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DOES CORRUPTION AFFECT EFFICIENCY AND PRODUCTIVITY CHANGE? AN AGGREGATE FRONTIER ANALYSIS

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Abstract

Over the last decade there has been growing interest in understanding the relationship between corruption and economic performance. The empirical evidence suggests that corruption conditions the levels of income and the growth rates of the economies, with results that tend more to support the existence of indirect effects through investment as against direct effects on productivity. Nevertheless, very few studies have focused on exploring the impact of corruption on efficiency levels and productivity growth. In this context, the objective of the present work is to analyze how corruption influences productivity levels and growth rates in a sample of O.E.C.D. countries. To this end, we shall adopt a frontier approach which will allow us, on the one hand, to study whether corruption conditions the efficiency levels at which the economies operate and, on the other, to determine the channels through which it can affect productivity growth, whether by influencing improvements in relative efficiency levels or by shifting the production frontier.

Key words: Corruption, efficiency, productivity.
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I. Introduction

The problem of corruption is generally associated with the quality of the institutions and the functioning of the public sector, so that the literature on corruption and economic results is closely related to the study of institutional integrity. This literature has undergone major developments in the last decade, stimulated by the appearance of various indicators of corruption and institutional quality which have enabled numerous empirical studies to be carried out. In general, the empirical evidence suggests that corruption leads to lower levels of domestic and foreign investment, less productive public expenditure, lower productivity growth and, consequently, slower growth rates[1].

Corruption is perceived as especially worrisome in less developed countries, while developed countries are seen as being in control of corruption. However, as Kaufmann (2004)

[1] For a review of the empirical literature on corruption and economic activity, see Jain (2001). Bardhan (1997) gives a detailed review of the theoretical literature on corruption.

observes, 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. Indeed, although the levels of corruption of O.E.C.D. countries are relatively low in comparison with those of other countries, there are also notable differences among the O.E.C.D. group. Nevertheless, most studies on corruption have considered broad samples including both developed and less developed or developing countries, and little work has been done on studying the effects of corruption in O.E.C.D. countries.

Studies on the relationship between corruption and economic activity have tended to centre on how corruption affects investment or production growth while the impact of this variable on productivity has received less attention. Moreover, efficient behaviour is generally assumed when studying productivity, thus making it impossible to investigate how corruption influences the efficiency at which different economies perform. The principal motivation of the present work is to study whether corruption affects the economic results of O.E.C.D. countries from a productivity-based perspective. A frontier approach is adopted, allowing us to estimate the relative efficiency levels with which the different economies operate, with the aim of analyzing whether corruption has an influence on the estimated levels of efficiency and the paths by which it can affect productivity growth.

In accordance with these objectives, the structure of this article is as follows: Section 2 presents a brief review of work concerning the effects of corruption on economic activity, with particular emphasis paid to the aspects related to efficiency and productivity growth. Section 3 studies the relationship between corruption and productivity in O.E.C.D. countries. A frontier approach is adopted to estimate the relative efficiency levels, and productivity growth is decomposed into efficiency gains and shifts of the production frontier by means of Malmquist productivity indices. These estimates are used to study whether corruption conditions the efficiency levels and productivity growth rates. Lastly, Section 4 presents the main conclusions of this work.

II. Corruption and economic performance

It has sometimes been argued that corruption may promote efficiency by enabling private agents to correct existing government failures. Therefore, arguments that stress the positive effects of corruption are based on ideas coming from "second-best" theory -given a set of distortions created by governmental procedures or policies, corruption would permit agents to evade those regulations that hinder economic activity, acting to "grease the wheels" of the economy (Leff 1964; Huntington 1968). In contrast to the hypothesis that corruption favours efficiency, emphasis is generally given to the problem posed by the implicit assumption that government failures are exogenous and independent of corruption, when in reality such distortions and corruption may be closely linked to each other. In this sense, corrupt politicians or bureaucrats may introduce excessive regulation precisely because of its potential for corruption, with the objective of attracting more offers of bribes. Also, most of the literature stresses that corruption leads to inefficient allocations by altering the incentives of economic agents, with a part of the economy's resources being used in the search for parties interested in participating in corruption activities, and in keeping those activities hidden, instead of being devoted directly to productive activities.

