Moreover, we use the OCDE (2005) nomenclature, which is called the classification of the function of government (COFOG), to measure the performance of public spending in OECD countries with DEA. In contrast to Ventelou and Bry (2006), this paper first reconsiders public spending data categorized by functions for a maximum number of OECD countries, as well as data concerning their GDP growth rates per capita. Second, we regroup public spending in our analysis into eight representative items, which is more precise than Ventelou and Bry (2006). In their paper, they rearrange public spending into five representative items due to data limitation. Third, our study period is over 8 years, from 1995 to 2002. There are two reasons for this choice. One is that the period chosen allows us to study the majority of the countries in our chosen sample. The

[6] *The non-parametric DEA approach does not depend on adopting a specific functional form, and does not make distributional assumption, at the cost of ignoring noise. Thus, this paper would not pay attention on the causality of public spending and economic growth etc. (Tsionas* et al*., 2003).*

[7] *Hondroyiannis and Papapetrou (1996) indicate that Greece is a country where the government spending to GDP is extremely high creating significant inefficiencies in the operation of the Greek economy. Besides, Garcia-Milà and McGuire (2001) investigate the effectiveness of the grants by comparing the economic performance of the regions before and after the implementation of the grant programs using a differences-in-differences approach.*

[8] They find that DEA is more stringent and efficient under FDH.

other reason considers financial development, especially after financial crises, which is neglected in Ventelou and Bry (2006).

In addition to analyzing productivity performance in multiple time periods, we also use the shares obtained by DEA models to calculate the Malmquist productivity index. The Malmquist productivity index is a well-known index for measuring productivity growth between two periods, and it was introduced by Caves *et al*. (1982). Färe *et al*. (1994) use the DEA for measuring the Malmquist productivity index. This index is a suitable tool for measuring productivity changes, because it has the ability to separate the efficiency from changes in technology and scale changes. However, Ventelou and Bry (2006) do not focus on this framework. Hence, the main contribution of our study is also to concentrate on the measures of productivity change.

This paper presents the technical efficiency measures for the entire period 1995-2002 and for the sub-periods 1995-1999 and 2000-2002, which illustrate how closely an operating unit functions in relation to the production frontier. Higher efficiency from one period to another does not necessarily suggest that the operating unit achieves higher productivity since technology may have changed. As can be seen in Maddala (1987), there are very few applications of the Tobit model of random effects with panel data, especially in this framework. We will first address this model to demonstrate the effects of exogenous environmental variables toward efficiency scores.

The main purpose and contribution of this paper are as follows. In the beginning, we evaluate the efficiency scores of the DEA estimation under constant returns to scale and separate its decomposition into variable returns to scale and scale efficiency. The analysis is applied to the evaluation of productivity performance in public spending in 18 OECD countries. Secondly, we use a decomposition of the Malmquist productivity index to locate the sources of productivity growth. The Malmquist productivity index is decomposed in two components, namely, technical change – *shift of the production frontier* – and efficiency change – *shift toward the best practice frontier*. Finally, we regress the efficiency scores on a set of environmental variables, including country specific factors, such as population and population density; trade specific factors and financial specific factors, such as creditor and corruption.

The paper is organized as follows: In Section 2 we provide the empirical method. Section 3 describes the dataset. Section 4 reports empirical results and an estimation of the impacts of the environment variables on DMU efficiency. Finally, Section 5 concludes and offers policy implications.

2. Methodology

2.1. Data Envelopment Analysis

Following Farrell (1957), Charnes *et al*. (1978) first introduce the term DEA to describe a mathematical programming approach to the construction of production frontiers and the efficiency measurement of the constructed frontiers. The latter authors propose a model that has an input orientation and assumes constant returns to scale (CSR). This model is known as the CCR model in the literature. Later studies consider alternative sets of assumptions. Banker *et al*. (1984) first introduce the assumption of variable returns to scale (VRS). This model is known in the literature as BCC model.

Since the models are well established and extensively applied in the literature, this paper limits any discussion. The general-purpose DEA developed by Charnes *et al.* (1978) considers *n* DMUs ($j = 1, \cdots, n$) using *q* inputs to secure *m* outputs. Let us denote x_{ij}, y_{ij} to be the observed level of the *q*th input and *m*th output, respectively, at DMU *j*. An efficient score for the *n*th DMU can be obtained by maximizing the ratio of total weighted output over total weighted input for all DMU subject to the constraint that all such ratios of the other DMUs in the sample are less than or equal to one. Mathematically, this can be written as:

$$\begin{aligned} & \max_{u,v} \quad \frac{uy_i}{vx_i} \\ & s.t. \quad \frac{uy_j}{vx_j} - 1 \leq 0 \end{aligned} \tag{1}$$

Here, *u* are the output weights and *v* are the input weights.

