Corporate Taxes and Firms' Performance: Evidence from an Emerging Economy*

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Abstract

Corporate taxes play an important role in a firm's decision-making as they are part of the cost of capital. Thus, understanding the effect of taxes on the performance of firms in the context of frequent tax reforms, as is the case of Colombia, is of great relevance. We used the meta-frontier stochastic techniques, which allow us to estimate in two steps the technical efficiency of firms within each economic sector and between economic sectors in relation to the set of firms in the country. Then, using quantile regression analysis, we estimate both the effect of corporate taxation on firm performance as well as the effect of efficiency on firms' tax payments. Results indicate that firms in some economic sectors could be benefiting from better production conditions, and that the most efficient firms

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within each sector paid more taxes as a share of assets. However, when compared to the meta-frontier, firms with higher efficiency paid less taxes, suggesting differences in the firms' tax burden across economic sectors.

Keywords: Corporate taxes; stochastic frontier analysis; firm performance.
JEL *Classification:* C23, D22, H25.

Impuestos corporativos y desempeño de las empresas: evidencia para una economía emergente

Resumen

Los impuestos corporativos juegan un papel importante en la toma de decisiones de las empresas, ya que son parte del costo de uso del capital. Por lo tanto, estudiar la relación entre los impuestos corporativos y el desempeño de las empresas es de gran relevancia, en un contexto de frecuentes reformas tributarias, como es el caso de Colombia. Para el análisis se utilizan técnicas de meta-frontera estocástica que permiten estimar, en dos etapas, la eficiencia técnica de las empresas dentro de cada sector económico y entre sectores económicos en relación con el conjunto de empresas en el país. Luego, se utiliza el análisis de regresión cuantílica para estimar tanto el efecto de los impuestos corporativos sobre el desempeño de las empresas, como el efecto de la eficiencia sobre los pagos de impuestos. Los resultados indican que las empresas, en algunos sectores económicos, podrían beneficiarse de mejores condiciones de producción y que las más eficientes dentro de cada sector pagan más impuestos, como proporción de sus activos. Sin embargo, cuando se comparan con la frontera de producción global del país, las empresas con mayor eficiencia pagan menos impuestos, lo que sugiere diferencias en la carga tributaria entre sectores económicos.

Palabras clave: impuestos corporativos; frontera estocástica; desempeño empresas.
Clasificación JEL*:* C23, D22, H25.

Impostos corporativos e desempenho das empresas: evidência para uma economia emergente

Resumo

Os impostos corporativos desempenham um papel importante na tomada de decisões de empresas, pois fazem parte do custo do uso de capital. Portanto, estudar a relação entre os impostos corporativos e o desempenho das empresas é de grande relevância, em um contexto de frequentes reformas tributárias, como é o caso da Colômbia. Para a análise, são utilizadas técnicas de metafronteira estocástica para estimar, em duas etapas, a eficiência técnica das empresas dentro de cada setor econômico e entre setores econômicos em relação ao conjunto de empresas do país. Na sequência, a análise de regressão quantílica é usada para estimar tanto o efeito dos impostos corporativos no desempenho das empresas quanto o efeito da eficiência nos pagamentos de impostos. Os resultados indicam que as empresas, em alguns setores econômicos, poderiam se beneficiar de melhores condições de produção e que as mais eficientes dentro de cada setor pagam mais impostos, proporcionalmente aos seus ativos. No entanto, quando comparadas à fronteira produtiva global do país, as empresas com maior eficiência pagam menos impostos, o que sugere diferenças na carga tributária entre os setores econômicos.

Palavras-chave: impostos corporativos; fronteira estocástica; desempenho das empresas.
Classificação JEL*:* C23, D22, H25.

Introduction

Corporate taxes have a central role in a firm's decision-making, which in turn affects economic activity and has implications for a country's fiscal accounts (Hanlon & Heitzman, 2010). Taxes might affect the performance of firms through different channels. Vartia (2008) points out three specific channels through which taxes can affect the performance of companies. Specifically, taxes can distort the efficient allocation of resources, affect the funding incentives by impacting the firm's expected return after taxes and can favor or discourage investment in research and development by affecting its after-tax cost.