The effects of corruption on economic results are not limited to its impact on efficiency, but extend to different variables that condition economic growth. In particular, the literature tends to focus on the negative effects of corruption on investment. Payment of bribes in order to get licenses, and the uncertainty that these activities introduce with respect to guarantees and property rights, tend to reduce the incentives for investment. Also, productive investment may be reduced as its profitability relative to that of "investment" in rent-seeking activities diminishes, and thus corruption will have an expulsion effect on productive investment. Furthermore, corruption can affect public investment by reducing fiscal revenue and distorting public expenditure, affecting negatively the rates of growth.

The literature on economic growth tends to note that capital accumulation can not by itself explain economic growth, but lays the emphasis on productivity growth as the determining factor of growth (Easterly and Levine 2001; Caselli 2005). In this sense, it is interesting to study whether corruption, apart from conditioning the level of productivity, also affects its growth rate. The relationship between corruption and productivity growth could manifest itself in different ways. For one thing, corruption can distort the allocation of human resources, generating incentives that lead the best qualified people to devote themselves to rent-seeking activities instead of productive or innovative activities, thus negatively affecting economic growth (Baumol 1990; Murphy *et al*. 1991). For another, corruption could also negatively affect innovation activities since the development of new products is usually closely linked to obtaining permits and licenses, and to the protection of the property rights of the innovations through patents, all of which may be directly affected by corruption. Moreover, Aidt *et al*. (2005) suggest that corruption could reduce productivity growth through two mechanisms: by its negative impact on innovation and, also, by reducing learning-by-doing externalities, thereby limiting the possibilities of exploiting previous technology developed by other economies.

Most of the empirical work analyzing the influence of corruption on productivity, investment, innovation, and, in sum, economic growth, has been based on cross-sectional analysis for different samples of countries. Many have used growth equations in which investment is included as a determining variable. When variables designed to measure some aspect of institutional quality are also introduced, they are interpreted as affecting the efficiency or productivity of investment, thereby having a direct effect on growth. These variables could also have an indirect effect on growth if they also influence the volume of investment. In this case, another equation is specified in order to analyze whether those variables do indeed affect the levels of investment. Sometimes, growth equations are estimated in a reduced form, where the investment variable is replaced by a set of variables that determine it. This allows the overall effect of corruption on growth to be analyzed although, as both direct and indirect effects are picked up together, it is not possible to differentiate the mechanisms through which this influence manifests itself.

In general, the empirical evidence points to a negative impact of corruption on economic growth. In the pioneering work of Mauro (1995), based on a production function where growth is a function of investment, the effects of institutional quality (property rights, bureaucracy, corruption) on growth and investment are estimated separately. It is found that an unfavourable institutional framework reduces investment, and the possibility that corruption affects economic growth by influencing governments' choice of projects is pointed out. Additionally, Mauro (1998) analyzes how corruption affects the composition of public expenditure, reducing public expenditure on education, health, and infrastructure maintenance. Knack and Keefer (1995, 1997) examine the effects of different institutional variables on growth. Starting from a reduced equation and estimating a structural equation that includes investment, they find results that are favourable to the hypothesis that corruption affects growth negatively, with an indirect effect through investment. Various studies suggest that corruption also affects economic growth due to its negative effects on foreign investment (Wei 2000; Hellman *et al*. 2002) or on trade and business activity (Kaufmann 2004).

Although most studies analyze the effects of corruption on growth or investment, one also finds some work that centres on the direct effects of corruption on productivity growth. Thus, Tanzi and Davoodi (1997) show how corruption leads to an inefficient allocation of public funds which negatively affects economic growth, by increasing the volume of public investment at the same time as reducing its productivity. Olson *et al*. (2000) calculate total factor productivity (TFP) in a residual form and then analyze which variables explain its variation across countries. They find results that support the influence of different measures of institutional quality, one of which is corruption.

Some recent work centres on the analysis of productivity levels instead of growth rates. This approach is based on the idea that the quantity of inputs and the efficiency with which these are transformed are determined by the country's institutions, which therefore condition the output level of the economy. Hence, institutional variables seem to influence not only the growth rate of an economy but also its income or productivity levels (Rodrik *et al*. 2004). In this vein, Hall and Jones (1999) find that disparities in physical and human capital only partially explain the differences in product per worker, a great part of them being due to differences in the Solow residual. These authors find that differences in productivity are fundamentally due to the differences existing in the institutions and governmental policies, which they term “social infrastructure”[2]. Lambsdorff (2003) studies how corruption affects the productivity of capital, suggesting that the negative impact of corruption on productivity is manifest in the correlation of this variable with a poor quality of the bureaucracy.

