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

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December 24, 2017

Abstract

As is well established (Robinson and Acemoglu, 2012), the economic performance of countries depends on the quality level of its institutions. Referring to 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, to what extent the aggregated performance depends on the level of quality and effectiveness of the subsequent national public institutions is analyzed. Further, whether or not the size of the public expenditure, and its level of efficiency, have an impact on the rate of economic growth is also determined. To conclude, the conditions that favor public expenditure as a driver for economic growth are determined. After a general overview, Colombia´s specific situation is analyzed. The results confirm the importance of the quality of the institutions in the respective levels of efficiency. As well as confirming how level of efficiency is a key factor in obtaining economic growth from public spending.

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

JEL Classification: E23, H21, O43

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*This document is part of a larger project funded by the Inter-American Development Bank (IDB), whose support is gratefully acknowledged. We are thankful to Hernando Vargas, Luis Ignacio Lozano-Espitia and other participants at the *XIV Ensayos Sobre Política Económica* Seminar organized by the *Banco de la República* de Colombia (Bogotá, October 2017) for helpful comments. All authors acknowledge the financial support of the *Spanish Ministerio de Economía y Competitividad* (ECO2013-46954-C3-2-R, ECO2013-44115-P and ECO2014-55221-P). Emili Tortosa-Ausina also acknowledges the financial support by *Universitat Jaume I* (P1·1B2014-17) and *Generalitat Valenciana* (PROMETEOII/2014/046). We also thank the helpful comments by Mario Loterszpil, which contributed to improve the overall quality of the article. The usual disclaimer applies.

1. Introduction

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

When planning this type of evaluations, the researcher should always consider which instrument will provide the clearest answers. In the field that concerns us, until recently, the researcher himself had to make an initial decision about the chosen research methods. In evaluating efficiency and productivity, the researcher can choose between parametric (which use econometric instruments to estimate production frontiers) (see, for instance, Lovell and Kumbhakar, 2000) and 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 error in the data is assumed to be non-existent. However, in the current state of the art, these differences have been alleviated; today it is possible to carry out deterministic or stochastic estimations with either tool.

A second criterion that should be taken into account is the existing knowledge on reference technology. In this way, taking into account the technological characteristics, one can opt for either parametric frontier estimation, with varying degrees of flexibility. When this is not the case, it could be counterproductive to arbitrarily impose a given functional form, so that the use of non-parametric methods is advisable

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

Our approach is different from the one carried out previously by, Afonso et al. (2005) for instance, because, apart from measuring the levels of efficiency for the Colombian public sector, we also attempt to shed some light on the extent to which the inefficiency detected is a burden that prevents achieving higher levels of economic growth. Answering that question demands statistically significant results, reason why considering parametric approaches might be more convenient given the challenges that non-parametric techniques face 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 make it possible to interpret the results obtained. Next, we detail the data used and its descriptive statistics. Later on, the results will allow us to analyze Colombia´s position with a greater level of detail. The final conclusions close the contents of this article.

2. Measuring Efficiency

With the modern theory of production as our starting point, we derived the concept of efficiency from productivity estimates. With 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. 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 the level corresponding to the units with the better performance (*best-practice* units).

Figure 1 shows, for example, a simplified representation of efficiency estimates. It represents a very simple case in which only one output is produced for 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, which 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 $_0$lie above these levels of production. For the inefficiency unit (P_0), the coefficient ($X_0 P_0 / X_0 P^*$) 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 to describe 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. T 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 considered segment of the border. 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 point P^*_0.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 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 t h e 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] by estimating production