The system of equations in (1) is a fractional programming model of computing technical efficiency and can be solved with non-linear programming techniques. To simplify the computation, a transformation of the fractional programming model allows the system of equations in (1) to be formulated as a linear programming problem. For the CCR model with constant return-to-scale and strong disposability, the following linear programming is solved to ascertain whether DMU i is DEA-efficient.

$$\begin{aligned} & \min_{z,\lambda} \lambda_i \\ & s.t. \quad \sum_{i=1}^{n} x_{ij} z_i - \lambda_i x_{ij} \leq 0 \\ & \qquad \sum_{i=1}^{n} y_{ij} z_i - \lambda_i y_{ij} \geq 0 \\ & \qquad z_i \geq 0, \lambda_i \quad free \end{aligned} \tag{2}$$

For the BCC model with variable return-to-scale and strong input disposability, the following linear programming is solved to ascertain whether DUM i is DEA-efficient.

$$\begin{aligned} & \min_{z,\lambda} \lambda_i \\ & s.t. \quad \sum_{i=1}^{n} x_{ij} z_i - \lambda_i x_{ij} \leq 0 \\ & \qquad \sum_{i=1}^{n} y_{ij} z_i - \lambda_i y_{ij} \geq 0 \\ & \qquad \sum z_i - 1 = 0, \lambda_i \quad free \end{aligned} \tag{3}$$

Here, *λ* is a scalar variable measuring the level of efficiency. The model works as follows. For a given set of feasible *λ* values, the left-hand sides of the input- and output-related constraints specify a production point within the production possibility set. The model seeks a production possibility set point which offers at least the output levels of DMU j_0 while using as low a proportion of its input levels as possible. With the superscript * denoting optimal values, the j_0 DMU is DEA-efficient if, and only if, $\lambda_0^* = 1$. If $\lambda_0^* \leq 1$, then the j_0 DMU is DEA-inefficient, where λ_0^* is a measurement of the radial DEA efficiency of DMU j_0.

The model assesses efficiency in a production context and its counterpart assesses efficiency in a value context. By virtue of duality, the primal and dual models yield the same efficiency ratings in respect of DMU j_0 (see Charnes *et al*., 1978 for details).

2.2. The Malmquist Productivity Index

An extension of the DEA model is the Malmquist productivity index which disentangles the total productivity change into technical efficiency change and technological efficiency change (Malmquist, 1953). Exploiting the time-series dimension of the data allows an estimation of technical progress (the movement of the frontier) and changes in efficiency over time (the distance of the inefficient DMUs from the best practice frontier). Radial efficiency measures (Farrell, 1957) of these two changes are sufficient to construct a Malmquist productivity index, since the latter is defined in terms of distance functions that are the reciprocals of the Farrell radial efficiency measures. We begin with the efficiency measures, which are straightforward.

Farrell (1957) introduces the non-parametric, deterministic efficiency frontier - expressed in terms of minimizing the input requirements vectors, *x*, per unit of output, *y*. Since the Malmquist productivity index is defined in terms of Shepard's (1953) distance function, let the distance function, $D^t(y^t, x^t)$, define the contraction of x^t that would take any inefficient observation, for any DMU i, to a position on the frontier. The Farrell efficiency measure, $F^t(y^t, x^t)$, is simply the inverse of the distance function. Thus, the efficiency problem is defined as:

$$F^t(y_i^t, x_i^t) = [D^t(y_i^t, x_i^t)]^{-1} = \min \lambda_i^t : \lambda_i^t x_i^t \in L^t(y^t), \quad (4)$$

where the minimized parameter, *λ*, determines the factor by which the observed input combination can be reduced, $L^t(y^t)$ is the output set for time period *t*.

The efficiency measure takes a value of one for the firms on the frontier and is between zero and one for those off the frontier.

These values are all relative to the efficiency frontier (the best-practice DMUs may be improving or regressing) and include both technical and scale efficiency. We now follow Forsund (1991) and Färe *et al*. (1994) by decomposing the measure of total efficiency into pure technical efficiency, $T(y, x)$, and scale efficiency, $S(y, x)$, in the following way:

$$D^t(y_i^t, x_i^t)^{-1} = F^t(y_i^t, x_i^t) = T^t(y_i^t, x_i^t) S^t(y_i^t, x_i^t) \quad (5)$$

The left-hand terms are determined above, where $T^t(y_i^t, x_i^t)$ is calculated as a programming problem in which constant returns to scale (CRS) are not imposed, so that technical efficiency is measured independently of scale effects. This has the effect of enveloping the data more closely, allowing variable returns to scale to be exhibited.

Coelli *et al*. (1997) report several ways in which environmental variables can be accommodated in a DEA analysis. The term “environmental variables” is usually used to describe factors which could influence the efficiency of DMUs. Consequently, the random effects Tobit models examine the relationship between each efficiency measure, and government and environment specific characteristics in this study.

3. Data

The sample used herein comprises 18 selected OECD countries over the period 1995-2002. The OECD countries are chosen because data for these countries have been collected following the same criteria and provided by the OECD itself. Moreover, this sample is not too heterogeneous in development conditions, so that an efficiency comparison across countries is meaningful (Afonso and Aubyn, 2005). The left-hand side of Table 1 lists the name of countries. Compared with Ventelou and Bry (2006), we add six countries such as Belgium, Ireland, Italy, South Korea, Luxembourg, and Portugal due to balanced data. For the calculation of efficiency and productivity, the study includes one output (growth rate of real per capital GDP) and eight inputs (real government spending per capita by function: general public services, defense and public safety, economic affairs, environmental protection, health, education, social protection, and miscellaneous expenditures). For the input, we follow Ventelou and Bry (2006) in order to work on a precise breakdown of public spending by function. We use the OCDE (2005) nomenclature (COFOG) to break down spending into eleven items and regroup them into eight representative items. Annual data for the growth rate of real per capital GDP are obtained from the *World Development Indicators* as published by the World Bank (2005, WDI). The units of all real variables are expressed in US dollars and are deflated with the consumer price index. We choose 1995 as the observation base year.