In sum, the available empirical evidence suggests that corruption conditions an economy's income and productivity levels and growth rate, with results that are generally more favourable to the existence of indirect effects through investment as against direct effects on productivity. However, it is worth noting that most of the works that study the channels through which corruption affects growth have centred on analyzing its effects on investment, while dealing with its effects on productivity, in the best of cases, only residually. Also, while it is generally admitted that corruption may affect the efficiency with which an economy performs, there is little work that studies the actual impact of this variable on efficiency levels. Thus, most of the studies based on production functions or growth accounting assume that the economies operate efficiently, producing the maximum output attainable from the available resources and technology. However, as Olson *et al*. (2000) observe, the attainable level of production could be limited by the structure of incentives inherent in the institutional or political framework, so that workers or enterprises might not have enough incentives to use the available resources or technology efficiently.

Some recent studies analyzing the effects of institutional quality on productivity have indeed considered the possibility that the economies operate in an inefficient way. A stochastic frontier approach is adopted in the work of Adkins *et al*. (2002), Klein and Luu (2003), Méon and Weill (2005) and Doucouliagos and Ulubasoglu (2005), who study the relationship between such variables as economic and political freedoms, or different governmental indicators, and the estimated efficiency levels. Using a non-parametric estimate of the production frontier, Lall *et al*. (2002) and Cherchye and Moesen (2003) focus on studying the processes of convergence,

[2] These authors define "social infrastructure" as the set of institutions and government policies that influence the individual incentives of economic agents. These incentives may foster productive activities, investment, or the development of new techniques, or, on the contrary, they may lead to predatory behaviour such as corruption or rent-seeking.

analyzing how different institutional variables contribute to convergence by favouring relative improvements in terms of efficiency.

III. Productivity and corruption in O.E.C.D. countries

In this work a non-parametric frontier approach is adopted in order to study the influence of corruption on productivity levels and growth rates. This will allow us, on the one hand, to analyze whether corruption conditions the efficiency levels at which the economies operate and, on the other, to determine the channels through which it can affect productivity growth, whether by influencing improvements in relative efficiency levels or by shifting the production frontier.

A. Efficiency levels and decomposition of TFP growth

In order to study the efficiency with which productive inputs are employed, it is necessary to estimate a production frontier which represents the maximum technically attainable level of production. An economy's relative inefficiency level will then be regarded as the difference between the level of production actually obtained and the production frontier. Productivity growth may be due to a more efficient use of the inputs for a given productive capacity or to technological improvements allowing an increase in that capacity. In this sense, one of the advantages of adopting a frontier approach is that productivity growth can be decomposed into technical progress (represented by a shift of the production frontier) and gains in relative efficiency (represented by a movement towards the technological frontier). It also allows us to study through which paths corruption can affect productivity growth. We shall use a non-parametric technique -Data Envelopment Analysis (DEA)[3]- to estimate the production frontier and the associated efficiency levels of each of the economies. Variations in total factor productivity will be estimated by means of Malmquist productivity indices which in turn are

[3] Data Envelopment Analysis is one of the most commonly used techniques among non-parametric approaches. The advantage of the latter is their greater flexibility since they neither require a particular functional form to be specified for the technology nor any assumption to be made about the distribution of the inefficiency term.

decomposed into technical progress and changes in relative efficiency, allowing us to analyze which part of productivity growth is due to each of these factors[4].

This analysis is illustrated in Fig. 1, which is based on the case of a single input (X) and a single output (Y) in order to simplify the representation. The pairs (Xt, Yt) and (Xt+1, Yt+1) represent observed values for an economy while the maximum potential production in periods t and t+1 (points E and A) correspond to the reference technology (St and St+1). As one observes, productivity growth may be due to either an approximation to the frontier or to a shift of the production frontier itself. The change in relative efficiency (term EC in equation A.5 in the appendix) represents movements towards the frontier, and is shown graphically by the distance OF-OE and OB-OA. Likewise, technological change (term TC in equation A.5) is measured by the geometric mean of the shift of the frontier in period t (the distance OE-OC) and t+1 (the distance OD-OA).