During the last decades, Colombian governments have approved frequent tax reforms. The tax system is complex and offers several tax incentives to firms. In particular, the government grants tax credits and discounts that may benefit some firms more than others, depending on characteristics such as the sector where they operate, the size of the firm, its location, and its debt ratio, among others (Garay-Salamanca & Espitia-Zamora, 2019). For example, in 2015, the tax benefits granted by the Colombian government to companies amounted to 0.8 % of GDP (Parra et al., 2016). Thus, studying the relationship between corporate taxes and the performance of firms might shed some light on the degree of effectiveness of the tax policies implemented in the country. The analysis considers differences across economic sectors since some industries could be more affected by taxes than others, given that the effective tax burden varies with the capital-labor ratio, the portfolio of assets, and the level of indebtedness, among other firms' characteristics. Moreover, the government grants tax benefits to firms of specific economic sectors.

An analysis of firms' efficiency from different economic sectors should consider they use different technologies to transform inputs into outputs. For instance, technologies used in firms belonging to the trade sector differ widely from those used in the agricultural one. Thus, firm performance, measured as the ability to obtain the maximum product given a set of inputs and a fixed technology, cannot be evaluated under the same production frontier. For this reason, our empirical analysis was carried out using meta-frontier stochastic techniques, which allowed us to estimate the efficiency of firms within each economic sector and between them in relation to the set of firms in the country. Specifically, we follow the two-steps methodology proposed by Huang et al. (2014), which allowed us to consider that firms operating in different economic sectors should be assessed under different production frontiers. Then, using quantile regression analysis, we estimated both the effect of corporate taxation on firm performance, as well as the reverse causality, considering the behavioral effects of firms on tax changes.

The empirical analysis was carried out for two periods, 2010-2012 and 2013-2015, using a panel of firms belonging to the following economic sectors: agriculture, forestry and fishing, construction, manufacturing, wholesale and retail trade, and services.[1] This database allows us to evaluate the effect of taxes across different economic sectors and through time. During the first period, the national government adopted two major tax reforms, in 2009 and 2012, respectively. In the second period, the tax reform was approved in 2014. These reforms adjusted the corporate tax rate, the tax base, and the tax benefits granted to firms. Indeed, the corporate income tax rate had several modifications, during this period. For the period 2008-2012, the prevalent statutory rate was 33 %. The 2012 tax reform reduced the tax rate to 25 %, but at the same time created a new tax on corporate income, named CREE, with a temporary rate of 9 % between 2013 and 2015. The revenues from this tax were used to finance the social security contributions of employees earning less than ten legal monthly minimum wages that companies previously paid directly to the country's social security system. The 2014 reform kept the tax rate at 9 % and established a surtax on the CREE tax of 5 % in 2015. This tax and the surtax were eliminated in the tax reform of 2016.

Although from an international perspective, the corporate statutory tax rate is high (Melo-Becerra et al., 2017), the Colombian tax system provides generous benefits and offers special regimes to specific economic sectors and firms, affecting the tax burden that firms effectively pay. For example, between 2004 and 2010, there was a tax deduction of 30-40 percent from the value of the investment on fixed assets. Other tax exemptions favored the use of new forest plantations, the selling of wind electricity generated energy, and the investment in social interest housing, among others. The legislation also granted a preferential rate of 9 % for hotel services, ecotourism services, and publishing companies of scientific and cultural books and journals. It also granted preferential tax rates for economic activities carried out in areas of the country affected by the armed conflict and for newly

1 The selected economic sectors represented on average the 47.8 % of Colombian GDP during 2010-2015, based on the National Department of Statistics (DANE). Other important sectors in Colombia's economy—such as mining, financial, real estate, public administration, education, and human health have a share of 35.1 %, were not included due to the complexity and heterogeneity of their production technology.The service sector includes accommodation and food service activities, information and communication, professional, scientific, and technical activities, administrative and support service activities, and other service activities.

incorporated small and medium-sized firms and non-profit organizations (Perret & Brys, 2015).