[1] As the analysis is at country level, 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 that we could obtain information for, 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 Colombia´s relative position 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, given that we are interested in going beyond simple technological descriptions and, in a second approximation, we will re-estimate the production frontiers to corroborate if efficiency levels depend upon the government quality of each country (Knack, 2002). This will help us verify if there is empirical evidence of a significant relationship between the levels of government quality (and the efficiency of national public institutions) and 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 aggregate efficiency levels of all its productive sectors. In this sense, we expect to check whether the 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 scope of this article). Moreover, as one referee pointed out, this process does not correct the otential bias caused by the aggregation, as stated by Oh (2012).[2] Specifically, 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 vast literature that has been using data from the Penn World Table (PWT) database to evaluate 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 allow for comparisons among countries at different stages of economic development. In addition, the 8th release of the PWT[3] (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 makes it possible to compare among prices of goods and services, which include purchasing power parity (PPP) adjustments. Therefore, we facilitate the comparison of magnitudes expressed in real terms between 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 use nonparametric estimation techniques. In contrast, our methods will be based on stochastic frontier analysis because, apart from finding out the inefficiency level assignable to the Colombian economy, we are also interested in understanding to what extent the estimates

3 Regularly 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, in 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 Worldwide Governance Indicators database, 2014,[4] which provides data on government effectiveness for the 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 million. 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,

[4] Data 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 corresponding to their human and physical capital.

Results in column (3) (Table 3) correspond to an overly restrictive specification of technology, and it is natural to inquire whether this 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 the 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 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 an 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, 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 that could explain 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 of the favorable effect that the quality of public institutions has on the real economy; either via the direct participation of the public sector or due to governments´ 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 of 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 government quality ,[5] confirming that, in fact, the public sector´s behavior 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 economy´s efficiency levels. 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.

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]

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

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

4.2. Results Corresponding to growth barriers

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 of the public sector´s effect 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

$$growth_{it} = \beta_0 + \beta_1 PUBLIC_{it} + \beta_2 PUBLIC_{it} \times EFF_{it} + \sum_{j=3} \beta_j X_{it} + \varepsilon_{it} \quad (4.1)$$

where $growth_{it}$ is the real GDP change for country *i* in year *t*, $PUBLIC_{it}$ reflects the percentage of public spending in 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 GDP per capita). Actually, in our application, the variable regarding the efficiency of the public sector is taken from the World Bank´s database, 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 public sector´s 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 on growth) and, finally, a negative sign for β_4 (this would confirm the existence of macroeconomic convergence, since countries with initially lower levels of GDP per capita 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 public management efficiency. 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 grow more slowly.

Delving more deeply into the relationship between economic growth and the size of the public sector, and taking expression (4.1) into account, it is easy to determine the necessary conditions for public management to contribute positively to economic growth:

$$\beta_1 PUBLIC_{it} + \beta_2 PUBLIC_{it} \times EFF_{it} > 0 \qquad (4.2)$$

which, finally, offers us the following condition:

$$EFF_{it} > \frac{\beta_1}{\beta_2} \qquad (4.3)$$

Those countries meeting Equation (4.3) are able to, given the high levels of efficiency of their public administrations, 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 Chile is the only Latin American country present in the subset of what we might refer to as "virtuous practices".

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. There are three studies in the literature Kumar and Russell (2002), Henderson and Russell (2005) and Badunenko et al. (2013), that use the same data sources to estimate efficiency at the country level, even though 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 sample[7]. It should be remembered that the efficiency indicator goes from zero (for very low efficiency levels) to one (for high efficiency levels).

efficiency level 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 efficiency level practically coincides 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 process of catching-up that would allow Colombia to approach the efficiency frontier, especially in recent years, even though improvements are still pending because its level of efficiency and productivity does not even reach half of the maximum possible level. 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 do not completely coincide.

A more detailed analysis will allow us to determine the role of government quality at the estimated levels. For this, we will take compare the results of Models II, III and IV. 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 the 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 ones 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.

[7] As 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 state that an improvement of the government´s quality and, in particular, of the effectiveness of Colombian public organizations, would positively impact other economic sectors. In this sense, the information in column (4) makes it clear that there is great potential for improvement.

4.4. Results Related to Obstacles to Growth in Colombia

Let us now examine 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 efficiency level being higher than a certain level, whose theoretical condition is expressed in Equation (4.3), is the *sine qua non* condition for public spending to generate economic growth in the country.

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. This is graphically 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 of the line in 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 Colombian public management must face in order to avoid its existence supposing a brake to economic growth.

