

The impact of efficiency on the economic growth of emerging economies: The case of Colombia

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Abstract

As is well established (Robinson and Acemoglu, 2012), the economic performance of countries depends on the level of quality of its institutions. Referring to the economic performance, this paper establishes the aggregate efficiency of 133 countries in the generation of GDP by using the production theory framework and considering the participation of human as well as physical capital. Additionally, it is analyzed to what extent the aggregated performance depends on the level of quality and effectiveness of the subsequent national public institutions. It is also determined whether or not the size of the public expending, and its level of efficiency, have an impact on the rate of economic growth. To conclude, the conditions to favor the public expending as a driver for economic growth are determined. After a general overview, the specific situation of Colombia is analyzed. The results confirm the importance of the quality of the institutions on the respective levels of efficiency. It is also verified how the level of efficiency is a key factor to obtain economic growth from the public spending.

Keywords: aggregate performance, economic growth, quality of institutions, stochastic frontier analysis

JEL Classification: E23, H21, O43

1. Introduction

In this paper we attempt to determine the level of efficiency of Colombia and its influence on the generation of economic growth. We also try to answer the question as to the extent to which growth is hindered by institutional and environmental factors, so that it is possible to evaluate the potential threat to economic growth that these factors could represent. An essential variable in the study will be the level of efficiency of the public sector, so that we can determine the extent to which economic growth depends on the size of the public sector as well as its level of efficiency.

When planning this type of evaluations, the researcher should always consider what is the best instrument to be used, in order to provide clear answers. In the field that concerns us, until a recent time it was the researcher himself who had to make an initial decision about the chosen research methods. In the evaluation of efficiency and productivity the researcher can choose among parametric (which use econometric instruments to estimate production frontiers) (see, for instance Lovell and Kumbhakar, 2000) or non-parametric estimation tools (using mathematical programming techniques) (see, for instance Cooper et al., 1999). Usually, the first option involves stochastic frontier estimations while the second one is carried out in a deterministic environment, in which the existence of error in the data is assumed to be non-existent. However, under the current state of the art these differences have been alleviated, since today it is possible to carry out deterministic or stochastic estimations can be made with any of them.

A second criterion that should be taken into account is the existing knowledge about the reference technology. In this way, taking account of the technological characteristics, one can opt for either parametric frontier estimations, with varying degrees of flexibility. When this is not the case, to impose arbitrarily a given functional form could be counter-productive, which would advise the use of non-parametric methods.

There are currently some proposals (Badunenko et al., 2012) that allow detecting the presence of inefficiency and also, according to the structure of the available data, choose the most appropriate estimation method. The preliminary results indicate that, in our specific scenario (an analysis for Colombia from an international perspective), the best alternative was to use parametric models for the estimation of production functions.

Our approach is different from the one carried out previously by, for instance, Afonso et al. (2005) because, apart from measuring the levels of efficiency for the Colombian public sector, we also attempt to shed some light as to what extent the inefficiency detected is a burden that prevents achieving higher levels of economic growth. Answering that question demands statistically significant results and, for this reason, considering parametric approaches might be more convenient given the challenges that non-parametric techniques confront in this regard (Simar and Wilson, 1998, 1999).

The rest of the document presents, in the first place, the concept of efficiency and offers the elements that allow interpreting the results obtained. Next, we detail the data used and its descriptive statistics. Later on, the results obtained, which will allow us to analyze the position of Colombia with a greater level of detail. The final conclusions close the contents of this article.

2. Measuring efficiency

Starting from the modern theory of production, we derived the concept of efficiency from productivity estimates. Having a specific productivity level, the economic units try to find out the degree to which their level is appropriate compared to that of their competitors. The systematic comparison (benchmarking) between the productivity of units belonging to the same industry gives rise to the concept of technical efficiency. The technical efficiency indices facilitate the evaluation of productivity because, instead of considering the output produced per unit of input consumed, the information is reported in relative terms. That is, to what extent productivity must be improved in order to reach that level corresponding to those units with better performance (*best-practice* units).

Figure 1 shows, for an example, a simplified representation of efficiency estimates. It represents a very simple case in which only one output is produced by one input. The *OC* line represents the simplest of technologies: absence of fixed costs, and presence of constant returns to scale. In this sense, a technically efficient unit would correspond to the one producing a level of output, with a given level of input consumption, that would lie on that line. We can also refer to the *OC* line as the frontier of production possibilities, since it indicates the maximum level of production for any consumption of factors, so that it would

be impossible for a given unit to lie above these levels of production. For the inefficient unit (P_0) the coefficient ($X_0P_0/X_0P_0^*$) indicates whether it is close or far from the maximum possible level of production. The efficiency coefficient will have a value close to unity when inefficiency is low, and approaches zero when the inefficiency levels are high.

For more complex technologies there are other ways of describing the frontiers of production possibilities. Thus, the *OV* curve serves to illustrate a technology with variable returns to scale. From the origin to the P_0^* , the slope grows more than proportionally, indicating the presence of increasing returns to scale. To the right of P_0^* , growth is less than proportional, indicating the existence of decreasing returns to scale. The simplest functional forms, such as the Cobb-Douglas production function, allow the description of technologies with constant, increasing or decreasing returns to scale, but they are inadequate when the returns to scale depend on the segment of the border that is considered. This limitation can be solved with more flexible functional forms such as, for example, the translog production function.

In most production processes, as in the situation presented in Figure 2, economies of scale are important. The *OV* curve indicates the production possibility frontier, whose optimal point (where the average productivity is maximum) is located at the point P_0^* . The points P_1 and P_2 lie on the frontier, but they cannot produce at the maximum productivity level because they are operating with a different size (lower or higher) than the optimum. For this reason, both combinations (P_1 and P_2) exhibit inefficiencies due to the inadequate scale of their operations.

In Appendix A we formalize the process that allows us to estimate a Cobb-Douglas and translog production functions, which will allow us to measure efficiency via frontier efficiency techniques, similar to those represented in both Figures 1 and 2. Here we will continue with the description of model used for the analysis, which is summarized in Figure 3.

As indicated above, the objective of this article is to determine Colombia's efficiency levels from an international perspective.¹ In order to do so, we will estimate production

¹As the analysis is at country level, the aggregation can create some problems due to the lack of homogeneity of countries with regards to the environment in with the production process is carried out. For this reason, in some of the estimations we also include the potential impact that could cause some environmental variables (there are other possible ways to control this problem, but their application require a process that is beyond the

frontiers which considers one output (the country's GDP) and two inputs: physical and human capital. Since production frontiers will be adjusted to the set of countries for which it was possible to obtain information, special care must be taken to compare the quantities expressed in different currencies, and different purchasing power levels—which will be explained in the following section.

The estimated production functions allow us to determine the relative position of Colombia in terms of the variables related to technology: comparative efficiency level, relative position in terms of returns to scale, technical change corresponding to the frontier, and technical change specific to Colombia. This covers the typical analysis using production frontiers. As we are interested going beyond simple technological descriptions and, in a second approximation, we will reestimate the production frontiers to corroborate if efficiency levels depend upon each country's quality of government (Knack, 2002), so that it is possible to verify if there is empirical evidence of a significant relationship between the levels of quality of government (and the efficiency of national public institutions) with the country's public and private productive efficiency levels. In other words, following North (1994), we attempt to verify whether there is a *cooperative effect* (North, 1994), so that the quality of institutions can be linked, using formal rules (statute law, common law, regulations) informal norms (conventions, norms of behavior, and self-imposed codes of conduct), or the enforcement characteristics of both,² with each country having the levels of aggregate efficiency of all its productive sectors. In this sense, we expect to check whether those countries that have a quality institutional framework are those that obtain higher relative efficiency values. If this were the case, it seems obvious that both economic growth and improvements of a country's efficiency levels should be based on the consolidation of a political and public framework that generates quality institutions.

We will conclude the article with a final exploration that, again, will attempt to connect economic growth with two variables that are representative of the importance and quality

normal limits of this article). Moreover, as one referee pointed out, this process does not correct the potential bias caused by the aggregation, as stated by Oh (2012).