Recent literature has focused on the evaluation of the taxes on corporate sector effect—Table A. 1 in the appendix summarizes the main contributions to this literature. Most of the papers use firm-level data for the calculations, and the main analytical techniques used to determine the effect of taxes are the difference in difference approach and the ordinary least squares regression. Many empirical studies provide evidence that taxes negatively affect the corporate sector. In particular, Bartolini (2018), Schwellnus and Arnold (2008), Vartia (2008), and Gemmell et al. (2018) found that higher taxes reduced productivity, measured as total factor productivity (TFP). Meanwhile, results from Schwellnus and Arnold (2008), Vartia (2008), Zwick and Mahon (2017), Djankov et al. (2010), and Maffini et al. (2019) indicate a negative effect between taxes and investment. Similarly, Mukherjee et al. (2017) and Djankov et al. (2010) found that more taxes diminish entrepreneurship and innovation in terms of patent and business generation. In contrast, Orjinta and Agubata (2017) and An (2012) show that taxation plays an important role in the companies' capital structure due to a positive relationship with debt decisions. It is worth noting the mixed results on the effect of taxes on firm performance. Specifically, Dabla-Norris et al. (2017) indicate that taxes have a positive effect on labor productivity, sales growth, and TPF measures; Lazar and Istrate (2018) found the opposite regarding the return on assets (ROA), and Kaunitz and Egebark (2017) found no incidence on exit rate and profitability.

Taking the above aspects into consideration, the main contribution of this paper is to study the relationship between corporate taxation and the performance of firms in an emerging economy characterized by frequent tax reforms and considerable tax credits granted to companies. In addition, a novel feature of our analysis is the use of stochastic meta-frontier techniques to assess firm performance. Meta-frontier stochastic techniques allow us to compare under the same production frontier firms operating in different economic sectors that have different sets of input-output combinations and tax burdens. Then, these results are used, through a quantile regression analysis, to evaluate if tax payments have an impact on firms' performance and whether more efficient companies pay more or fewer taxes in a country that has been affected by continuous violence.

Results indicate that firms can obtain significant gains in terms of performance in different economic sectors. Nevertheless, companies of some economic sectors could benefit from better economic conditions, allowing them to be closer to the production potential of the country. When firms are classified by size, larger firms perform better compared to medium and small ones. Regarding the effect of corporate taxation on firm performance and the reverse causality, corporate taxes have a negative effect on the efficiency of firms. Besides, from the quantile regression analysis, we found that firms closer to the sector-specific frontiers paid on average higher corporate taxes in all quantiles of the tax distribution, but when compared to the meta-frontier, more efficient firms paid lower taxes. Lastly, it is worth mentioning that high levels of violence negatively affect firm efficiency.

This paper is divided into five sections, including the introduction. Section two presents the empirical strategy, which considers the stochastic meta-frontier estimations and the quantile regression analysis. Section three provides information about the data used in the analysis. In section four, we present and discuss the results of the estimations. The final section is the conclusions.

Empirical Strategy

Technical efficiency of firms operating in different economic sectors may not be comparable under the same production frontier since companies face different technologies and consequently have different sets of input-output combinations. To overcome this difficulty, in this paper, we used meta-frontier stochastic techniques to compare the efficiency of firms within each economic sector and between each sector, and the meta-frontier, which comprises firms belonging to all sectors.[2] Bearing in mind that meta-frontier models are recommended when the companies of the different groups, in our case economic sectors, use different technologies, but the same types of inputs to produce the same types of products, the variables of the firms are expressed in monetary terms, so that they can be compared between sectors. The product was measured using the operating income, and, as inputs, we considered the costs of raw materials, direct labor costs, and interest payments. In this methodology, in the first stage, the production frontiers were estimated for the firms of each economic sector. Then, we estimated the meta-frontier, considering the firms of all the economic sectors and the results obtained from the specific-sector frontiers.