Figure 1: Decomposition of TFP growth

The sample used in this study refers to 22 O.E.C.D. countries and covers the period 1980-2000[5]. In each case, a single output -the Gross Domestic Product- and two inputs -capital and labour- are considered. The capital stock estimates are taken from Kamps (2004). They were calculated by means of the permanent inventory method based on historical investment series for the O.E.C.D.[6] These estimates are presented in three categories: private non-residential capital; residential stock; and public capital. Residential capital was excluded since it is not linked to productive activity, so the measure of capital stock adopted in the present study includes both (non-residential) private and public capital. Data on real production was obtained from this same source, with both variables being expressed in terms of constant 1995 dollars. Labour is measured in annual hours worked, as estimated by the GGDC from the number of

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[4] A formal presentation of the Malmquist productivity indices and their decomposition is given in the Appendix.

[5] The 22 countries of the sample are: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Holland, Iceland, Ireland, Italy, Japan, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, and United States.

people employed in the economy and the hours worked per employee, according to data of the OECD and national sources[7].

Table 1 presents a summary of the estimates of the efficiency levels and productivity growth. The first row provides descriptive statistics of the estimated relative efficiency for our sample of O.E.C.D. countries in the period 1980-2000, and the second row the statistics relating to TFP growth, which is decomposed into relative efficiency change and technological change (third and fourth rows, respectively). Also, the last two rows give the statistics relating to the level and growth of productivity as measured conventionally (real production per hour worked). As one observes, the mean efficiency level in O.E.C.D. countries during these years was around 85%. Nevertheless, there were notable differences between countries in terms of productivity, with these differences being more marked when both capital and labour were considered as productive factors than when productivity was measured only with respect to the hours worked. Thus, in contrast to countries that tended to be located on the production frontier throughout almost the whole period (i.e., Belgium and France, and Canada until 1995), there was a minimal level of relative efficiency (in the case of Portugal) that hardly reached 56%. With respect to productivity growth, this was close to 2% per annum in terms of hours worked, while TFP growth was, on average, around 1% per annum, with variations between the economies being similar for the two indicators. It is also noteworthy that TFP growth was mainly due to variations in the production frontier, while the efficiency levels stayed relatively stable.

Table 1: Productivity levels and growth: statistical summary

B. Corruption effects on productivity

The empirical literature on corruption has frequently adopted different measures of institutional quality, covering variables related to the attributes of the institutions and the

[6] See Kamps (2004) for a detailed explanation of the sources and methods used to estimate the capital stock series.

[7] Groningen Growth and Development Centre (GGDC): Total Economy Database (August, 2005). Detail of sources and methods in http://www.ggdc.net.

evaluation of their performance. In the last few years, however, there have appeared different measures of corruption that have contributed significantly to the development of this literature[8].

On the one hand, there is an extensive set of indicators prepared by international organisations or private agencies with the objective of evaluating companies' investment opportunities in third countries. By the mid-1990s, two of the most frequently used sets of indicators in the literature on corruption were those of Business International (BI), applied in the pioneering work of Mauro (1995), and those of International Country Risk Guide (ICRG), applied in Knack and Keefer (1995) and in Mauro (1998). They both consist of a series of indices relating to different institutional variables (amongst others: bureaucratic efficiency, political stability, and institutional efficiency, in the case of BI; quality of the bureaucracy, contract guarantees, and property rights or risk of expropriation, in the case of ICRG), although they also include partial indicators of corruption.

On the other hand, together with agencies that elaborate indicators aimed at evaluating investment risks and opportunities, other organisms have a perspective oriented towards the fight against corruption. This has recently given rise to the development of specific indicators of corruption, outstanding amongst which are those of Transparency International (TI) and the World Bank[9]. Both are composite indicators, aggregating various indices elaborated from surveys carried out by different organisms. TI's corruption perception indices (CPI) have probably been the most extensively used in the recent empirical literature on corruption. These indicators, elaborated from opinion surveys and studies conducted among business people and analysts, have been published annually since 1995. In addition, CPIs have been constructed for the period 1980-85 (from the Business International and Political Risk Service databases), and for the period 1988-92 (using, as well as the two foregoing databases, those of the World Competitiveness Report and of the Political and Economic Risk Consultancy).