In addition, the model is used to measure the longest times series covering the period between 1972 and 1995. However, for some selected countries the observations of the first ten years as well as the last few years are missing, which prompted the truncation of the time period in the analysis to 1975-1993. Moreover, eight previously used countries (Belgium, Greece, Ireland, Italy, Japan, Norway, Portugal and the United Kingdom) had to be dropped, because the data were missing for some years and the functional disaggregation of consolidated government expenditure.

4. Empirical Results

4.1. The Simple Efficiency

Table 1 summarizes the results of the efficiency scores of the DEA estimation under constant returns to scale (CRS) and its decomposition into variable returns to scale (VRS) and scale efficiency (SCALE). As can be seen, under the assumption of CRSTE, the DEA efficiency scores show that only one country, Luxembourg, out of the eighteen OECD countries, is totally efficient, while the lowest efficiency score corresponds to Japan and South Korea over the 8-year study period. With reference to the Luxembourg result, there may be a slight possibility that a smaller population will more easily result in better performance, whereas the results of Japan and South Korea may have been affected by lower expenditures in economic affairs and higher expenditures in health. In addition, fourteen countries exhibit VRS, meaning that they could reduce technical inefficiency through internal scale economies, and although Denmark, Japan, South Korea, Norway, and Sweden end up on average with scores of less than 10% in 2002, the remainder exhibit efficiency scores of more than 50%. Such inefficiency is reflected by an operative scale problem illustrated by the scale efficiency parameter that by 2002 these fourteen countries have scales below 27%. Those are countries that offer more expenditure in different functions.

It is of interest to investigate whether DMUs maintain their relative positions on the frontier from one year to the other. Some useful insight may be gained by examining the overall distribution that is also shown in Table 1. There are fluctuations among individual DMUs with respect to efficiency scores from one year to other. In terms of the number of frontier units maintaining their relative positions, only four countries appear on the frontier when all years of observation are considered. This fact demonstrates the rate of fluctuation in performance of 18 selected OECD countries. In general, we may conclude that there is a higher variability in the ability of those countries to meet their targets as the efficiency scores range from 0.4% (least efficient) to 1 (best practice country) across all years of observation. Furthermore, the mean efficiency scores have fallen after 2000, indicating that countries are experiencing difficulties in meeting their gargets. Nonetheless, these results should be of considerable interest to the public sectors of 18 OECD countries and may be useful when setting targets again.

In addition, we can see that the results of Table 1 and Table A1 of Appendix almost coincide, which indicates that the two measures of DEA scores ranking very close results. Luxembourg is still has the highest scores in CRS model between 10 countries, but Korea is the lowest one. This agrees with our earlier findings from the analysis of Table 1. However, under the assumption of VRS, DEA scores in Table A1 shows that two out of the ten countries are totally efficient. The highest efficiency score corresponds to Luxembourg and Germany for 19 years, but France has the lowest score on average under 1975-1993. It means France could increase government expenditure in different classification of the functions to reduce technical inefficiency.

4.2. Productivity Change

A DEA study in general considers performance analysis at a given point of time. However, extensions to the DEA procedures, such as the Malmquist productive index approach, have been reported to provide performance analysis over a period of time. We now begin by looking at the total factor productivity (hereafter, TFP) of the observed inputs and outputs used in 18 OECD countries over the period 1995/96 to 2001/02. Table 2 presents the Malmquist productivity index, i.e., total factor productivity change (TFPCH), and its components - efficiency change (EFFCH), technical change (TECHCH), pure efficiency change (PECH), and scale efficiency change (SECH) - for the period 1995-2002.[9] If the value of the Malmquist productivity index or any of its components is lower (higher) than one, then it denotes a deterioration (improvement) in performance. The results indicate that total factor productivity (TFPCH) increases at an average rate of 2.12% per year over the entire 1995-2002 period. On average, this improvement is ascribed to a technical progress (TECHC) of 3.02%. It in turn is attributed to a scale efficiency improvement (SECH) of 0.95%.

Comparing the two sub-periods, 1995-1999 and 2000-2002, the first sub-period has a higher TFP than the second one. The finding that TFP, on average, is higher in the first sub-period could be attributed to the increased competition and internationalization of the banking system, which took place in the first sub-period due to the accelerated liberalization and deregulation of the financial system. Hondroyiannis *et al*. (1999) provide evidence of increased competition in the banking sector during the first sub-period. However, we compare the TFP based on the two study period, 1975-1993 and 1995-2002. Table A2 shows the evolution of average TFP in 1975-1993 is less than it in 1995-2002. Examining columns 3 to 5 of Table 2 and Table A2, we can also see that TECHCH has generated a significant divergence by means of its effect on TFP. For this reason, using Malmquist productivity index in our study, Table 2 and Table A2 show the growth rate of TFP and its breakdown into technical change and changes in efficiency of the selected OECD countries considering, as well as classification of the functions of the government, given its importance as an important productive factor.