This methodology was first introduced by Battese and Rao (2002), Battese et al. (2004), and O'Donnell et al. (2008), who used a two-step procedure to estimate the meta-frontier. In the first stage, these authors estimated the

2 This section relies heavily on Huang et al. (2014) and Melo-Becerra and Orozco-Gallo (2017).

specific frontier for each group using stochastic frontier analysis. In the second stage, Data Envelopment Analysis (DEA) was used to estimate the meta-frontier. Recently nevertheless, the meta-frontier has been estimated using stochastic frontier techniques (Huang et al., 2014). This approach has the advantage of directly estimating the technological gaps between each sector's specific frontier and the meta-frontier and identifying the source of variation across economic sectors.

Traditionally, stochastic frontier analysis is used to obtain technical efficiency for each production unit from the estimation of a production frontier, as follows:

$$Y_{jit} = f_t^i\left(X_{jit}\right)e^{V_{jit}-U_{jit}} \tag{1}$$

Where Y_{jit} corresponds to the output of firm i in sector j at a time t; X_{jit} is the input vector used by a firm i in sector j at a time t; V_{jit} is distributed independently and identically as $N\left(0,\sigma_v^{j^2}\right)$, that captures the stochastic noise, assuming that deviations from the frontier are not totally under the control of the firm; finally, U_{jit} is a variable that measures technical inefficiency that only takes non-negative values.[3] Furthermore, it is assumed that Y_{jit} is independent of U_{jit}, which follows a truncated-normal distribution, N+($\mu j(Z_{jit})$, $\mu j^2(Z_{jit})$); that is, the distribution is truncated from below at zero and with mode at $\mu j(Z_{jit})$. Based on Battese and Coelli (1995), the methodology assumes that the inefficiency term is a function of M environmental variables, Z_{jit}, that are not under the control of the firms but affect their performance, that is,

$$U_{jit} \sim N\left[\delta_0 + \sum_{i,j=1}^{M} \delta_{jt} Z_{jit} \sigma^2\right] \tag{2}$$

Where δ_0 and δ_{ij} are the parameters to be estimated.

From the estimation of the first stage, we obtained an expression for each firm's technical efficiency with respect to the specific sector frontier, as follows:

$$TE_{it}^{j} = \frac{Y_{jit}}{f_t^j\left(X_{jit}\right)e^{V_{jit}}} = e^{-U_{jit}} \tag{3}$$

3 If a firm is completely efficient, $U_{jit} = 0$ and the distance to the frontier, completely random.

Then, in the second stage, the meta-frontier, $f_t^M\left(X_{jit}\right)$, encompasses all sectoral frontiers, $f_t^j\left(X_{jit}\right)$, according to the following expression:

$$f_t^j\left(X_{jit}\right) = f_t^M\left(X_{jit}\right)e^{-U_{jit}}, \forall j, i, t \tag{4}$$

Where $U_{jit}^M \geq 0$ and $f_t^M(\cdot) \geq f_t^j(\cdot)$. Moreover, it is possible to compute the distance between the specific production frontier and the meta-frontier, namely the technological gap ratio (TGR), which is given by:

$$TGR_{it}^j = \frac{f_t^j\left(X_{jit}\right)}{f_t^M\left(X_{jit}\right)} = e^{-U_{jit}} \leq 1 \tag{5}$$