[8] Aron (2000: 107-113) gives a summary of the institutional indicators most commonly used in the empirical literature, distinguishing between objective and subjective measures. Also Jain (2001: 117-121) offers a synthesis of the different institutional measures commonly employed in the literature on corruption. Johnston (2001) discusses in detail the measurement and analysis of different indices of corruption.

[9] The World Bank indicators comprise six measures of governmental quality, with one of them corresponding to the control of corruption. In particular, the six measures are: (i) voice and accountability; (ii) political stability; (iii) government effectiveness; (iv) regulatory quality; (v) rule of law; and (vi) control of corruption.

In the present work we use different indicators of corruption in order to check whether the results are robust to choice of index. In particular, we use those of Mauro (1995), which refers to the period 1980-83, and of Knack and Keefer (1995), which refers to the period 1980-89. Both indicators were taken from Easterly and Levine (1997). We also consider the CPI corresponding to the first half of the 1980s (1980-85). Hence, the different corruption indicators employed refer to similar years -which coincide with the beginning of the period considered in this study- and have been extensively used in the empirical literature. Table 2 presents a statistical summary of these indicators and Table 3 gives the partial correlations between them. In all the cases, greater values of the indices correspond to less corruption. The CPI and the Mauro indicator are on a scale whose maximum is 10, while the maximum value on the scale of the Knack and Keefer indicator is 6. There are some differences between these measures of corruption. The Knack and Keefer indicator has the least variation for our sample of countries while the CPI and Mauro indicators have quite a similar dispersion, although the Mauro indicator tends to have slightly higher values than the CPI. In spite of these differences, however, the partial correlations between the three indicators are very strong, between 0.85 and 0.925 with a significance level of 99%.

Table 2: Corruption indicators: statistical summary

Table 3: Corruption indicators: partial correlations

We first estimate the effects of corruption on productivity levels. The results are presented in Table 4, including the estimates with a conventional measure of productivity (production per hour worked) and with the efficiency measure in the frontier approach considering both capital and labour as productive factors. The estimates point to a negative impact of corruption on productivity, with a positive correlation between the corruption indicators (higher values indicate less corruption) and productivity levels. This negative effect tends to be greater with regard to the level of efficiency estimated by the frontier approach, although it is more significant in the case of the production per hour worked. Furthermore, it is noteworthy that the Mauro and CPI indicators give quite similar results whereas the Knack and Keefer indicator shows a greater effect on productivity but with a lower significance level.

Table 4: Corruption and productivity: effects on productivity levels

With respect to productivity growth, we next estimate the effects of corruption on the Malmquist productivity indices calculated in the previous section. This allows us to study whether corruption has a significant effect on the TFP growth rates, and, if so, whether this effect is apparent through variations in relative efficiency or shifts of the production frontier. In studying productivity growth, one must bear in mind that it can be conditioned by the economy's base efficiency level. In this sense, one would expect the initial efficiency level to be positively correlated with technological change, since this will be the way followed by economies that are already highly efficient in order to increase their productivity. Initially less efficient economies, however, could raise their productivity by improving their relative efficiency, so that one would expect a negative correlation between initial efficiency and efficiency gains. Since these are two contrary effects, the total effect of the initial efficiency level on TFP growth is difficult to anticipate.

Table 5 presents the results of estimating the effects of corruption on productivity growth, also considering how the initial level of productivity affects its growth rate. In examining the relationship between the initial level of efficiency and TFP growth, one finds evidence favourable for a process of convergence in terms of productivity among the O.E.C.D. countries -the economies that start out from lower levels of relative efficiency have, on average, a greater TFP growth. Corruption also affects productivity growth, with the economies showing lower levels of corruption being those that have faster growth rates. Again, the results using the Mauro and CPI indices were very similar, while the coefficient estimated with the Knack and

Keefer index was less significant (although it remained significant at a 90% level). Nonetheless, all three indicators point to corruption having a negative effect on TFP growth.