Important differences are observed by countries. As can be seen in Table 3, about 67% of the OECD countries show total productivity progress. The top three countries are Greece, Portugal, and South Korea in the rank order of total factor productivity. In the case of Greece, the gains of productivity are due both to gains in efficiency and technical progress, and thus productivity grew above the OECD average in the period. Also outstanding is the behavior of Portugal and South Korea, which during the periods experienced important gains in productivity. United Kingdom, Japan, and Sweden, on the contrary, experienced losses in all the periods considered. By Table A3, important close results are again observed. Luxembourg still has the highest productivity progress, but Sweden is the lowest one during 1975-1995.

4.3. The Random Effect Tobit Model

Coelli *et al*. (1997) discuss several ways in which environmental variables can be accommodated in a DEA analysis. The term "environmental variables" is usually used to describe factors which could influence the efficiency of a DMU. In this study, such factors are not traditional inputs and are assumed to be outside the control of the authorities. The two-stage method used in this paper involves the solution of a DEA problem in a first-stage analysis which comprises only the traditional outputs and inputs. In the second stage, the efficiency scores obtained from the first stage are regressed on the environmental variables.

Although there are alternative approaches to dealing with environmental variables, in most cases Coelli *et al*. (1997) recommend the use of the two-stage approach,

[9] *Efficiency change and technical change could also be represented catch-up effect and frontier shift effect respectively (Coelli and Rao, 2005).*

because of its numerous advantages. The main advantages of the two-stage approach are that it can accommodate more than one variable; it can accommodate both continuous and categorical variables; it makes no prior assumption regarding the direction of the effect of the categorical variable; hypothesis tests can be performed to test if the variables have any significant effect on efficiency; and the method is simple and easy to calculate.

In order to evaluate the effect of exogenous variables, we now address some important controlled variables. Altinay and Karagol (2004) demonstrate the inter-relationship between energy consumption and GDP of Turkey. Lee (2005) indicates that long-run and short-run causalities run from energy use to GDP, but not vice versa. Thus, two energy specific variables, energy production and energy use, are taken into account. La Porta *et al*. (1997) also show that countries which protect shareholders have more valuable stock markets and a larger number of listed securities per capita than do countries without such protection. Beck *et al*. (2000) show that countries with better creditor rights tend to have more highly developed financial intermediaries. On these premises, they claim that growth prospects are enhanced, because a sound legal environment encourages the development of financial intermediation. Besides, it has sometimes been argued that corruption may promote efficiency by enabling private agents to circumvent governmental procedures or regulations that hinder economic activity, acting to "grease the wheels" of the economy. The study by Salinas-Jiménez and Salinas-Jiménez (2007) points out whether corruption affects the economic results of OECD countries from a productivity-based perspective.[10] Goel and Nelson (1998) also examine the effect of government size on corruption by public officials by including both demand and supply side incentives for engaging in corrupt practices. Most research on the relationship between corruption and economic activity has centered on how corruption affects investment or production growth while the impact of this variable on efficiency has received less attention.

This study thus considers the effects of population, population density, energy production, energy use, creditor protection, and corruption level.[11] We also add one dummy variable into our study, which represents an energy exporter or importer. The rationale behind this is to determine whether the efficiency scores are affected by trade characteristic.

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[10] *As Kaufmann (2004) works, differences in terms of corruption appear mainly between certain regions, noting by way of example that differences in the levels of corruption between the Nordic countries and the countries of southern Europe are greater than between this latter group and the average of the emerging economies. Aidt* et al*. (2008) use a threshold model to estimate the impact of corruption on growth where corruption is treated as an endogenous variable. They find two governance regimes, conditional on the quality of political institutions. In the regime with high quality political institutions, corruption has a substantial negative impact on growth. In the regime with low quality institutions, corruption has no impact on growth.*

[11] *Both variables, CREDITOR and CORRUPTION, are also taken by La Porta* et al*. (1997, 1998). Olson* et al*. (2000) also calculate total factor productivity (TFP) growth in a residual form and then analyze which variables explain its variation across countries, with results that support the influence of different measures of institutional quality, one of which is corruption.*

The efficiency scores, i.e. TE, are regressed on the government and environment specific factors using a random effects Tobit model, since levels of efficiency vary from zero to one.[12] Consequently, the random effects Tobit model for examining the relationship between each efficiency measure, and government and environment specific characteristics in this paper can be constructed as follows:

$$TE_{it} = f(POP_{it}, POPDEN_{it}, EPRO_{it}, EUSE_{it}, EXPORT_{it}, CREDITOR_{it}, CORRUPTION_{it}) \quad (6)$$

Here, $i = 1, \cdots, 17$ members of the panel, except for Luxembourg due to data shortage, and $t = 1995, \cdots, 2002$, TE_{it} represents the efficiency scores, POP_{it} is the population for the *i*-th country in the *t*-th period, $POPDEN_{it}$ is population density, $EPRO_{it}$ is energy production, $EUSE_{it}$ is energy use, $EXPORT_{it}$ is a country specific dummy variable, which takes the value of zero for import energy and the value of one for export energy, $CREDITOR_{it}$ is the creditor protection index which ranges from 0 to 4 with lower scores representing lower creditor protection, and $CORRUPTION_{it}$ is an index, ranging from 1 to 10 with a higher number denoting less corruption. All variables are obtained from WDI (2005), except for the two variables of $CREDITOR$ and $CORRUPTION$ which are obtained from La Porta *et al*. (1998).