Finally, let us perform 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 indicate 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 scenario under which the public sector could generate positive economic growth, would be the improvement of 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 explain the discrepancies in countries´ living standards and economic progress. 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, we confirm the proposition that emerges from the institutional theory, which states that the existing institutions in each country have a decisive impact on their economic performance. 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 translated into higher growth rates. These estimations also allowed us to determine what the necessary conditions are for public spending to be a driver, and not a hindrance, to economic growth. 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 that can be drawn from this, is 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. As well as 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 this issue the attention it requires may involve maintaining or even widening the discrepancies among different areas of economic influence.

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Appendix A Formalization of the Stochastic Parametric Frontier

In this appendix, we present the characteristics of the Cobb-Douglas production function and also of 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:

$$ln(y_{it}) = \beta_0 + \sum_{j=1}^{2} \beta_j ln(x_{jit}) + \theta t + \varepsilon_{it} \qquad (A.1)$$

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 ($N(0, \sigma^2)$). The parameter θ_{ε}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, *cæteris paribus*, the same amount of inputs make it possible to produce 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 ($0 < \xi_{it} \leq 1$). When $\xi_{it} = 1$ the unit under analysis is producing its maximum possible output level, given the consumed inputs x_{jit} . When $\xi_{it} < 1$, the unit is not producing at its potential level.[8]

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

$$ln(y_{it}) = \beta_0 + \sum_{j=1}^{2} \beta_j ln(x_{jit}) + \theta t + \upsilon_{it} - u_{it} \qquad (A.2)$$

The interpretation of the coefficients υ_{it} and u_{it} is as follows: υ_{it} represents the measurement and specification error that is assumed to be independently distributed among the observations $N(0, \sigma^2_\upsilon)$ with a symmetric distribution. The term u_{it} has a non-negative distribution[9] and represents inefficiency. In the empirical part we assume that u_{it} is exponentially distributed with variance σ^2_u. It is also assumed that υ_{it} and u_{it} are mutually independent.

A.3 Frontier Estimation with Panel Data

This model is described by the following expression:

$$ln(y_{it}) = \beta_0 + \sum_{j=1}^{2} \beta_j ln(x_{jit}) + \theta_t t + \upsilon_{it} - u_{it} \qquad (A.3)$$

[8] The output has to be strictly positive ($y_{it} > 0$), which implies that the technical efficiency coefficients have to be strictly positive ($xi_i > 0$).

[9] In the literature we can find different ways to define the distribution for u_i. Aigner et al. (1977) assume a half-normal distribution ($u_{it} \sim N^+(0, \sigma^2_u)$), 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.

Where υ_{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:

$$u_{it} = exp\{-\eta(t - T_i)\}u_i \quad (A.4)$$

where T_i refers to the last available period, η the trend parameter ($\eta > 0$ indicates that the level of inefficiency decreases with time and $\eta < 0$ reports that the degree of inefficiency increases over time). u_i and υ_{it} are assumed to be 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 that were found. The initial proposals come from 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:

$$u_{it} = z_{it}\delta + W_{it} \quad (A.5)$$

where the random variable W_{it} is distributed as a
σ^2, the truncation point being $-z_{it}\delta$

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

estimation of the parameters of the stochastic frontier, and o f the model that explains the levels of inefficiency, occurs from the following expression:

$$ln(y_{it}) = \beta_0 + \sum_{j=1}^{2} \beta_j ln(x_{jit}) + \theta_t t + \upsilon_{it} - (z_{it}\delta + W_{it}) \quad \text{(A.6)}$$

A.5 The Translog Production Function

The translog production function is an expansion of the Cobb-Douglas function, created to overcome its difficulties and inflexibilities. 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:

$$ln(y_{it}) = \beta_0 + \sum_{j=1}^{2} \beta_j ln(x_{jit}) + (1/2) \sum_{j=1}^{2} \sum_{k=1}^{2} \beta_{jk} ln(x_{jit}) ln(x_{kit}) + \theta t + \varepsilon_{it} \quad \text{(A.7)}$$