²Specifically, the dimensions to be evaluated are: (a) voice and accountability; (b) political stability and absence of violence/terrorism; (c) government effectiveness; (d) regulatory quality; (e) rule of law; and, finally, (f) control of corruption. These are the variables for which we have information for the vast majority of the available sample, and they reflect the notions of formal rules, informal norms or the enforcement characteristics defined by North (1994).

of public sector management. In this sense, if the estimates obtain statistical significance, it will be possible to determine whether sluggish economic growth might be derived from inefficiencies in the public sector.

3. Data

There is a vast literature that has been using data from the Penn World Table (PWT) database for evaluating countries' macroeconomic performance. Although there are alternative sources of information such as, among others, those cited by Inklaar and Timmer (2013): OECD Productivity Database, Conference Board Total Economy Database, EU KLEMS and GGDC Productivity Level Database, none of them allows comparisons among countries at different stages of economic development. In addition, the 8th release of the PWT³ (published in July 2013) reports indicators of capital stock (and not of the annual investment flow), and also of the level of human capital (and not simply the number of employees), allowing for multilateral comparisons of efficiency and productivity among countries with a very detailed definition of inputs.

In Summers and Heston (1991), it is stated that the variables contained in PWT basically allowing making comparisons among prices of goods and services which include purchasing power parity (PPP) adjustments. Therefore, we facilitate comparing magnitudes expressed in real terms among countries. The characteristics of this database enabled Färe et al. (1985) to use this data to compare productivity growth for 17 OECD countries. Other studies that have used these data for estimating efficiency and productivity are Chambers et al. (1996), Ray and Desli (1997), Färe et al. (2000), Kumar and Russell (2002), Badunenko and Romero-Ávila (2013), Henderson and Russell (2005), Färe et al. (2004), Angelopoulos et al. (2008), Pires and Garcia (2012) and Badunenko et al. (2013). Among them, and excepting the studies of Angelopoulos et al. (2008) and Pires and Garcia (2012), all of them use nonparametric estimation techniques. In contrast, our methods will be based on stochastic frontier analysis because, apart from knowing the level of inefficiency assignable to the Colombian economy, we are also interested in understanding to what extent the estimates

³Regularly updated by the Center for International Comparisons at the University of Pennsylvania, and accessible via: <https://pwt.sas.upenn.edu/>.

made are consistent with the axioms and postulates of production theory (for instance, to what extent the monotonicity axiom is accomplished in all the points, whether the required slopes of the marginal rates of inputs substitution or the inputs elasticity appear with the right sign).

Version 8 of PWT includes data from 189 countries and, for most cases, it encompasses a long time span (1950-2010). Here we will define a shorter period because, in addition to estimating levels of inefficiency by country, we want to check the impact of government effectiveness on efficiency levels. To this end, we will take data from the World Bank, and more specifically from the database The Worldwide Governance Indicators, 2014,⁴ which provides data on government effectiveness for years 1996 to 2012. As a conclusion, the empirical work is carried out on 133 countries and considers a data panel of 16 years (between 1996 and 2012).

Table 1 defines the variables used, and Table 2 reports the descriptive statistics of these variables. They show that the country with the smallest size employs 24,800 workers, while the largest one employs 784 millions. Also that the greatest number of unknown values (528) is confined to the human capital variable. In contrast, the variables related to governability have a variability ranging between -3.5 (for the worst score) and $+3.5$ (for the best score). The highest mean value corresponds to Regulatory Quality (RQ) (Political Stability and Absence of Violence, PSAV, if we consider the median) while the lowest is PSAV (Control of Corruption, COC, if we consider the median). If we refer to the dispersion, then the interquartile range indicates that the greatest dispersion corresponds to the Voice and Accountability (VAA) variable, whereas the lowest one corresponds to RQ.

4. Results

4.1. Results corresponding to production frontiers and inefficiency levels

The results corresponding to the parametric estimates are presented in Table 3. Column 3 shows the results corresponding to the Cobb-Douglas production function. The coefficients have a positive sign and all variables are statistically significant, which guarantees the condition of monotonicity for all 134 countries. The sum $\beta_1 + \beta_2$ is lower than unity,

⁴Data accessible via <http://data.worldbank.org/data-catalog/worldwide-governance-indicators>.

indicating that the technology exhibits decreasing returns to scale (just the section $P \times V$ of Figure 2). It is also clear that there is a positive technical change, albeit with a level close to zero. Given the characteristics that define Model I, we find that the level of inefficiency is high (0.4277), which implies that, in general, countries have problems obtaining the maximum GDP given their human capital and physical capital endowments.

Results in column 3 (Table 3) correspond to an overly restrictive specification of technology, and it is natural to inquire whether might arise due to an inadequate specification. In order to verify this, columns 4, 5 and 6 report results corresponding to the estimates of the translog production functions. Column 4 reports the results corresponding to the first estimate of the translog function. It should be noted that the likelihood ratio test indicates that the translog model is preferable to Cobb-Douglas. Additionally, using an F -test we can reject the hypothesis that $\beta_{11} = \beta_{22} = \beta_{12} = 0$. In the same way, results show a reasonable technological orientation as there is no evidence of severe specification problems: although the translog production function cannot be globally monotone (as it occurs with the Cobb-douglas production function), for the vast majority of observations the monotonicity condition is fulfilled—with positive output elasticities. It is also clear that levels of inefficiency increase.

In addition, an analysis of economies of scale (see Figure 4) confirms that the predominant situation is of decreasing returns to scale (elasticities lower than unity), although these diseconomies of scale are not very high either, since the number of countries with a elasticity lower than 0.9 is quite low.

With respect to technical change, Figure 5 displays a perspective of its distribution: it seems that roughly half of the countries in the sample went through positive technical change although, globally, the values are very low, especially if we compare them with the values corresponding to technical inefficiency. The assumption about the technical change is that it is Hicks neutral, say it does not change the output elasticities nor the inputs marginal substitution rates. The estimation assumes a fixed rate of yearly technical change.

In the results presented so far, apart from the temporal evolution, we did not consider any variable explaining technical inefficiency. In both cases (columns 3 and 4 of Table 3), we see that inefficiency has a tendency to increase—with a value of 0.0142 in the case of Model

II. The results reported in columns (5) and (6) also refer to the estimation of the production function but, in these cases, they add explanatory variables corresponding to the quality of government (these results come from the estimation of model 6 from the appendix). The results strongly confirm the hypothesized signs. Specifically, in column (5) we see how the average value of the government's quality variables has a negative and significant impact (-0.6146), suggesting that countries with high government quality scores have associated low inefficiency levels, and vice versa. Therefore, we find evidence on the favorable effect of the quality of public institutions on the real economy, either via the direct participation of the public sector or due to government's ability to regulate private economic activities, in general.

The same approach is taken in column (6) (Table 3) although, instead of including the average value to government quality, only one of its components is included: the efficacy of public administrations and other public institutions. In fact, we can corroborate that this dimension has an even greater impact than that corresponding to the average of quality of government,⁵ confirming that, in fact, the behavior of the public sector and its efficacy levels have a direct impact on the country's efficiency levels. In other words, any initiatives to boost GDP growth should take into account, apart from the primary factors of production (human and physical capital), the impact of public institutions' performance as well as the efficiency levels of the economy. In other words, an efficient public sector has a positive effect on the key macroeconomic variables of any country, since it avoids wasteful and counterproductive allocations of funds, reducing the need for public financing and acting as a revitalizing factor for the economy as a whole.

In order to conclude with the explanations of Table 3's contents, it should be noted that the different estimations are convergent with each other since there are no sign changes or contrary values to those expected.⁶

⁵After carrying out the corresponding analyses, it was concluded that government effectiveness is the factor with a greater impact on the levels of efficiency of the country's economy.

⁶In order to determine the robustness of the results, it was checked whether the variance of the residuals u and v had linear dependence with the value of the inputs. By rejecting this relationship, it was confirmed that heteroskedasticity was not a major problem in the estimations.