Table 4 displays the results. The first column depicts the efficiency scores' OLS regression pooled equations. The second column reports the random effects Tobit model for the efficiency scores. Maddala (1987) reviews some problems that arise in the analysis of panel data when the dependent variables are truncated, censored, or qualitative. Thus, the results of the first and second columns are quite different. Furthermore, the low values of the R-Squared, i.e. 0.14 for the OLS pooled model, show that the explanatory power of the model is not significant. It predicts that the OLS pooled model does not fit the data. In this case, we focus on the random effects Tobit model. The results show that population and population density have a negative impact on efficiency, where the latter is statistically significant at the 1% significance level - that is, efficiency scores decline as the population density increase. A negative relationship exists between the efficiency scores and energy production at the 1% significance level. In other words, a government putting forth much effort toward energy production cannot lead to an increase in efficiency scores, but the effect of energy use has a positive impact at the 1% significant level. In other words, energy use leads to high growth with higher efficient scores. The effect of corruption is negative on efficiency scores at the 1% significant level, indicating that X-inefficiency exists in the government sector or corruption may affect the efficiency with which an economy performs. Finally, the coefficients of the trade specific dummy and creditor are negative and have a positive effect on efficient scores, respectively, but are not significant.

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[12] *There are very few applications of the Tobit model of random effects with panel data, see Maddala (1987).*

5. Concluding remarks

The aim of this paper is to provide new empirical evidence on the performance of public spending in 18 OECD countries during 1995 to 2002 with DEA. First developed by Charnes *et al*. (1978), the DEA model evaluates the relative efficiency of several “decision making units”, considered as coherent and complete groups that permit a quantity of outputs to be produced using a vector of inputs. Using the data of these vectors, the DEA constructs an “efficiency frontier”, and this then serves as a base from which to calculate the relative effectiveness of the selected organizational units. In other words, DEA is a linear programming technique that enables management to benchmark the DMUs. To the best of our knowledge there is rare study of disaggregated data assessing the performance of public spending by classifying public spending into eight representative items. We herein have developed a neutral evaluation, unbiased a priori by any type of criteria, of the proportions in which the goal of productive spending is pursued, for any expenditures classified by function. This paper first uses the Malmquist productivity index to measure and decompose the total factor productivity growth. Finally, this paper has addressed the random effects Tobit model for examining the relationship between each efficiency measure, and government and environment specific characteristics.

The results can be summarized in three points: (1) for the period under study fourteen countries exhibit VRSTE, meaning that they could reduce technical inefficiency through internal scale economies. (2) TFP, on average, is higher in the first sub-period, 1995-1999, which could be attributed to the increased competition and internationalization of the banking system, which took place in this sub-period due to the accelerated liberalization and deregulation of the financial system. (3) For having robust empirical study, we extend period from 1975 to 1993. This paper could have close results with previous study in this article. (4) The random effects Tobit model results show that population density, energy production, and corruption have negative effects on efficiency score; while, in contrast, energy use and creditor have positive effects on them. Therefore, equilibrium developing in region, management of resource, greater commitment to reduce corruption and enhance good governance practices is essential. Besides, the economic growth rate itself also depends on the level of economic affairs spending. A government may contribute to technical change and scale change through increasing expenditures in economics affairs which seems to benefit agricultural, fishery, forestry, mining, and industrial sectors.

This paper finds that population factors, which affect efficiency scores in the random effects Tobit model, now increase higher efficiency scores from a government’s optimal response through its spending share adjustments in health care. More spending on health care will help cause the death rate to decrease, leading to a greater size in population. It seems that health care spending has not benefited from the efficient scores. Our results also support an alternative view on energy use, which matches with the findings of Masih and Masih (1998) and Lee (2005), whereby high energy use tends to show high economic performance, but energy conservation may harm economic performance.

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Appendix

Table 1

DEA efficiency scores of OECD countries from 1995-2002

DMU	1995			1996			1997			1998		
	CRSTE	VRSTE	SCALE	CRSTE	VRSTE	SCALE	CRSTE	VRSTE	SCALE	CRSTE	VRSTE	SCALE
AUSTRIA	0.061	0.545	0.112	0.061	0.558	0.109	0.063	0.578	0.109	0.065	0.598	0.109
BELGIUM	0.093	0.495	0.189	0.087	0.517	0.168	0.084	0.544	0.155	0.081	0.569	0.142
DENMARK	0.012	0.054	0.218	0.012	0.055	0.211	0.011	0.058	0.191	0.011	0.061	0.188
FINLAND	0.094	0.6	0.157	0.091	0.519	0.175	0.093	0.492	0.190	0.103	0.496	0.208
FRANCE	0.011	0.607	0.019	0.011	0.526	0.022	0.010	0.485	0.021	0.010	0.481	0.021
GERMANY	0.008	0.535	0.015	0.008	0.542	0.015	0.008	0.554	0.014	0.008	0.556	0.014
GREECE	0.184	1	0.184	0.173	1	0.173	0.160	1	0.160	0.148	1	0.148
IRELAND	0.209	0.739	0.282	0.189	0.738	0.256	0.192	0.728	0.263	0.191	0.733	0.260
ITALY	0.012	0.544	0.022	0.011	0.531	0.021	0.011	0.593	0.018	0.010	0.622	0.017
JAPAN	0.000	0.01	0.007	0.000	0.009	0.008	0.000	0.009	0.008	0.000	0.004	0.020
KOREA, SOUTH	0.000	0.006	0.016	0.000	0.005	0.015	0.000	0.005	0.015	0.000	0.005	0.012
LUXEMBOURG	1	1	1	1	1	1	1	1	1	1	1	1
NETHERLANDS	0.036	0.532	0.069	0.043	0.559	0.076	0.035	0.499	0.070	0.033	0.526	0.063
NORWAY	0.017	0.06	0.291	0.019	0.057	0.325	0.019	0.056	0.342	0.020	0.054	0.364
PORTUGAL	0.077	1	0.077	0.065	1	0.065	0.061	1	0.061	0.059	1	0.059
SWEDEN	0.004	0.041	0.108	0.006	0.047	0.119	0.005	0.048	0.112	0.005	0.048	0.109
U.K.	0.018	1	0.018	0.021	1	0.021	0.022	1	0.022	0.025	1	0.025
UNITED STATES	0.004	0.512	0.008	0.004	0.535	0.008	0.004	0.56	0.008	0.004	0.594	0.007