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 each observation´s condition of monotonicity, 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:

$$= {}_{ji} + {}_{ki} = \frac{\delta ln(y_{it})}{ln(x_{jit})} + \frac{\delta ln(y_{it})}{ln(x_{kit})} = \beta_j + \sum_{k=1}^{2} \beta_{jk} ln(x_{kit}) + \beta_k + \sum_{j=1}^{2} \beta_{kj} ln(x_{jit}) =$$

$$= \beta_j + \beta_k + \sum_{j=1}^{2} \sum_{k=1}^{2} \beta_{jk} ln(x_{kit})^{1} \quad \text{(A.8)}$$

Appendix B List of analyzed countries

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

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Continent/group	**Country**	**Code**
Africa	Sao Tome and Principe	STP
Africa	Senegal Sierra	SEN
Africa	Leone South	SLE
Africa	Africa Sudan	ZAF
Africa	Swaziland	SDN
Africa	Tanzania Togo	SWZ
Africa	Tunisia	TZA
Africa	Uganda	TGO
Africa	Yemen	TUN
Africa	Zambia	UGA
Africa	Zimbabwe	YEM
Africa	Bangladesh	ZMB
Africa	Cambodia	ZWE
Asia	Hong Kong	BGD
Asia	India	KHM
Asia	Indonesia	HKG
Asia	Laos	IND
Asia	Macao	IDN
Asia	Malaysia	LAO
Asia	Mongolia	MAC
Asia	Nepal	MYS
Asia	New Zealand	MNG
Asia	Pakistan	NPL
Asia	Panama	NZL
Asia	Philippines	PAK
Asia	Singapore	PAN
Asia	Sri Lanka	PHL
Asia	Suriname	SGP
Asia	Taiwan	LKA
Asia	Tajikistan	SUR
Asia	Thailand	TWN
Asia	Turkmenistan	TJK
Asia	Uzbekistan	THA
Asia	Vietnam	TKM
Asia	Argentina	UZB
Asia	Bolivia	VNM
Latinoamérica	Brazil	ARG
Latinoamérica	Colombia	BOL
Latinoamérica	Costa Rica	BRA
Latinoamérica		COL
Latinoamérica		CRI

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Continent/group	**Country**	**Code**
Latinoamérica	Dominica	DMA
Latinoamérica	Dominican Republic	DOM
Latinoamérica	Ecuador	ECU
Latinoamérica	El Salvador	SLV
Latinoamérica	Grenada	GRD
Latinoamérica	Guatemala	GTM
Latinoamérica	Honduras	HND
Latinoamérica	Paraguay	PRY
Latinoamérica	Peru	PER
Latinoamérica	Uruguay	URY
Latinoamérica	Venezuela	VEN
No OCDE	Albania	ALB
No OCDE	Antigua and Barbuda	ATG
No OCDE	Armenia	ARM
No OCDE	Azerbaijan	AZE
No OCDE	Bahamas	BHS
No OCDE	Bahrain	BHR
No OCDE	Barbados	BRB
No OCDE	Belarus	BLR
No OCDE	Belize	BLZ
No OCDE	Bermuda	BMU
No OCDE	Bhutan	BTN
No OCDE	Bosnia and Herzegovina	BIH
No OCDE	Brunei	BRN
No OCDE	Bulgaria	BGR
No OCDE	China	CHN
No OCDE	Croatia	HRV
No OCDE	Cyprus	CYP
No OCDE	Fiji	FJI
No OCDE	Georgia	GEO
No OCDE	Jamaica	JAM
No OCDE	Jordan	JOR
No OCDE	Kazakhstan	KAZ
No OCDE	Kuwait	KWT
No OCDE	Kyrgyzstan	KGZ
No OCDE	Latvia	LVA
No OCDE	Lebanon	LBN
No OCDE	Lithuania	LTU
No OCDE	Macedonia	MKD
No OCDE	Malta	MLT
No OCDE	Moldova	MDA