4.2. Results corresponding to the barriers to growth

Once the results are known from an annual perspective, it is clear that poor quality institutions have an impact on the inefficiency levels of the country. However, we are now interested in providing details on the effect of public sector on the national economy from a dynamic perspective. In other words, we attempt to determine the direct impact of public sector efficiency on economic growth. For this, we will consider the model proposed by Angelopoulos et al. (2008) to explain those factors that affect the economic growth of the country:

$$growth_{it} = \beta_0 + \beta_1 PUBLIC_{it} + \beta_2 PUBLIC_{it} \times EFF_{it} + \sum_{j=3}^4 \beta_j X_{it} + \varepsilon_{it} \quad (1)$$

where $growth_{it}$ is the real GDP change for country i in year t , $PUBLIC_{it}$ reflects the percentage of public spending on the GDP, EFF_{it} refers to the level of efficiency of public spending, and X_{it} is the effect of other environmental variables (in our case, the percentage of GDP devoted to investment and the value of per capita GDP). Actually, in our application the variable regarding the efficiency of the public sector is taken from the database of the World Bank, so its estimation is totally exogenous to the proposed model.

According to Angelopoulos et al. (2008), a negative sign is expected for β_1 (which would capture the negative impact of the size of the public sector on growth), a positive sign for β_2 (which would indicate that public efficiency favors the country's economic growth), a positive sign for β_3 (capturing the positive impact of investment in growth) and, finally, a negative sign for β_4 (this would confirm the existence of macroeconomic convergence, since countries with initially lower levels of per capita GDP grow faster).

Results reported in Table 4 confirm the predictions, with robust estimations. Therefore, regardless of the estimation method—pooled regression in column (3), panel data in column (4), and frontier regression in column (5)—the signs of the regressors coincide with the predictions, so that the relationship between the size of the public sector and GDP growth depends on the level of efficiency of public management. It is also clear that investment has a positive impact on growth, and that there is a convergence process because countries with higher GDP per capita growth more slowly.

Delving more deeply into the relationship between economic growth and the size of the public sector, and taking expression (1) into account, it is easy to determine the necessary condition for public management to contribute positively to economic growth:

$$\beta_1 PUBLIC_{it} + \beta_2 PUBLIC_{it} \times EFF_{it} > 0 \quad (2)$$

which, finally, offers us the following condition:

$$EFF_{it} > \frac{\beta_1}{\beta_2} \quad (3)$$

Those countries meeting Equation (3) are able to, given the high levels of efficiency of their public administrations, to induce economic growth. This is the case for Australia, Austria, Belgium, Bahamas, Bermuda, Barbados, Canada, Czech Republic, Chile, Cyprus, Denmark, Estonia, Finland, France, Hong Kong, Hungary, Ireland, Iceland, Israel, Japan, Luxembourg, Macau, Malaysia, Malta, Norway, New Zealand, Netherlands, Portugal, Singapore, Slovenia, Sweden, Switzerland, Taiwan and USA. It should be noted that the above condition is not fulfilled for all the years analyzed in Korea, Slovenia, Spain, Hungary, Macao, Malta, Portugal, and Taiwan. It should also be mentioned that no African country is listed among those countries benefiting from good governance. Finally, it should also be noted that the only Latin American country present in the subset of what we might refer as “virtuous practices” is Chile.

4.3. Results corresponding to Colombia

So far we have performed an overall analysis of the results obtained. In this section we focus on the comparative results of Colombia. First, we collect the results obtained in previous studies. In this sense, there are three studies in the literature Kumar and Russell (2002), Henderson and Russell (2005) and Badunenko et al. (2013) using the same data sources to estimate efficiency at the country level, although the methodological approach for the estimation of efficiency is different from ours.

Table 5 presents the results of these previous studies and those that are deduced from our application. For comparison purposes, the average results are added for Latin America,

for OECD countries and for the total sample⁷. It should be remembered that the efficiency indicator goes from zero (for very low efficiency levels) to one (for high efficiency levels). It is verified that in the previous works it is always verified that the relative efficiency level of Colombia is low and inferior to any of the groups with which it is compared. On the other hand, it is clear from our estimates that Colombia's level of efficiency coincides practically with the average value of the sample analyzed, surpassing the average level in Latin America, although there is still a significant distance from the OECD countries. These results point to a catching up process that would allow Colombia to approach the efficiency frontier, especially in recent years, although improvements are still pending because its level of efficiency and productivity does not even reach half of the level maximum possible. In any case, the above comparisons should be taken with some caution because the results come from estimates for different time periods and the country samples are not completely coincident.

A more detailed analysis will allow us to determine the role of government quality at the estimated levels. For this we will take the results of Models II, III and IV and compare them. In Table 6 we present the corresponding results. In column (1) we summarize the results of model II, and it is clear that the existing inefficiency is considerable, except for the OECD countries, the level of efficiency does not even reach half of the potential level. However, when we monitor for government quality levels, column (3) reveals that residual efficiency levels grow significantly. In both cases, Colombia's efficiency level is around the average for all countries in the sample, slightly above the Latin American average and still far from the OECD average.

Another way to measure the effect of the environment variables is to determine what part of the inefficiency appears related to the environment variable considered. Thus, column (3) indicates that, in all cases, more than half of the inefficiency found is due to the respective levels of government quality, a fact that reiterates the importance of the efficiency of public management for any National economy. Importantly, column (3) does not present the highest percentage for Colombia, which indicates that in other geographical areas the impact of government effectiveness on the rest of the economy may be even higher.

⁷As the samples and time periods are different, these results are not directly comparable. Here we present them just to illustrate that our results are aligned with those obtained in previous research works.

In order to have a complete view of the situation, we must also pay attention to the content of column (4), and it is clear that the level of government quality in Colombia is below average. As a final conclusion we obtain that an improvement of the quality of the government and, in particular, of the effectiveness of the Colombian public organizations would impact of very positive form to the other economic sectors. In this sense, the information in column (4) makes it clear that there is a great potential for improvement.

4.4. Results related to obstacles to growth in Colombia

Let us now analyze the results of the analysis of obstacles to growth from a Colombian perspective (see model (1) above). From this model, it was clear that the *sine qua non* condition for public spending to generate economic growth in the country is that its efficiency level is higher than a certain level, whose theoretical condition is expressed in Equation (3).

However, with the results obtained (presented in Table 4), it is clear that this condition is not met in Colombia, which indicates that, inexorably, Colombian public spending becomes a brake on growth due to the insufficient level of public efficiency. A graphical illustration of the problem is illustrated in Figure 6. For Colombia's public efficiency level (-0.17), model (1) gives us a negative growth, indicating that the country's GDP growth is reduced by 2.10%. If this situation is to be avoided, we should move to the right in the line of Figure 6. In this case, for an efficiency level of 0.8, Colombia would begin to experience economic growth from the activity related to public spending. That is the challenge that must face the Colombian public management to avoid that its existence suppose a brake to the economic growth.

Finally, let us make an analysis based on the alternative variable. Thus, if the contribution to the growth of the public sector depends on its importance (that is, on the size of public expenditure) and also on its level of efficiency, suppose that, given the difficulties in improving the levels of public efficiency, it is decided to operate with the size of public expenditure (which, for the years analyzed, is around 11.65% of GDP). Figure 7 shows the results offered by this strategy, which indicates that there is no possible size of the Colombian public sector that can provide positive economic growth. In conclusion, it is clear that the only viable strategy to get the public sector to help generate positive economic growth

rates is to improve public efficiency levels.

5. Conclusions

As indicated by several reputed scholars (North, 1990, 1994; Acemoglu and Robinson, 2008; Robinson and Acemoglu, 2012), one of the most relevant determining factors that explains the differences in prosperity among countries is related to how their economic institutions differ. Specifically, the disparate quality levels of both formal and informal institutions helps to understand the discrepancies in the living standards and economic progress of countries. With this theoretical background, our study has analyzed the efficiency differences of a relevant group of countries (all those included in the Penn World Tables database and The World Governance Indicators of the World Bank). In a first stage, we evaluated the differences in performance (efficiency, returns to scale, and technical change of the reference frontier) and, in a second stage, we examined the extent to which institutional variables explained these differences.