Table 5: Corruption and productivity: effects of productivity growth rates

The results of estimating the impact of corruption on the components of TFP growth - variations in relative efficiency and shifts in the technological frontier- are presented in Tables 6 and 7. Firstly, one notes that the aforementioned process of productivity convergence is the result of the gains in efficiency undergone by the initially less efficient economies, without the initial efficiency level being significantly correlated with shifts of the production frontier. Hence, Table 7 also presents the results of the estimates made by excluding the initial efficiency level in studying the effects of corruption on technological change. With respect to the effects of corruption on the components of the TFP, one observes that, while this variable shows the expected sign, it does not reach significance in explaining the variations in efficiency. This suggests that, at least in the group of O.E.C.D. countries, corruption does not limit the less productive economies' possibilities of exploiting the existing technology. Corruption has, however, a negative influence on technological change (at a significance level of 99% with the CPI indicator, and 95% with the Mauro indicator), suggesting that the negative effect of corruption on the TFP growth is manifested through its impact on shifts of the production frontier.

Table 6: Corruption and efficiency change

Table 7: Corruption and technological change

IV. Conclusions

Studies of the relationship between corruption and economic activity have often noted that, because of the distortions that it introduces into the incentives of economic agents, corruption may condition the efficiency with which productive resources are used. Nevertheless, most of these studies implicitly assume that the economies operate efficiently, producing the maximum output attainable from the resources and technology available, and one finds hardly any work that has inquired into the impact of corruption on efficiency levels. In the present work a frontier approach has been adopted in order to study the efficiency with which productive inputs are used, estimating a production frontier that represents the maximum technically attainable level of production and the associated levels of relative efficiency. The sample considered referred to 22 O.E.C.D. countries during the period 1980-2000. The results using different corruption indicators showed that this variable affects negatively the efficiency levels at which these economies perform.

The literature on corruption suggests that corruption does not only condition an economy's productivity level, but also its rate of growth. Most empirical work has stressed the influence of corruption on growth through its indirect effects on investment, while its effects on productivity growth have been less studied. In this sense, one of the advantages of adopting a frontier approach is to decompose productivity growth into gains in relative efficiency and shifts of the production frontier. This allows one to study the paths through which corruption can influence productivity growth. The results suggested that corruption affects TFP growth, with economies that have lower levels of corruption recording, on average, faster growth rates. This negative effect of corruption on productivity growth is manifest through its impact on shifts of the technological frontier, while its influence was not found to be significant in explaining the variations of efficiency in O.E.C.D. countries.

Corruption is generally associated with problems of development of the less advanced economies. Nonetheless, despite the lower levels of corruption perceived in the O.E.C.D. countries, the results of the present study suggest that corruption also represents an economic problem for many of the more developed economies, since it conditions both their productivity levels and their rates of technological progress, thereby negatively influencing their possibilities of growth.

Appendix

Let S^t be the technology of production at period t (t=1,...T):

$$S^t = \{(X^t, Y^t) : X^t \, can \, produce Y^t\} \quad \text{(A.1)}$$

where X^t and Y^t are the vectors of inputs and outputs, respectively.

Following Shephard (1970), the distance function at period t is defined as[10]:

$$D_o^t(X^t, Y^t) = \min\{\theta : (X^t, Y^t/\theta) \in S^t\} \quad \text{(A.2)}$$

which allows a perfect characterization of the technology, since $(X^t, Y^t) \in S^t$ if, and only if, $D_o^t(X^t, Y^t) \leq 1$.

In order to define the Malmquist productivity index, we need to relate the input and output vectors at period t to the technology of the next period, S^{t+1}:

$$D_o^{t+1}(X^t, Y^t) = \min\{\theta : (X^t, Y^t/\theta) \in S^{t+1}\} \quad \text{(A.3)}$$

Similarly, we could define $D_o^t(X^{t+1}, Y^{t+1})$, where the input and output vectors at period t+1would be related to the period t technology.

On the basis of the above concepts, Färe et al. (1994) define the following Malmquist productivity index:

$$M_o^{t+1}(X^{t+1}, Y^{t+1}, X^t, Y^t) = \left[\frac{D_o^t(X^{t+1}, Y^{t+1})}{D_o^t(X^t, Y^t)} \frac{D_o^{t+1}(X^{t+1}, Y^{t+1})}{D_o^{t+1}(X^t, Y^t)} \right]^{1/2} \quad \text{(A.4)}$$

As it can be observed, this index is the geometric mean of two Malmquist indices, the first related to the technology of period t, and the second to the technology of period t+1[11].