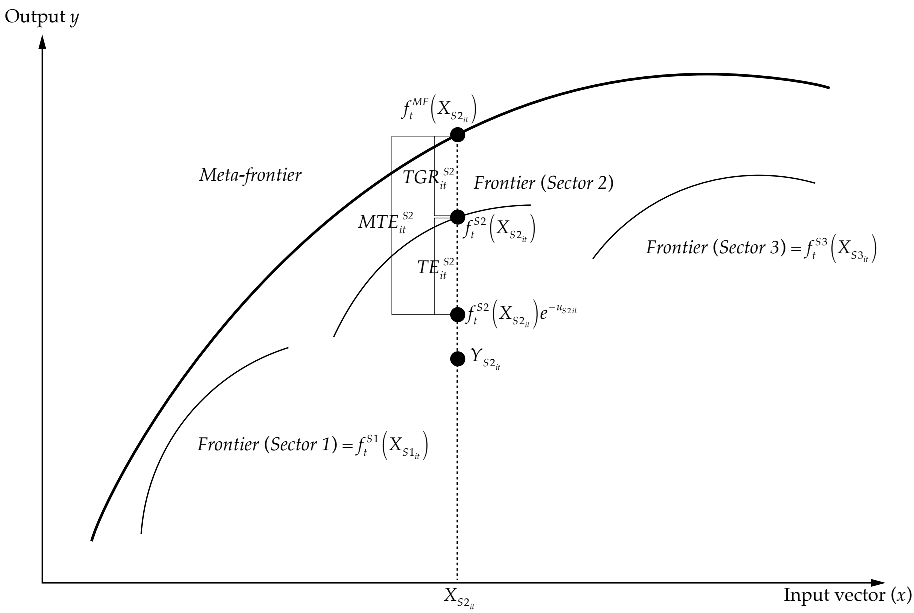

Figure 1. Meta-Frontier Production Function for Different Economic Sector Frontiers

Source: Based on Huang et al. (2014).

In addition to the TGR_{it}^{j}, it is possible to obtain the technical efficiency of each firm with respect to the frontier of its sector TE_{it}^{j}, and a random noise component $\left(\frac{Y_{jit}}{f_t^j\left(X_{jit}e^{-u_{ijt}}\right)}=e^{V_{itj}}\right)$ (Huang et al., 2014). Thus,

$$\frac{Y_{jit}}{f_t^M\left(X_{jit}\right)}=TGR_{it}^{j}\times TE_{it}^{j}\times e^{V_{jit}} \tag{6}$$

Given that the random component is obtained from the stochastic frontier estimation, equation (6) can be written as:

$$MTE_{jit}=\frac{Y_{jit}}{f_t^M\left(X_{jit}\right)}=TGR_{it}^{j}\times TE_{it}^{j}\times e^{V_{jit}} \tag{7}$$

Where MTE_{jit} corresponds to the firm's technical efficiency with respect to the meta-frontier $\left(f_t^M(\cdot)\right)$. As an illustration, Figure 1 shows for a given input vector x and output y the combination of the *ith* firm in sector j the corresponding TE, TGR, and MTE.

In the estimation of the meta-frontier, Huang et al. (2014) used the estimated error from each sector-specific frontier as follows:

$$\ln\hat{f}_t^j\left(X_{jit}\right)-\ln f_t^j\left(X_{jit}\right)=e_{jit}-\hat{e}_{jit} \tag{8}$$

Then, the relation of the estimated errors to the meta-frontier can be written as:

$$\ln\hat{f}_t^j\left(X_{jit}\right)=\ln f_t^M\left(X_{jit}\right)-U_{jit}^M+V_{jit}^M,\ \forall i,t,j=1,\ldots,J \tag{9}$$

Where $V_{jit}^M=e_{jit}-\hat{e}_{jit}$ and $\ln\hat{f}_t^j\left(X_{jit}\right)$ correspond to the sector-specific frontier from the first stage estimation of the logarithmic transformation in equation (1), which is estimated j times:

$$\ln Y_{jit}=\ln f_t^j\left(X_{jit}\right)+V_{jit}-U_{jit},\ i=1,\ldots,N;\ t=1,\ldots,T \tag{10}$$

Then, equation 9, which resembles the traditional stochastic frontier regression, was estimated by pooling together all *j* sector estimations. The sector-specific frontier and the meta-frontier were estimated by maximum likelihood.

Moreover, it was assumed that the non-negative technological gap $\left(U_{jit}^{M}\right)$ is distributed as truncated-normal and independent from VM, which is asymptotically normally distributed with zero mean. Also, the estimated *TGR* is a function of the environmental variables (Z_{jit}) via the mode $\mu^{M}(Z_{jit})$ and the heteroscedastic variance $\left(\sigma_{u}^{M2}\left(Z_{jit}\right)\right)$. The approach used by Huang et al. (2014) for the meta-frontier can be summarized by the estimation of equations (9) and (10).