Results confirm that the estimated models offer a good fit and that production functions preserve the monotonicity conditions for most observations. Therefore, there are no indications of problems with the specification of the production model. Results also show the prevalence of decreasing returns to scale (albeit very lightly) and a positive technical change for almost half of the sample (with a very small value). However, there is a high level of technical inefficiency, which also seems to increase over time. Finally, factoring in institutional variables indicates that the quality of government and, to a greater extent, the effectiveness of public administration and other public institutions has a significant influence on the levels of inefficiency in each country. Therefore, the proposition that emerges from the institutional theory that the existing institutions in each country have a decisive impact on their economic performance is confirmed. These results might imply that, in developing countries such as Colombia, a good growth strategy requires improving the quality of their institutions.

In the second stage, we evaluated the impact of public sector efficiency levels on economic growth. The results were again robust, indicated clearly that higher levels of public efficiency translates were associated to higher growth rates. These estimations also al-

lowed us to determine the necessary conditions for public spending to be a driver that contributes positively to economic growth, and not a hindrance. Results are again very indicative, pointing out that no African country meets this requirement, and also that in Latin America the only country that meets it is Chile. The general conclusion would suggest that, in developing countries, increased public expenditures not accompanied by acceptable efficiency levels will have a limited impact on economic growth prospects.

The results for Colombia indicate that there is still a long way to go, because GDP per capita levels are still well below the OECD average values. It has also been found that more than half of the country's inefficiency is related to poor institutional quality, which is a more severe factor for Colombia than for other economies in the region. Therefore, improving the country efficiency levels requires improving the quality of government and, in particular, the effectiveness of public institutions. In the analysis of the relationship between public spending and growth strategies, it was found that the lack of public efficiency implies slower growth for the country (two points of GDP), and that improvements in the efficient provision of public services and infrastructures are necessary to reverse the situation.

To conclude, we should emphasize that both the global analysis as well as the specific analysis for Colombia reveal the paramount importance of institutions as an engine of growth and economic progress. The institutional improvement is, therefore, a challenge that policy makers must face as a way of laying the pillars of growth. Failure to give it the attention this issue requires may involve maintaining or even widening the discrepancies among different areas of economic influence.

Appendix A Formalization of the stochastic parametric frontier

We present in this appendix the characteristics of the Cobb-Douglas production function and also the Translog production function. Regarding estimation methods, we will deal with the estimation by using ordinary least squares, data panel and also estimating parametric frontiers.

A.1 The Cobb-Douglas production function

As is well known, the Cobb-Douglas production function is defined as a linear function of the logarithm of production (dependent variable) that depends on the logarithm of the inputs (independent variables), multiplied by regression coefficients (β) that represent the elasticities of the inputs and that define the technological characteristics of the production function. The simplest way to make estimates with a panel structure is to pool the data (that is, without considering temporal and individual structures), and then constraining the estimation to the usual process of pooled ordinary least squares. Assuming that the technology allows producing an output with the consumption of two inputs, this model is expressed as:

$$\log(y_{it}) = \beta_0 + \sum_{j=1}^2 \beta_j \log(x_{jit}) + \theta t + \varepsilon_{it} \quad (4)$$

where i represents the unit that is analyzed and t refers to time. The error term, ε_{it} is assumed to be independently distributed among the observations ($N(0, \sigma_\varepsilon^2)$). The parameter θ introduces the notion of technical change (neutral technical change) in the sense of Hicks, that is, assuming that innovations do not modify technology or marginal rates of substitution between inputs (β_j), which remain constant throughout weather). When θ is positive, the presence of technical progress is confirmed, indicating that, *ceteris paribus*, the same amount of inputs allows producing a higher level of outputs than in the previous period. On the contrary, when θ is negative, there is technological regression, which implies that, over time, obtaining a certain level of output becomes much more difficult (in other words, a kind of amnesia prevents maintaining levels of productivity and efficiency which will complicate the production of future periods).

A.2 The stochastic frontier production function

Introduced by Aigner et al. (1977) and Meeusen and Van den Broeck (1977), the estimation of the stochastic frontier is a generalization of the standard regression model, assuming that, due to the existence of inefficiency, each firm produces an output level below the potential (that is, the estimated production function will always be above the observed levels of outputs). This inefficiency is captured by an error term of one tail ($0 < \zeta_{it} \leq 1$).

When $\zeta_{it} = 1$ the unit under analysis is obtaining its maximum possible output level, given the consumed inputs x_{jit} . When $\zeta_{it} < 1$, the unit is not producing at its potential level.⁸

In the Cobb-Douglas production function, after taking logarithms, $u_{it} = -\log(\zeta_{it})$ is the term corresponding to inefficiency and v_{it} describes the random errors. The function that must be estimated is:

$$\log(y_{it}) = \beta_0 + \sum_{j=1}^2 \beta_j \log(x_{jit}) + \theta t + v_{it} - u_{it} \quad (5)$$

The interpretation of the coefficients v_{it} and u_{it} is as follows: v_{it} represents the measurement and specification error that is assumed to be independently distributed among the observations $N(0, \sigma_v^2)$ with a symmetric distribution. The term u_{it} has a non-negative distribution⁹ and represents inefficiency. In the empirical part we assume that u_{it} is exponentially distributed with variance σ_u^2 . It is also assumed that v_{it} and u_{it} are mutually independent.

A.3 Frontier estimation with panel data

This model is described by the following expression:

$$\log(y_{it}) = \beta_0 + \sum_{j=1}^2 \beta_j + \log(x_{jit}) + \theta t + v_{it} - u_{it} \quad (6)$$

Where v_{it} is the symmetric error while u_{it} captures the inefficiency and has a non-negative distribution. Battese and Coelli (1992) propose two possible specifications for inefficiency: i) invariant efficiency over time ($u_{it} = u_i$); and ii) variant inefficiency over time by the following specification:

$$u_{it} = \exp\{-\eta(t - T_i)\}u_i \quad (7)$$

where T_i refers to the last available period, η the trend parameter ($\eta > 0$ indicates that the

⁸The output has to be strictly positive ($y_{it} > 0$), what implies that the technical efficient coefficients have to be strictly positive ($x_{it} > 0$).

⁹In the literature we can find different ways to define the distribution for u_i . Aigner et al. (1977) assume a Half-Normal distribution ($u_{it} \sim N^+(0, \sigma_u^2)$), Meeusen and Van den Broeck (1977) defined an exponential distribution ($u_{it} \sim \varepsilon(\sigma_u)$), Stevenson (1980) a normal-truncated distribution and Greene (1980) a gamma distribution.

level of inefficiency decreases with time and $\eta < 0$ reports that the degree of inefficiency increases over time). u_i and v_{it} are assumed independently distributed.

A.4 Impact of environmental variables

An extension that has received research interest is the determination of the factors that explain the levels of inefficiency found. The initial proposals are due to Pitt and Lee (1981) and Kalirajan (1981) that defined the so-called “two-stage model”. Thus, in the first stage, the parameters of the frontier production function are estimated and then, once the efficiency levels are determined, a second estimation is made in which the dependent variable is, precisely, the inefficiency found in the first step.¹⁰ Two-stage models have received severe criticism because they are inconsistent, contradicting the initial assumptions of identically distributed inefficiencies, and also because they consider that environmental variables, explanatory of efficiency levels, are separable from technology. Obviously, the researcher should check for this assumption beforehand (Bădin et al., 2012). One way to solve the above problems is to estimate, simultaneously, the parameters of the production function and the inefficiency model. In this sense, Battese and Coelli (1995) define the following specification:

$$u_{it} = z_{it}\delta + W_{it} \quad (8)$$

where the random variable W_{it} is distributed as a normal truncated with null mean and variance σ^2 , the truncation point being $-z_{it}\delta(W_{it} \geq -z_{it}\delta)$. Thus, the simultaneous estimation of the parameters of the stochastic frontier and the model that explains the levels of inefficiency occurs from the following expression:

$$\log(y_{it}) = \beta_0 + \sigma_{j=1}^2 \beta_j \log(x_{jit}) + \theta_i t + v_{it} - (z_{it}\delta + W_{it}) \quad (9)$$

¹⁰Inefficiency X, a term coined by Leibenstein (1966), refers precisely to that, inefficiencies difficult to explain and which, in the case of companies (public or private), are usually attributed to management differences. Even so, there is a relevant literature that analyzes the possible causes of the inefficiency that, in this work, we have considered relevant not to address because we understand it would be rather the object of a more specific type of study that explicitly addressed the differences of inefficiency found.