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Continent/group	**Country**	**Code**
No OCDE	Montenegro	MNE
No OCDE	Oman	OMN
No OCDE	Qatar	QAT
No OCDE	Romania	ROU
No OCDE	Russia	RUS
No OCDE	Saudi Arabia	SAU
No OCDE	Serbia	SRB
No OCDE	St. Kitts & Nevis	KNA
No OCDE	St. Lucia	LCA
No OCDE	St.Vincent & Grenadines	VCT
No OCDE	Syria	SYR
No OCDE	Trinidad & Tobago	TTO
No OCDE	Ukraine	UKR
OCDE	Australia	AUS
OCDE	Austria	AUT
OCDE	Belgium	BEL
OCDE	Canada	CAN
OCDE	Chile	CHL
OCDE	Czech Republic	CZE
OCDE	Denmark Estonia	DNK
OCDE	Finland	EST
OCDE	France	FIN
OCDE	Germany	FRA
OCDE	Greece	DEU
OCDE	Hungary	GRC
OCDE	Iceland	HUN
OCDE	Ireland	ISL
OCDE	Israel	IRL
OCDE	Italy	ISR
OCDE	Japan	ITA
OCDE	Korea, Republic of	JPN
OCDE	Luxembourg	KOR
OCDE	Mexico Netherlands	LUX
OCDE	Norway	MEX
OCDE	Poland	NLD
OCDE	Portugal	NOR
OCDE	Slovak Republic	POL
OCDE	Slovenia	PRT
OCDE	Spain	SVK
OCDE		SVN
OCDE		ESP

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Continent/group	**Country**	**Code**
OCDE	Sweden	SWE
OCDE	Switzerland	CHE
OCDE	Turkey	TUR
OCDE	United Kingdom	GBR
OCDE	United States	USA

Tables and figures

Table 1: Definition of the Relevant Variables

Type of variable	Name	Definition
Output	y : *rgdpo*	Country's Gross Domestic Product, PPP adjusted, in thousands of constant 2005 US$ Input
Input	x_l : *emp*	Number of workers (millions)
	x_{hc} : *hc*	Human capital index (per person), based on schooling years (Barro & Lee 2013), as well as on returns on education (Psacharopoulos 1994)
Input	x_k : *rkna*	Capital stock (thousands of constant 2005 US$)
Government quality	*VAA*: 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	*PSAV*: 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	*GE*: Government Effectiveness	It captures perceptions of the quality of public services, the quality of the civil service and its degree of independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies.
Government quality	*RQ*: 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	*ROL*: 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	*COC*: 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.

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

Table 2: Summary Statistics for the Relevant Variables

Variable	Min.	Q1	Median	Mean (arithmetic)	Q3	Max.	NA's
rgdpo	131	9564	31884	329570	192729	13193478	0
emp	0.0248	0.9636	3.4269	16.5755	9.414	784.4269	56
hc	1.136	2.037	2.59	2.466	2.886	3.619	528
rkna	354	24824	86489	1050831	595339	44642460	0
VAA	-2.12	-0.85	-0.10144	-0.02798	0.87	1.83	20
PSAV	-3.18481	-0.71201	0.03166	-0.06851	0.74022	1.66807	33
GE	-1.982	-0.7009	-0.13012	0.04409	0.71765	2.42965	33
RQ	-2.41273	-0.58195	-0.06714	0.06866	0.79836	2.24734	31
ROL	-2.22985	-0.8033	-0.19315	-0.02464	0.73572	1.99964	23
COC	-2.05746	-0.77355	-0.24004	0.01997	0.64782	2.58562	31