The firm's technical efficiency with respect to the meta-frontier (*MTE*) can be calculated as the product of the estimated *TGR* and the firms' technical efficiency (*TE*); that is:

$$\widehat{MTE}_{it}^{j} = \widehat{TGR}_{it}^{j} \times \widehat{TE}_{it}^{j} \tag{11}$$

Where $\widehat{TGR}_{it}^{j} \leq 1$ to ensure that the sector-specific frontiers are smaller than or equal to the meta-frontier.

Once the technical efficiencies have been estimated for each firm (both *TE* and *MTE*), we proceeded to calculate both the effect of corporate taxation on firm performance, as well as the reverse relationship between efficiency and taxes, by using quantile regression analysis. In particular, we estimated the effect that the payment of corporate income tax has on the efficiency measures obtained from the meta-frontier estimations. Then, we assessed whether the efficiency of firms affects the firms' tax payments. The use of quantile regression analysis allowed us to account for asymmetries in the distribution of the dependent variable (either tax payments or efficiency) and has the advantage that it does not require segmenting the sample according to the unconditional distribution of the variable (Margaritis & Psillaki, 2007).

Data

The data comes from the Business Information System administered by Colombia's Superintendencia de Sociedades. This data set contains the financial statements and interest expenses with a cut-off at 31 December of each year, at the firm level. This information is supplied by the companies that are subject to inspection and surveillance by this entity.[4] Besides, firms provide information about employment, the economic sector where they operate, tax payments, among other variables.

The period of study runs from 2010 to 2015. However, the analysis was carried out for two sub-periods, 2010-2012 and 2013-2015, since we wanted to maximize the number of companies included in the analysis. If we consider the whole period, given that the companies that report to the Superintendencia vary every year, the number of firms is greatly reduced (1943) and would limit the analysis for those economic sectors with fewer companies such as construction.[5] As a result, the samples were made up of 4.178 firms for the period 2010-2012 and 3.327 firms for 2013-2015. It is also important to mention that in each sub-period, the government approved major tax reforms.

Table 1 reports the descriptive statistics of inputs and environmental variables used in the first and second stages of the stochastic frontier analysis by economic sector and period. For the analysis, firms were classified according to the sector where they operate, namely agriculture, forestry and fishing, manufacturing, construction, wholesale and retail trade, and services. Monetary variables are expressed in constant 2015 pesos. The methodology employed requires the definition of an output variable, inputs, and environmental variables for the first and second stages of the meta-frontier analysis. In the case of the output, when the analysis was carried out using monetary variables, in the literature, it is customary to use the operating revenue, which is associated with the firm's primary business activity and in this regard is considered as a proxy for the firm's performance. Regarding inputs, raw materials costs, direct labor costs, and interest expenses[6] are included for all economic sectors.

According to the methodology, environmental variables, which are not inputs but help explain the firm's technical efficiency, were included in the two stages of the meta-frontier estimation. In the first stage, following the

4 The criteria to define the companies subject to the supervision of the *Superintendencia de Sociedades* are in articles 83 and 85 of Law 222 of 1995 and in the Decrees 3100 of 1997, 4350 of 2006, 2300 of 2008, 2669 of 2012, and 1219 of 2014. In general, the sample was composed of formal companies that are large in assets or income and companies with the highest tax burden in the country.

5 Another reason for the reduction in the number of firms in the sample stems from the missing values for labor and raw materials, which are obtained from the annexes to the financial statements that not all companies report, which are crucial for our empirical analysis.