Table 1 (*continued*) **DEA efficiency scores of OECD countries from 1995-2002**

DMU	1999			2000			2001			2002		
	CRSTE	VRSTE	SCALE	CRSTE	VRSTE	SCALE	CRSTE	VRSTE	SCALE	CRSTE	VRSTE	SCALE
AUSTRIA	0.072	0.601	0.119	0.070	0.651	0.107	0.065	0.659	0.099	0.083	0.656	0.127
BELGIUM	0.085	0.584	0.145	0.075	0.665	0.112	0.087	0.69	0.126	0.077	0.622	0.123
DENMARK	0.012	0.064	0.187	0.012	0.068	0.171	0.011	0.071	0.149	0.015	0.073	0.209
FINLAND	0.121	0.535	0.226	0.107	0.556	0.192	0.116	0.584	0.199	0.135	0.591	0.228
FRANCE	0.011	0.505	0.022	0.010	0.514	0.019	0.010	0.512	0.020	0.011	0.506	0.022
GERMANY	0.008	0.561	0.015	0.007	0.745	0.010	0.007	0.642	0.011	0.008	0.67	0.012
GREECE	0.126	1	0.126	0.112	1	0.112	0.109	1	0.109	0.114	1	0.114
IRELAND	0.178	0.728	0.245	0.204	0.756	0.269	0.198	0.772	0.256	0.204	0.765	0.267
ITALY	0.011	0.64	0.016	0.012	0.919	0.013	0.011	0.732	0.015	0.019	0.804	0.024
JAPAN	0.000	0.006	0.014	0.000	0.006	0.013	0.000	0.008	0.011	0.000	0.007	0.015
KOREA, SOUTH	0.000	0.004	0.012	0.000	0.005	0.012	0.000	0.005	0.012	0.000	0.005	0.013
LUXEMBOURG	1	1	1	1	1	1	1	1	1	1	1	1
NETHERLANDS	0.032	0.527	0.061	0.029	0.637	0.045	0.031	0.604	0.052	0.028	0.592	0.048
NORWAY	0.020	0.058	0.339	0.018	0.06	0.302	0.022	0.059	0.367	0.021	0.058	0.371
PORTUGAL	0.056	1	0.056	0.052	1	0.052	0.051	1	0.051	0.053	1	0.053
SWEDEN	0.005	0.046	0.107	0.007	0.055	0.126	0.007	0.055	0.126	0.008	0.05	0.159
U.K.	0.029	1	0.029	0.028	1	0.028	0.026	1	0.026	0.026	1	0.026
UNITED STATES	0.005	0.662	0.007	0.004	0.691	0.006	0.004	0.694	0.006	0.004	0.661	0.006

Table 2

Malmquist productivity index and its components

Year	EFFCH	TECHCH	PECH	SECH	TFPCH
1995-1996	0.915333	1.139111	1.016944	0.900222	1.037833
1996-1997	0.998667	1.035778	1.009611	0.9995	1.032111
1997-1998	1.022611	0.946167	0.914333	1.125111	0.965556
1998-1999	0.983444	1.065222	0.967222	1.023667	1.046611
1999-2000	1.010889	1.015611	1.055944	0.9955	1.026111
2000-2001	1.033222	0.956944	1.001889	1.032556	0.988667
2001-2002	1.000167	1.052333	1.012111	0.99	1.051611
Mean	0.994905	1.030167	0.996865	1.009508	1.021214

Notes: EFFCH is efficiency change, TECHCH is technical change, PECH is pure efficiency change, SECH is scale efficiency change, TFPCH is the total productivity change (Malmquist productivity index).