A.5 The translog production function

The translog production function is an expansion of the Cobb-Douglas function, created to overcome the difficulties and inflexibilities of it. The translog production function provides the technology with a greater flexibility in terms of scale elasticity (which, unlike that corresponding to the Cobb-Douglas production function, depends on the volume of input consumption) and elasticity of substitution between the inputs (which was assumed equal to one in the Cobb-Douglas production function). This new specification of technology is desirable insofar as it represents a technology with fewer restrictions. Its specification is as follows:

$$\log(y_{it}) = \beta_0 + \sum_{j=1}^2 \beta_j \log(x_{jit}) + (1/2) \sum_{j=1}^2 \sum_{k=1}^2 \beta_{jk} \log(x_{jit}) \log(x_{kit}) + \theta t + \varepsilon_{it} \quad (10)$$

However, the greater flexibility also has negative aspects because, unlike the Cobb-Douglas function, the translog function is not globally monotonous, which happens when all first-order coefficients (β_j) are positive and all second-order coefficients (β_{kj}) are null. For this reason, it is convenient to analyze the condition of monotonicity for each observation because, if frequent violations of this condition occur, it is possible that there are problems of specification in the estimated model.

Among the positive aspects it is worth mentioning that the elasticities of substitution are variable and that the elasticities of output are flexible and dependent on the level of the inputs consumption:

$$\begin{aligned} \epsilon = \epsilon_{ji} + \epsilon_{ki} &= \frac{\delta \log(y_{it})}{\log(x_{jit})} + \frac{\delta \log(y_{it})}{\log(x_{kit})} = \beta_j + \sum_k k = 1^2 \beta_{jk} \log(x_{kit}) + \beta_k + \sum_{j=1}^2 \beta_{kj} \log(x_{jit}) = \\ &= \beta_j + \beta_k + \left[\sum_{j=1}^2 \sum_{k=1}^2 \beta_{jk} \log(x_{kit}) \right] \quad (11) \end{aligned}$$

References

- Acemoglu, D. and Robinson, J. (2008). *The Role of Institutions in Growth and Development*. World Bank, Washington DC.
- Afonso, A., Schuknecht, L., and Tanzi, V. (2005). Public sector efficiency: An international comparison. *Public choice*, 123(3):321–347.
- Aigner, D., Lovell, C. A. K., and Schmidt, P. (1977). Formulation and estimation of stochastic frontier production models. *Journal of Econometrics*, 6:21–37.
- Angelopoulos, K., Philippopoulos, A., and Tsionas, E. (2008). Does public sector efficiency matter? Revisiting the relation between fiscal size and economic growth in a world sample. *Public Choice*, 137(1):245–278.
- Bădin, L., Daraio, C., and Simar, L. (2012). How to measure the impact of environmental factors in a nonparametric production model. *European Journal of Operational Research*, 223(3):818–833.
- Badunenko, O., Henderson, D. J., and Kumbhakar, S. C. (2012). When, where and how to perform efficiency estimation. *Journal of the Royal Statistical Society, Series A (Statistics in Society)*, 175(4):863–892.
- Badunenko, O., Henderson, D. J., and Russell, R. R. (2013). Polarization of the worldwide distribution of productivity. *Journal of Productivity Analysis*, 40(2):153–171.
- Badunenko, O. and Romero-Ávila, D. (2013). Financial development and the sources of growth and convergence. *International Economic Review*, 54(2):629–663.
- Battese, G. E. and Coelli, T. J. (1992). Frontier production functions, technical efficiency and panel data: With application to paddy farmers in India. *Journal of Productivity Analysis*, 3:153–169.
- Battese, G. E. and Coelli, T. J. (1995). A model for technical inefficiency effects in a stochastic frontier production function for panel data. *Empirical economics*, 20(2):325–332.

- Chambers, R. G., Chung, Y., and Färe, R. (1996). Benefit and distance functions. *Journal of Economic Theory*, 70(2):407–419.
- Cooper, W. W., Seiford, L. M., and Tone, K. (1999). *Data Envelopment Analysis: A comprehensive text with models, applications, references and DEA-Solver software*. Kluwer Academic Publishers, Boston.
- Färe, R., Grosskopf, S., and Hernández-Sancho, F. (2004). Environmental performance: an index number approach. *Resource and Energy Economics*, 26(4):343–352.
- Färe, R., Grosskopf, S., and Lovell, C. A. K. (1985). *The Measurement of Efficiency of Production*. Studies in Productivity Analysis. Kluwer-Nijhoff Publishing, Dordrecht.
- Färe, R., Grosskopf, S., and Zaim, O. (2000). An index number approach to measuring environmental performance: an Environmental Kuznets Curve for the OECD countries. In *New Zealand Econometrics Study Group Meeting*.
- Greene, W. H. (1980). On the estimation of a flexible frontier production model. *Journal of Econometrics*, 13:101–115.
- Henderson, D. J. and Russell, R. R. (2005). Human capital and macroeconomic convergence: A production-frontier approach. *International Economic Review*, 46(4):1167–1205.
- Inklaar, R. and Timmer, M. (2013). Capital, Labor and TFP in PWT8. 0. Working Paper (unpublished), University of Groningen, Groningen.
- Kalirajan, K. (1981). An econometric analysis of yield variability in paddy production. *Canadian Journal of Agricultural Economics*, 29(3):283–294.
- Knack, S. (2002). Social capital and the quality of government: evidence from the States. *American Journal of Political Science*, 46(4):772–785.
- Kumar, S. and Russell, R. R. (2002). Technological change, technological catch-up, and capital deepening: Relative contributions to growth and convergence. *American Economic Review*, 92(3):527–548.

- Leibenstein, H. (1966). Allocative efficiency vs “X-efficiency”. *American Economic Review*, 56(3):392–415.
- Lovell, C. A. K. and Kumbhakar, S. C. (2000). *Stochastic Frontier Analysis*. Cambridge University Press, Cambridge.
- Meeusen, W. and Van den Broeck, J. (1977). Efficiency estimation from Cobb-Douglas production functions with composed error. *International Economic Review*, 18(2):435–444.
- North, D. (1990). *Institutions, Institutional Change, and Economic Performance*. Cambridge Univ Press, New York.
- North, D. C. (1994). Economic performance through time. *American economic review*, 84(3):359–368.
- Oh, H. (2012). Aggregation bias in stochastic frontier models employing region-level data: an empirical analysis with Korean manufacturing data. *Applied Economics Letters*, 19(9):813–821.
- Pires, J. O. and Garcia, F. (2012). Productivity of nations: a stochastic frontier approach to TFP decomposition. *Economics Research International*.
- Pitt, M. M. and Lee, L.-F. (1981). The measurement and sources of technical inefficiency in the Indonesian weaving industry. *Journal of Development Economics*, 9(1):43–64.
- Ray, S. C. and Desli, E. (1997). Productivity growth, technical progress, and efficiency change in industrialized countries: comment. *American Economic Review*, 87(5):1033–1039.
- Robinson, J. A. and Acemoglu, D. (2012). *Why Nations Fail: The Origins of Power, Prosperity, and Poverty*. Crown Business, New York.
- Simar, L. and Wilson, P. W. (1998). Sensitivity analysis of efficiency scores: How to bootstrap in nonparametric frontier models. *Management Science*, 44(1):49–61.
- Simar, L. and Wilson, P. W. (1999). Estimating and bootstrapping Malmquist indices. *European Journal of Operational Research*, 115:459–471.