This is in fact an index of productivity change between period t and t+1 and can be decomposed into efficiency change (EC) -change in relative efficiency between periods t and

[10] The subscript o refers to output based distance functions. See *Färe* (1988) for a discussion of input and output distance functions.

[11] A similar productivity index, based on Malmquist (1953), was proposed by Caves *et al*. (1982). However, these authors assumed $D_o^t(X^t, Y^t)$ and $D_o^{t+1}(X^{t+1}, Y^{t+1})$ to be equal to unity, so that technical inefficiencies were not considered.

t+1- and technological change (TC) -the geometric mean of the shift in the frontier between these two periods:

$$M_o^{t+1} = EC \cdot TC$$

where $EC = \frac{D_o^{t+1}(X^{t+1}, Y^{t+1})}{D_o^t(X^t, Y^t)}$ and $TC = \left[\frac{D_o^t(X^{t+1}, Y^{t+1})}{D_o^{t+1}(X^{t+1}, Y^{t+1})} \frac{D_o^t(X^t, Y^t)}{D_o^{t+1}(X^t, Y^t)} \right]^{1/2}$ (A.5)

In order to estimate the component distance functions of the Malmquist index, we use the data envelopment analysis (DEA)[12] non-parametric technique of linear programming. By assuming constant returns to scale[13] and exploiting the fact that the distance functions can be estimated as reciprocals of Farrell efficiency measures[14], the specific problem to calculate $D_o^t(X^t, Y^t)$ can be expressed as:

$$\left[D_o^t(X_t, Y_t)\right]^{-1} = \max_{\phi\lambda} \phi$$

$$\begin{aligned} s.t. \quad & -\phi\, y_{i,t} + Y_t\lambda \geq 0 \\ & x_{i,t} - X_t\lambda \geq 0 \\ & \lambda \geq 0 \end{aligned} \qquad \text{(A.6)}$$

The other three distance functions are calculated similarly, substituting the appropriate period index (i.e. t or t+1).

[12] Method developed by Charnes *et al*. (1978), based on Farrell (1957) technical efficiency measures.

[13] Grifell-Tatjé and Lovell (1995) show that the Malmquist index may not be an accurate measure of TFP change when non-constant returns are assumed. Furthermore, the constant returns to scale assumption is sufficient condition to guarantee that the optimization problem has a solution.

[14] Specifically,

$$\begin{aligned} D_O^t(X^t, Y^t) &= \min\{\theta : (X^t, Y^t/\theta) \in S^t\} \\ &= \left[\max\{\theta : (X^t, \theta Y^t) \in S^t\}\right]^{-1} \\ &= 1 / F_O^t(X^t, Y^t) \end{aligned}$$

where $F_O^t(X^t, Y^t)$ is the Farrell output based measure of technical efficiency.

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Figure 1: Decomposition of TFP growth

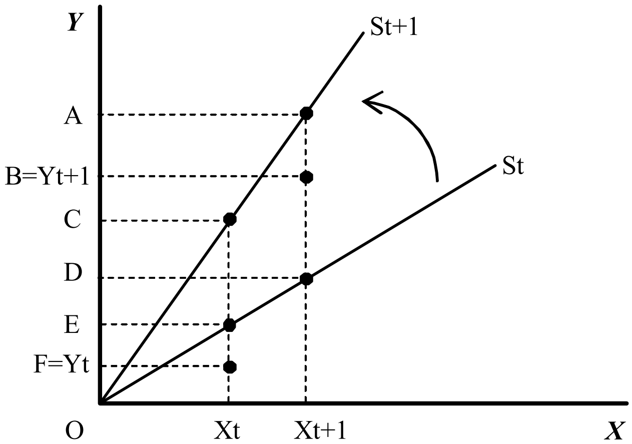

Table 1: Productivity levels and growth: statistical summary

	Mean	St. Dev.	Min.	Max.
ef_80_00	0,856868	0,1052266	0,5609	0,9980
tfp_ch_80_00	1,009498	0,0082720	0,9946	1,0308
ef_ch_80_00	0,999632	0,0075098	0,9889	1,0149
tec_ch_80_00	1,010154	0,0033454	1,0029	1,0157
GDP/L_80_00	0,033753	0,0107743	0,0138	0,0488
GDP/L_ch_80_00	1,019158	0,0082053	1,0061	1,0422