Table 3

Productivity change in OECD countries during 1995/1996-2001/2002ct

DMU	EFFCH	TECHCH	PECH	SECH	TFPCH	Ranking
AUSTRIA	0.959714	1.029286	0.974	0.987143	0.984714	13
BELGIUM	1.032571	1.032143	0.97	1.068857	1.061857	4
DENMARK	0.974143	1.063571	0.959286	1.016143	1.015857	11
FINLAND	0.954714	1.029286	1.004429	0.952857	0.978286	14
FRANCE	1.008	1.029286	1.028	0.982714	1.032714	8
GERMANY	0.998571	1.029286	0.975	1.043	1.024	10
GREECE	1.072571	1.029286	1	1.072571	1.102143	1
IRELAND	1.005286	1.031143	0.995286	1.009857	1.038143	7
ITALY	0.957	1.023429	0.958143	1.011143	0.973714	15
JAPAN	0.938571	1.030857	1.123286	0.954714	0.964857	17
KOREA, SOUTH	1.052571	1.029286	1.018429	1.033571	1.081286	3
LUXEMBOURG	1	1.042286	1	1	1.042286	6
NETHERLANDS	1.042571	1.019857	0.988571	1.063286	1.055	5
NORWAY	0.973571	1.029286	1.006714	0.979	1.000714	12
PORTUGAL	1.056286	1.032	1	1.056286	1.089143	2
SWEDEN	0.931	1.015286	0.977429	0.951429	0.942571	18
UNITED KINGDOM	0.952429	1.019286	1	0.952429	0.969714	16
UNITED STATES	0.998714	1.028143	0.965	1.036143	1.024857	9

Table 4

OLS pooled and Tobit results of efficiency from 1995-2002

Variable	OLS pooled	Tobit-panel-RE
Intercept	0.8269	1.2336***
POP	-3.36e-10	-4.05e-10
POPDEN	-0.0002**	-0.0006***
EPRO	-1.06e-06***	-7.30e-07***
EUSE	9.29e-07	7.51e07***
EXPORT	-0.0223	-0.0251
CREDITOR	-0.0481	0.0392**
CORRUPTION	-0.0258	-0.0759***
R-Square	0.1473	
Log likelihood		104.98

*Notes: *** and ** indicate that the coefficients are significantly different from zero at 1% and 5% levels, respectively.*

Table A1

DEA efficiency scores of 10 OECD countries during 1975-1993

Year	Austria			Denmark			Finland			France			Germany		
	CRSTE	VRSTE	SCALE	CRSTE	VRSTE	SCALE	CRSTE	VRSTE	SCALE	CRSTE	VRSTE	SCALE	CRSTE	VRSTE	SCALE
1975	0.045	0.220	0.203	0.522	1	0.522	0.203	0.894	0.228	0.017	0.068	0.248	0.509	1	0.509
1976	0.305	0.516	0.590	1	1	1	0.004	1	0.004	0.106	0.107	0.986	1	1	1
1977	0.346	1	0.346	0.570	1	0.570	0.776	1	0.776	0.105	0.242	0.431	1	1	1
1978	0.000	0.154	0.000	0.300	0.591	0.508	0.736	1	0.736	0.056	0.061	0.921	0.976	1	0.976
1979	0.176	0.195	0.904	1	1	1	1	1	1	0.038	0.063	0.609	1	1	1
1980	0.163	0.170	0.963	0.390	0.534	0.731	1	1	1	0.044	0.061	0.734	1	1	1
1981	0.116	0.174	0.669	0.456	0.682	0.669	1	1	1	0.060	0.071	0.851	1	1	1
1982	0.215	0.215	0.999	1	1	1	1	1	1	0.071	0.072	0.987	1	1	1
1983	0.212	1	0.212	0.700	0.759	0.923	0.826	1	0.826	0.012	0.050	0.250	0.979	1	0.979
1984	0.000	0.182	0.000	0.550	0.785	0.701	0.425	1	0.425	0.009	0.050	0.183	1	1	1
1985	0.174	0.176	0.990	1	1	1	1	1	1	0.025	0.049	0.516	1	1	1
1986	0.038	0.172	0.223	0.342	0.661	0.517	0.219	0.887	0.247	0.013	0.055	0.226	0.594	1	0.594
1987	0.077	0.179	0.430	0.038	0.729	0.052	0.854	0.878	0.972	0.036	0.058	0.634	0.873	1	0.873
1988	0.089	0.217	0.411	0.001	0.794	0.001	0.525	0.874	0.600	0.032	0.058	0.545	1	1	1
1989	0.071	0.198	0.359	0.048	0.791	0.060	0.503	0.830	0.606	0.025	0.064	0.389	1	1	1
1990	0.185	0.214	0.866	0.384	0.995	0.386	0.002	0.877	0.002	0.037	0.068	0.551	1	1	1
1991	0.137	0.207	0.660	0.521	0.932	0.560	0.002	0.833	0.002	0.037	0.069	0.536	1	1	1
1992	0.321	1	0.321	1	1	1	0.006	0.874	0.006	0.071	0.097	0.730	1	1	1
1993	0.045	0.220	0.203	0.522	1	0.522	0.203	0.894	0.228	0.017	0.068	0.248	0.509	1	0.509
Ave.	0.143	0.337	0.492	0.544	0.855	0.617	0.541	0.939	0.561	0.043	0.075	0.557	0.918	1.000	0.918
Rank	8	9	8	3	4	3	4	3	4	9	10	5	2	1	2

Table A1 (*continued*) **DEA efficiency scores of 10 OECD countries during 1975-1993**