Stevenson, R. E. (1980). Likelihood functions for generalized stochastic frontier estimation. *Journal of Econometrics*, 13:57–66.

Summers, R. and Heston, A. (1991). The Penn World Table (Mark 5): an expanded set of international comparisons, 1950–1988. *Quarterly Journal of Economics*, 106(2):327–368.

Table 1: Definition of the relevant variables

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Figure 6: Economic growth and government effectiveness

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Appendix B. List of countries in the sample

<u>Continent or grouping</u>	<u>Country</u>	<u>Code</u>
Africa	Angola	AGO
Africa	Benin	BEN
Africa	Botswana	BWA
Africa	Burkina Faso	BFA
Africa	Burundi	BDI
Africa	Cameroon	CMR
Africa	Cape Verde	CPV
Africa	Central African Republic	CAF
Africa	Chad	TCD
Africa	Comoros	COM
Africa	Congo, Dem. Rep.	COD
Africa	Congo, Republic of	COG
Africa	Cote d'Ivoire	CIV
Africa	Djibouti	DJI
Africa	Egypt	EGY
Africa	Equatorial Guinea	GNQ
Africa	Ethiopia	ETH
Africa	Gabon	GAB
Africa	Gambia, The	GMB
Africa	Ghana	GHA
Africa	Guinea	GIN
Africa	Guinea-Bissau	GNB
Africa	Iran	IRN
Africa	Iraq	IRQ
Africa	Kenya	KEN
Africa	Lesotho	LSO
Africa	Liberia	LBR
Africa	Madagascar	MDG
Africa	Malawi	MWI
Africa	Maldives	MDV
Africa	Mali	MLI
Africa	Mauritania	MRT
Africa	Mauritius	MUS
Africa	Morocco	MAR
Africa	Mozambique	MOZ
Africa	Namibia	NAM
Africa	Niger	NER
Africa	Nigeria	NGA
Africa	Rwanda	RWA
Africa	Sao Tome and Principe	STP
Africa	Senegal	SEN
Africa	Sierra Leone	SLE
Africa	South Africa	ZAF
Africa	Sudan	SDN

Africa	Swaziland	SWZ
Africa	Tanzania	TZA
Africa	Togo	TGO
Africa	Tunisia	TUN
Africa	Uganda	UGA
Africa	Yemen	YEM
Africa	Zambia	ZMB
Africa	Zimbabwe	ZWE
Asia	Bangladesh	BGD
Asia	Cambodia	KHM
Asia	Hong Kong	HKG
Asia	India	IND
Asia	Indonesia	IDN
Asia	Laos	LAO
Asia	Macao	MAC
Asia	Malaysia	MYS
Asia	Mongolia	MNG
Asia	Nepal	NPL
Asia	New Zealand	NZL
Asia	Pakistan	PAK
Asia	Panama	PAN
Asia	Philippines	PHL
Asia	Singapore	SGP
Asia	Sri Lanka	LKA
Asia	Suriname	SUR
Asia	Taiwan	TWN
Asia	Tajikistan	TJK
Asia	Thailand	THA
Asia	Turkmenistan	TKM
Asia	Uzbekistan	UZB
Asia	Vietnam	VNM
Latin America	Argentina	ARG
Latin America	Bolivia	BOL
Latin America	Brazil	BRA
Latin America	Colombia	COL
Latin America	Costa Rica	CRI
Latin America	Dominica	DMA
Latin America	Dominican Republic	DOM
Latin America	Ecuador	ECU
Latin America	El Salvador	SLV
Latin America	Grenada	GRD
Latin America	Guatemala	GTM
Latin America	Honduras	HND
Latin America	Paraguay	PRY
Latin America	Peru	PER
Latin America	Uruguay	URY
Latin America	Venezuela	VEN

Non OECD	Albania	ALB
Non OECD	Antigua and Barbuda	ATG
Non OECD	Armenia	ARM
Non OECD	Azerbaijan	AZE
Non OECD	Bahamas	BHS
Non OECD	Bahrain	BHR
Non OECD	Barbados	BRB
Non OECD	Belarus	BLR
Non OECD	Belize	BLZ
Non OECD	Bermuda	BMU
Non OECD	Bhutan	BTN
Non OECD	Bosnia and Herzegovina	BIH
Non OECD	Brunei	BRN
Non OECD	Bulgaria	BGR
Non OECD	China	CHN
Non OECD	Croatia	HRV
Non OECD	Cyprus	CYP
Non OECD	Fiji	FJI
Non OECD	Georgia	GEO
Non OECD	Jamaica	JAM
Non OECD	Jordan	JOR
Non OECD	Kazakhstan	KAZ
Non OECD	Kuwait	KWT
Non OECD	Kyrgyzstan	KGZ
Non OECD	Latvia	LVA
Non OECD	Lebanon	LBN
Non OECD	Lithuania	LTU
Non OECD	Macedonia	MKD
Non OECD	Malta	MLT
Non OECD	Moldova	MDA
Non OECD	Montenegro	MNE
Non OECD	Oman	OMN
Non OECD	Qatar	QAT
Non OECD	Romania	ROU
Non OECD	Russia	RUS
Non OECD	Saudi Arabia	SAU
Non OECD	Serbia	SRB
Non OECD	St. Kitts & Nevis	KNA
Non OECD	St. Lucia	LCA
Non OECD	St. Vincent & Grenadines	VCT
Non OECD	Syria	SYR
Non OECD	Trinidad & Tobago	TTO
Non OECD	Ukraine	UKR
OECD	Australia	AUS
OECD	Austria	AUT
OECD	Belgium	BEL
OECD	Canada	CAN

OECD	Chile	CHL
OECD	Czech Republic	CZE
OECD	Denmark	DNK
OECD	Estonia	EST
OECD	Finland	FIN
OECD	France	FRA
OECD	Germany	DEU
OECD	Greece	GRC
OECD	Hungary	HUN
OECD	Iceland	ISL
OECD	Ireland	IRL
OECD	Israel	ISR
OECD	Italy	ITA
OECD	Japan	JPN
OECD	Korea, Republic of	KOR
OECD	Luxembourg	LUX
OECD	Mexico	MEX
OECD	Netherlands	NLD
OECD	Norway	NOR
OECD	Poland	POL
OECD	Portugal	PRT
OECD	Slovak Republic	SVK
OECD	Slovenia	SVN
OECD	Spain	ESP
OECD	Sweden	SWE
OECD	Switzerland	CHE
OECD	Turkey	TUR
OECD	United Kingdom	GBR
OECD	United States	USA

Type of variable	Name	Definition
Output	y : <i>rgdpo</i>	Country's Gross Domestic Product, PPP adjusted, in thousands of constant 2005 US\$
Input	x_j : <i>emp</i>	Number of workers (millions)
Input	x_{hc} : <i>hc</i>	Human capital index (per person), based on schooling years (Barro & Lee 2013), as well as returns on education (Psacharopoulos 1994)
Input	x_k : <i>rkna</i>	Capital stock (thousands of constant 2005 US\$)
Government quality	<i>VAA</i> : Voice and Accountability	It captures perceptions of the extent to which a country's citizens are able to participate in selecting their government, as well as freedom of expression, freedom of association, and a free media.
Government quality	<i>PSAV</i> : Political Stability and Absence of Violence/Terrorism	It measures perceptions of the likelihood of political instability and/or politically motivated violence, including terrorism.
Government quality	<i>GE</i> : Government Effectiveness	It captures perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies.
Government quality	<i>RQ</i> : Regulatory Quality	It captures perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development.
Government quality	<i>ROL</i> : Rule of Law	It captures perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence.
Government quality	<i>COC</i> : Control of Corruption	It captures perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests.

Table 1. Definition of the relevant variables

Source: Penn World Table (PWT) and The Worldwide Governance Indicators, 2014.