Table 2: Corruption indicators: statistical summary

	Mean	St. Dev.	Min.	Max.
CPI_80_85	7,676818	1,3739390	4,2000	9,3000
Corrup_K&K	5,380682	0,7329178	3,8125	6,0000
Corrup_Mauro	9,113636	1,2044740	6,2500	10,0000

Table 3: Corruption indicators: partial correlations

	CPI_80_85	Corrup_K&K	Corrup_Mauro
CPI_80_85	1	0,888 (*)	0,925 (*)
Corrup_K&K		1	0,848 (*)
Corrup_Mauro			1

Pearson correlation. (*) Correlation significant at 99%.

Table 4: Corruption and productivity: effects on productivity levels

	GDP/L_80_00			Ef_80_00		
Cte	0.00712308 (0.581197)	0.00067155 (0.0414346)	-0.00171886 (-0.103862)	0.608738 (5.03105)***	0.573944 (3.53947)***	0.533669 (3.25294)***
CPI_80_85	0.00346892 (2.20583)**			0.0323219 (2.08184)*		
Corrup_K&K		0.00614826 (2.05913)*			0.0525814 (1.76015)*	
Corrup_Mauro			0.00389221 (2.1612)**			0.0354632 (1.98639)*
$\hat{\sigma}$	0.009901	0.010028	0.009941	0.097752	0.100334	0.098542
R^2 (adjust.)	0.155462	0.133664	0.148791	0.137011	0.908357	0.123018

t-statistic in parentheses; *** significant at 99%; ** significant at 95%; * significant at 90%.

Table 5: Corruption and productivity: effects of productivity growth rates

	tfp_ch_80_00		
cte	1.01389 (88.1734)***	1.01067 (70.6942)***	1.00529 (73.78)***
Efi_80	-0.0334066 (-2.56105)**	-0.0290418 (-2.13749)**	-0.031825 (-2.46718)**
CPI_80_85	0.00300453 (2.48118)**		
Corrup_K&K		0.00421899 (1.78432)*	
Corrup_Mauro			0.00333172 (2.43908)**
$\hat{\sigma}$	0.007118	0.007580	0.007147
R^2 (adjust.)	0.259602	0.160395	0.253455

t-statistic in parentheses; *** significant at 99%; ** significant at 95%; * significant at 90%.

Table 6: Corruption and efficiency change

	ef_ch_80_00		
cte	1.01296 (90.1475)***	1.00908 (76.8891)***	1.00687 (77.0831)***
Efi_80	-0.0294156 (-2.30771)**	-0.0283814 (-2.27552)**	-0.0295963 (-2.39337)**
CPI_80_85	0.00141377 (1.19475)		
Corrup_K&K		0.00257983 (1.18856)	
Corrup_Mauro			0.00187532 (1.4321)
$\hat{\sigma}$	0.006955	0.006958	0.006852
R^2 (adjust.)	0.142179	0.141559	0.167586

t-statistic in parentheses; *** significant at 99%; ** significant at 95%; * significant at 90%.

Table 7: Corruption and technological change

	tec_ch_80_00					
Cte	1.00274 (212.264)***	1.0002 (278.452)***	1.0037 (158.345)***	1.003 (189.237)***	1.00066 (166.501)***	0.999225 (194.111)***
Efi_80	-0.00447636 (-0.835321)		-0.00129107 (-0.214315)		-0.00278592 (-0.489649)	
CPI_80_85	0.001445 (2.90464)***	0.00129607 (2.81197)***				
Corrup_K&K			0.0013957 (1.33131)	0.00132865 (1.36071)		
Corrup_Mauro					0.00129312 (2.14626)**	0.00119919 (2.1407)**
$\hat{\sigma}$	0.002924	0.002902	0.003361	0.003280	0.003152	0.003092
R^2 (adjust.)	0.23596	0.247506	0.0000	0.38969	0.111982	0.145738

t-statistic in parentheses; *** significant at 99%; ** significant at 95%; * significant at 90%.