Year	Korea			Luxembourg			Netherlands			Sweden			United States		
	CRSTE	**VRSTE**	**SCALE**	**CRSTE**	**VRSTE**	**SCALE**	**CRSTE**	**VRSTE**	**SCALE**	**CRSTE**	**VRSTE**	**SCALE**	**CRSTE**	**VRSTE**	**SCALE**
1975	0.019	1	0.019	1	1	1	0.372	0.623	0.597	0.011	1	0.011	0.406	0.444	0.915
1976	0.122	1	0.122	1	1	1	0.455	0.478	0.952	0.100	0.383	0.260	0.457	0.458	0.999
1977	0.063	1	0.063	1	1	1	0.415	0.639	0.650	0.001	0.358	0.002	0.466	1	0.466
1978	0.037	1	0.037	1	1	1	0.165	0.287	0.575	0.125	0.324	0.386	0.376	1	0.376
1979	0.053	0.063	0.839	1	1	1	0.053	0.299	0.179	0.479	0.492	0.972	0.144	0.313	0.460
1980	0.000	0.017	0.002	1	1	1	0.167	0.311	0.537	0.399	0.526	0.760	0.116	0.321	0.362
1981	0.183	1	0.183	0.923	1	0.923	0.002	0.330	0.005	0.620	0.639	0.970	0.622	1	0.622
1982	0.024	1	0.024	1	1	1	0.094	0.364	0.259	0.325	0.334	0.976	0.011	0.422	0.025
1983	0.035	1	0.035	1	1	1	0.185	0.387	0.478	0.251	0.411	0.609	0.504	1	0.504
1984	0.013	1	0.013	1	1	1	0.180	0.393	0.457	0.306	0.434	0.706	0.478	1	0.478
1985	0.025	1	0.025	1	1	1	0.334	0.395	0.847	0.366	0.473	0.773	0.458	0.663	0.690
1986	0.010	1	0.010	1	1	1	0.111	0.402	0.275	0.135	0.494	0.273	0.132	0.376	0.352
1987	0.019	1	0.019	1	1	1	0.153	0.423	0.361	0.422	0.463	0.912	0.391	0.404	0.968
1988	0.007	1	0.007	1	1	1	0.167	0.460	0.364	0.147	0.511	0.288	0.216	0.392	0.550
1989	0.004	0.006	0.670	1	1	1	0.206	0.465	0.444	0.127	0.530	0.241	0.166	0.382	0.434
1990	0.011	1	0.011	1	1	1	0.445	0.522	0.853	0.098	0.673	0.145	0.095	0.395	0.241
1991	0.005	1	0.005	1	1	1	0.326	0.541	0.603	0.235	0.652	0.361	0.178	0.417	0.426
1992	0.014	1	0.014	1	1	1	0.666	0.867	0.769	0.343	0.805	0.426	0.506	1	0.506
1993	0.019	1	0.019	1	1	1	0.372	0.623	0.597	0.011	1	0.011	0.406	0.444	0.915
Ave.	0.035	0.847	0.111	0.996	1.000	0.996	0.256	0.464	0.516	0.237	0.553	0.478	0.323	0.602	0.542
Rank	10	5	10	1	1	1	6	8	7	7	7	9	5	6	6

Table A2

Malmquist productivity index and its components summary of annual means during 1975-1993

Year	EFFCH	TECHCH	PECH	SECH	TFPCH
1973/1974	0.671	0.433	1.168	0.574	0.291
1974/1975	0.908	1.105	1.282	0.708	1.003
1975/1976	0.516	1.007	0.627	0.824	0.520
1976/1977	2.443	0.905	0.765	3.192	2.210
1977/1978	0.477	1.140	0.822	0.580	0.544
1978/1979	1.820	0.191	1.798	1.012	0.347
1979/1980	0.906	3.727	0.922	0.983	3.378
1980/1981	1.263	0.625	1.225	1.031	0.789
1981/1982	0.338	1.939	0.852	0.397	0.655
1982/1983	3.473	0.449	0.988	3.517	1.560
1983/1984	0.385	3.049	0.910	0.423	1.174
1984/1985	1.562	0.336	1.023	1.528	0.526
1985/1986	0.514	2.259	1.045	0.492	1.161
1986/1987	1.303	0.978	0.592	2.198	1.274
1987/1988	0.899	0.516	1.824	0.493	0.464
1989/1990	1.041	2.725	0.992	1.049	2.837
1991/1992	1.896	0.339	1.433	1.323	0.644
1992/1993	0.601	0.782	0.758	0.793	0.470
Mean	0.948	0.904	1.007	0.941	0.857

Table A3

Productivity change in 10 OECD countries during 1975/1976-1992/1993

DMU	EFFCH	TECHCH	PECH	SECH	TFPCH	Ranking
AUSTRIA	0.929	0.898	1.010	0.920	0.835	7
DENMARK	0.984	0.912	1.014	0.970	0.897	4
FINLAND	0.915	0.873	0.994	0.921	0.799	9
FRANCE	0.935	0.895	0.996	0.939	0.837	6
GERMANY	0.965	0.898	1	0.965	0.867	5
KOREA	0.876	0.922	1	0.876	0.808	8
LUXEMBOURG	1.082	0.952	1	1.082	1.030	1
NETHERLANDS	1.032	0.882	1.047	0.985	0.910	3
SWEDEN	0.779	0.915	1	0.779	0.713	10
UNITED STATES	1.022	0.894	1.015	1.007	0.914	2