Variable	Min.	Q1	Median	Mean (arithmetic)	Q3	Max.	NA's
<i>rgdpo</i>	131	9564	31884	329570	192729	13193478	0
<i>emp</i>	0.0248	0.9636	3.4269	16.5755	9.4140	784.4269	56
<i>hc</i>	1.136	2.037	2.590	2.466	2.886	3.619	528
<i>rkna</i>	354	24824	86489	1050831	595339	44642460	0
<i>VAA</i>	-2.12000	-0.85000	-0.10144	-0.02798	0.87000	1.83000	20
<i>PSAV</i>	-3.18481	-0.71201	0.03166	-0.06851	0.74022	1.66807	33
<i>GE</i>	-1.98200	-0.70090	-0.13012	0.04409	0.71765	2.42965	33
<i>RQ</i>	-2.41273	-0.58195	-0.06714	0.06866	0.79836	2.24734	31
<i>ROL</i>	-2.22985	-0.80330	-0.19315	-0.02464	0.73572	1.99964	23
<i>COC</i>	-2.05746	-0.77355	-0.24004	0.01997	0.64782	2.58562	31

Table 2. Summary statistics for the relevant variables

Source: own elaboration from *Penn World Table (PWT)* and *The Worldwide Governance Indicators, 2014* data.

Variables (1)	Parameters (2)	PANEL DATA Model I (3)	PANEL DATA Model II (4)	PANEL DATA Model III (5)	PANEL DATA Model IV (6)	
<i>Constante</i>	β_0	0.8778534***	0.7043481***	0.3254291***	0.3140554***	
<i>ln(x_{hc})</i>	β_1	0.4356712***	0.2272791***	0.2459954***	0.2410062***	
<i>ln(x_k)</i>	β_2	0.4800882***	0.6430666***	0.7646516***	0.7463103***	
<i>(1/2) ln(x_{hc})²</i>	β_{11}		0.032887	0.1588080***	0.1345746***	
<i>(1/2) ln(x_k)²</i>	β_{22}		0.1035062***	0.1470096***	0.1517269***	
<i>ln(x_{hc}).ln(x_k)</i>	β_{12}		-0.0784149***	-0.1433770***	-0.1362771***	
<i>T</i>	θ_t	0.0063906***	-0.0040469*	-0.0015002	-0.0020182	
<i>t.ln(x_{hc})</i>	θ_{t1}		-0.0022214*	-0.0019034	-0.0011606	
<i>t.ln(x_k)</i>	θ_{t2}		0.0035924***	0.0014877	0.0001865	
<i>(1/2) (t)²</i>	θ_{tt}		0.0002443	-0.0002028	-0.0002182	
Ineficiencia	variable					
<i>Trend</i>		0.0063906***	0.0142043***			
<i>Lambda</i>	σ_u/σ_v	0.9836670***	0.9784019***	0.70823876***	0.7405273***	
<i>Sigma²</i>	$\sigma_u^2 + \sigma_v^2$	1.2853761***	0.9382679***	0.28341925***	0.2765146***	
<i>Mean efficiency</i>		0.427771	0.460832	0.7011875	0.6948282	
<i>Government quality</i>	\bar{Z}			-0.6145916***		
<i>Government effectiveness</i>					-0.7566569***	
<i>N_{it}</i>	<i>n_{it}</i>	<i>obser.</i>	2144	2144	2128	2128
		<i>Groups</i>	134	134	133	133

Table 3. Estimation of the parameters of the production function

*, **, *** indicates significance at the 10%, 5% and 1% levels, respectively.
^c Modelo I: panel regression, *Cobb-Douglas* production function.
Modelo II: panel regression, *translog* production function.
Modelo III: panel regression, *translog* production function.
Modelo IV: panel regression, *translog* production function.

Source: own elaboration.

Variable (1)	Parameter (2)	POOL DATA Model I (3)	PANEL DATA Model II (4)	PANEL DATA Model III (5)
Constant	β_0	0.071498***	0.074824***	0.1087216***
PUBLIC%	β_1	-0.135340***	-0.176622***	-0.1617783***
(PUBLIC%*EFF)	β_2	0.137599*	0.166404*	0.1351016
Investment%	β_3	0.059975*	0.056371	0.0528533
Log(GDP/popula tion)	B_4	-0.005439*	-0.005260*	-0.0063070**
Adjusted R ²		0.046	0.058	
N _{it}	observat.	1976	1995	1995
N _{it}	Groups		133	133

Figure 4. Estimation of the drivers of growth

* , ** , *** indicate significance at the 10%, 5% and 1% levels, respectively.

^c Model I: Pool regression.

Model II: Panel regression (RE).

Model III: Panel regression (frontier).

Source: own elaboration.

<u>Kumar and Russell (2002)</u>	1965	1990
Colombia	0.41	0.45
Latin America	0.66	0.56
OECD	0.75	0.80
Total sample	0.64	0.65
<u>Henderson and Russell (2005)</u>	1965	1990
Colombia	0.48	0.54
Latin America	0.72	0.58
OECD	0.79	0.78
Total sample	0.68	0.67
<u>Badunenko, Henderson and Russell (2005)</u>	Average	1965-2007
Colombia	0.39	
Latin America	0.48	
OECD	0.60	
Total sample	0.50	
<u>Our estimations: Model II</u>	Average	1996-2011
Colombia	0.48	
Latin America	0.42	
OECD	0.65	
Total sample	0.46	

Table 5. Estimation of the aggregate efficiency for Colombia's economy (comparison with previous studies)

Source: own elaboration.

	Efficiency Model II	Efficiency controlling for government's quality	Impact of government's quality on inefficiency (3)	Government's quality level (4)
	(1)	(2)		
Model III				
Colombia	0.48	0.70	51.40 %	-0.53
Latin America	0.42	0.68	55.43 %	-0.15
OECD	0.65	0.85	62.27 %	1.18
Total sample	0.46	0.70	54.06 %	0.00
Modelo IV				
Colombia	0.48	0.73	57.12 %	-0.17
Latin America	0.42	0.66	52.10 %	-0.21
OECD	0.65	0.87	67.67 %	1.35
Total sample	0.46	0.70	54.06 %	0.04

Table 6. Estimation of the aggregate efficiency for Colombia's economy

Source: own elaboration.