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

Table 3: Estimation of the Parameters of the Production Function

Variables (1)	**Parameters (2)**	**Panel data Model I (3)**	**Panel data Model II (4)**	**Panel data Model III (5)**	**Panel data Model IV (6)**
Constant	β_0	0.8778534 ***	0.7043481 ***	0.3254291 ***	0.3140554 ***
$ln(x_{hc})$	β_1	0.4356712 ***	0.2272791 ***	0.2459954 ***	0.2410062 ***
$ln(x_k)$	β_2	0.4800882 ***	0.6430666 ***	0.7646516 ***	0.7463103 ***
$(1/2)\, ln(x_{hc})^2$	β_{11}		0.032887	0.158808 ***	0.1345746 ***
$(1/2)\, ln(x_k)^2$	β_{22}		0.1035062 ***	0.1470096 ***	0.1517269 ***
$ln(x_{hc})\, ln(x_k)$	β_{12}		-0.0784149 ***	-0.143377 ***	-0.1362771 ***
t	θ_t	0.0063906 ***	-0.0040469 *	-0.0015002	-0.0020182
$t\, ln(x_{hc})$	θ_{t1}		-0.0022214 *	-0.0019034	-0.0011606
$t\, ln(x_k)$	θ_{t2}		0.0035924 ***	0.0014877	0.0001865
$(1/2)\, t^2$	θ_{tt}		0.0002443	-0.0002028	-0.0002182
Ineficiency Variable					
Trend		0.0063906 ***	0.0142043 ***		
Lambda	σ_u / σ_v	0.983667 ***	0.9784019 ***	0.70823876 ***	0.7405273 ***
Sigma[2]	$\sigma_u^2 + \sigma_v^2$	1.2853761 ***	0.9382679 ***	0.28341925 ***	0.2765146 ***
Mean efficiency		0.427771	0.460832	0.7011875	0.6948282
Government quality				-0.6145916 ***	
Government effectiveness	Z				-0.7566569 ***
Num. observat.		2144	2144	2128	2128
Num. groups		134	134	133	133

*,**,*** indicates significance at the 10%, 5.0% and 1.0% levels, respectively.
Model I: panel regression, *Cobb-Douglas* production function.
Model II: panel regression, *translog* production function.
Model III: panel regression, *translog* production function.
Model IV: panel regression, *translog* production function.
Source: own elaboration.

Table 4: Estimation of Growth Drivers

Variables (1)	Parameters (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	-0.13534	***	-0.176622	***	-0.1617783	***
(PUBLIC% ∗ EFF)	β_2	0.137599	*	0.166404	*	0.1351016	
Investment(%)	β_3	0.059975	*	0.056371		0.0528533	
$Log(GDP/population)$	β_4	-0.005439	*	-0.00526	*	-0.006307	**
Adjusted R^2		0.046		0.058			
Num. observat.		1976		1995		1995	
Num. groups				133		133	

*,**,*** indicates significance at the 10%, 5.0% and 1.0% levels, respectively.
Model I: pool regression
Model II: panel regression (PE) Model
III: panel regression (frontier)

Source: own elaboration.

Table 5: Estimation of the Aggregate Efficiency of Colombia's Economy (comparison with previous studies)

Kumar and Russell (2002)	**1965**	**1990**
Colombia	0.41	0.45
Latin America	0.66	0.56
OECD	0.75	0.8
Total sample	0.64	0.65
Henderson and Russell (2005)	**1965**	**1990**
Colombia	0.48	0.54
Latin America	0.72	0.58
OECD	0.79	0.78
Total sample	0.68	0.67
Badunenko, Henderson and Russell (2005)	**Average 1965-2007**	
Colombia	0.39	
Latin America	0.48	
OECD	0.6	
Total sample	0.5	
Our estimations: Model II	**Average 1996-2011**	
Colombia	0.48	
Latin America	0.42	
OECD	0.65	
Total sample	0.46	

Source: own elaboration.

Table 6: Estimation of the Aggregate Efficiency of Colombia's Economy

	Efficiency Model II (1)	Efficiency controlling for government's quality (2)	Impact of government s quality on inefficiency (3)	Government's quality level (4)
Model III				
Colombia	0.48	0.7	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	0.7	54.06%	0
Model 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	0.7	54.06%	0.04

Source: own elaboration.

Figure 1: Graphical Representation of the Frontier Evaluation

Figure 2: Production Frontiers and Returns to Scale

Figure 3: Synthesis of the Analytical Model

Figure 4: Distribution of Scale Economies

Figure 5: Distribution of Technical Change

Figure 6: Economic Growth and Government Effectiveness

Figure 7: Economic Growth and Size of the Public Sector