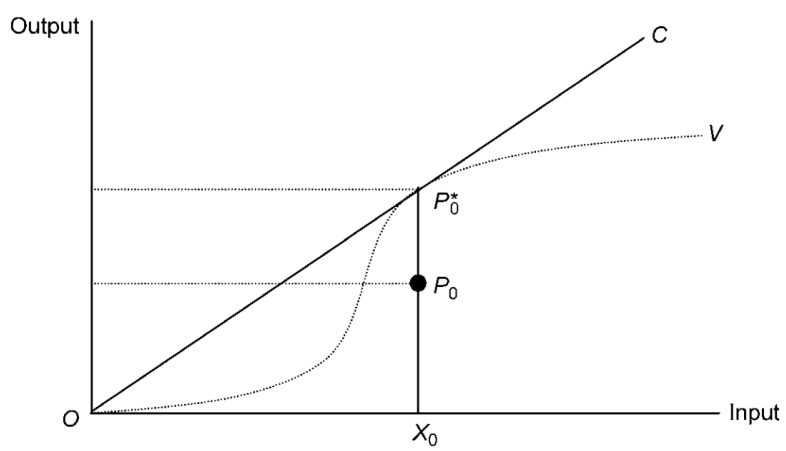


Figure 1. Graphical representation of the frontier evaluation

Source: own elaboration

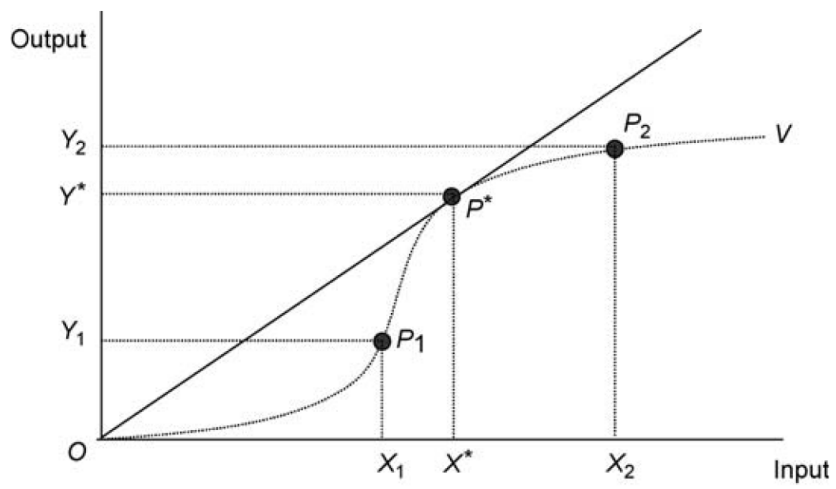


Figure 2. Production frontiers and returns to scale

Source: own elaboration

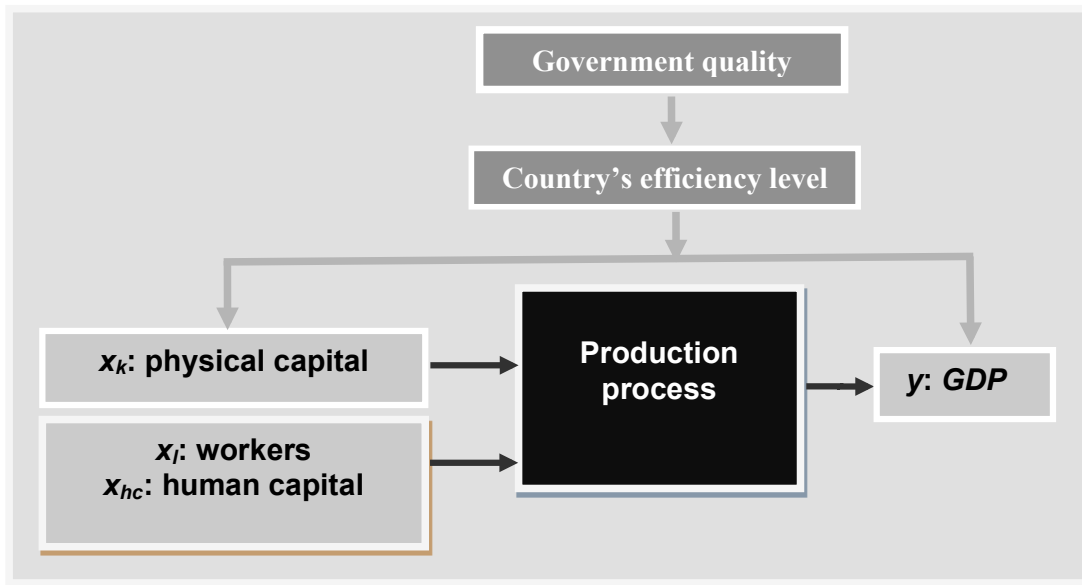


Figure 3. Synthesis of the analytical model

Source: own elaboration

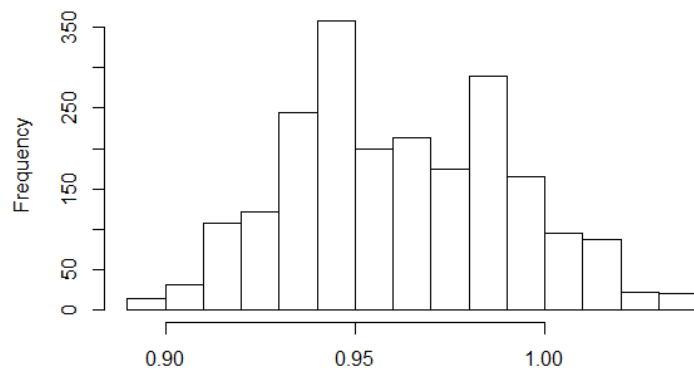


Figure 4. Distribution of scale economies

Source: own elaboration.

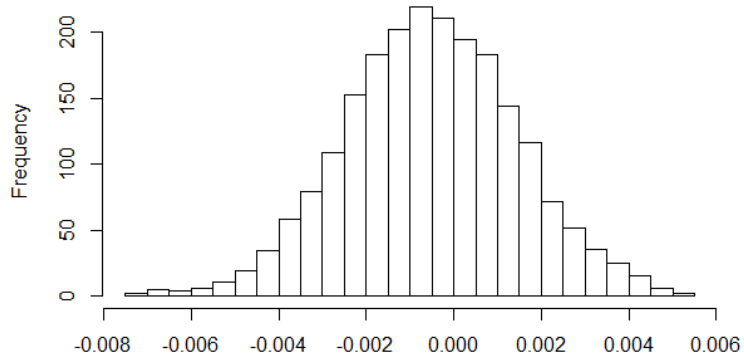


Figure 5. Distribution of technical change

Source: own elaboration

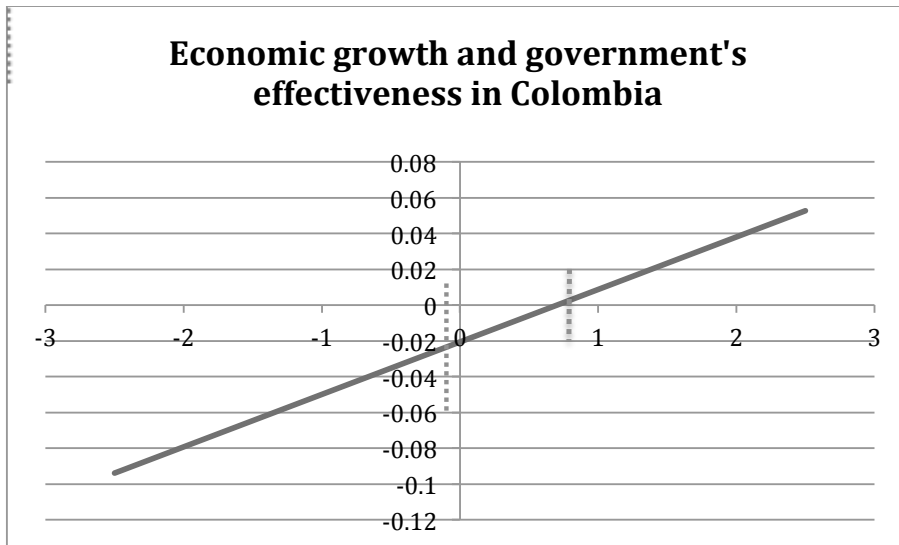


Figure 6. Economic growth and government effectiveness

Source: own elaboration

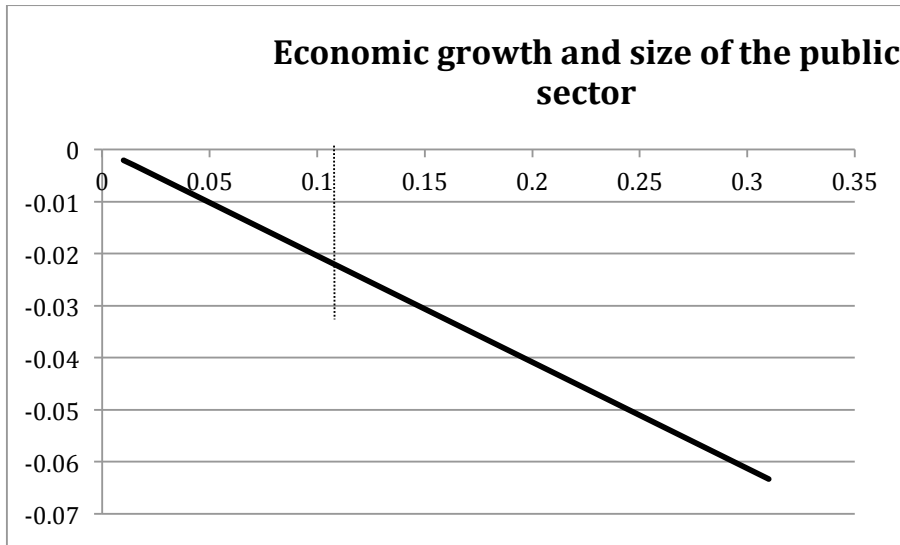


Figure 7. Economic growth and size of the public sector