6 This variable was included to account for the access to credit to finance their productive processes, which could affect the performance of firms.

literature, we chose the marginal effective tax rate that measures the corporate tax burden,[7] total assets, which control for the companies' size,[8] the debt ratio that measures the extent of a company's leverage defined by the ratio of total debts to total assets, and the income generated abroad, included as a dummy variable. In the second stage, the environmental variables helped explain the sector-specific technological gap ratios. They include the share of employment of each economic sector in total employment of the country, the share of sectoral production in total national output, as well as the degree of each region's specialization, defined as the share of regional production of each sector on the sectoral production at the national level.[9]

Table 1 shows that, in terms of output, the largest firms on average operate in the construction sector in both periods. In contrast, firms operating in the agricultural sector are, on average, the smallest. Regarding the environmental variables, the agriculture, forestry, and fishing firms have, on average, the highest marginal effective tax rates and report the lowest debt ratio. In addition, manufacturing firms are the largest in terms of assets in the period 2010-2012 and include an important number of companies that generate some of their income abroad. Wholesale and retail trade and construction are the sectors with the highest debt ratio. As to the environmental variables used in the second stage, it is important to mention that these reflect aggregate indicators, as taken from the national and regional accounts of the country. The statistics show that wholesale and retail trade and services have the highest employment rate. Regarding production, wholesale and retail trade and manufactures have the highest value of production. On the contrary, agriculture, forestry and fishing, and construction have the lowest regional production.

Results

The meta-frontier estimation was conducted in two stages for the periods 2010-2012 and 2013- 2015. In the first stage, we estimated the specific stochastic

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7 The marginal effective tax rate comes from Melo-Becerra et al. (2017) and differs in each period due to the tax reforms and sector characteristics. Marginal effective tax rates, contrary to the statutory rates, consider tax benefits and exemptions and avoidance and evasion practices.

8 Total assets were not considered as an input because they are a stock and do not necessarily change with the output level of the firm.

9 These indicators are standardized by the geometrical mean of the five analyzed economic sectors. The national and regional level variables come from the National Department of Statistics, DANE.

production frontiers for each economic sector included in the analysis. In the second stage, the estimators, $\ln \hat{f}^{j}\left(X_{jit}\right)$, obtained from the frontiers of the J economic sectors, were grouped to estimate each period's meta-frontier. Then, using quantile regression analysis, we estimated the effect of taxes on the efficiency measures resulting from the meta-frontier analysis and the reverse causality to assess the relationship between efficiency and tax payments.

Stochastic Frontier Analysis

The estimation of the *jth* stochastic frontiers for each economic sector was conducted using a translog function and the Battese and Coelli (1995) approach, which, in addition to assessing the effect of inputs, allowed us to control for environmental variables that might affect the firms' performance.[10] Tables 2 and 3 present the estimated parameters and standard errors for the frontiers of the different economic sectors for the 2010-2012 and 2013-2015 periods, respectively. The tables also show the variance of the two components of the error term $\left(\sigma_u^2 \text{ and } \sigma_v^2\right)$, which gives information about the percentage of the variance explained by the inefficiency term, and the γ coefficient, which represents the estimated share of the inefficiency term in the variance of the compound error. As expected, in all cases, the first-order coefficients indicate that there is a positive and significant relationship between inputs and the operating revenue, which is associated with the firm's primary business activity, and in this regard is used as a proxy for the firm's performance.

In turn, the coefficients of the environmental variables indicate that firms with larger assets and effective marginal tax rates are, in general, closer to the production frontiers of their respective sectors.[11] In fact, larger firms can benefit from scale economies and achieve better results from using materials and labor in generating more revenues. The results also indicate that firms with a higher tax burden are closer to their sector-specific frontier. In the period 2010-2012, companies with a higher debt ratio in the manufacturing, construction, and trade sectors were closer to the production frontier, whereas the coefficient was not significant for services and agricultural sectors. For the period 2013-2015, this variable was not significant neither for services not for trade. These results are associated to the impact of the cost of the debt

10 The translog functional form was chosen because of its flexibility and less restrictive nature compared with the Cobb-Douglas function.

11 In the Battese and Coelli (1995) approach, a positive coefficient negatively affects efficiency and vice-versa.

on the firm's finances and credit constrains. In the theoretical and empirical literature, the relationship between debt and the firm's performance is mixed (Kebewar, 2013; Abdullah & Tursoy, 2019). Firms that generate income from abroad also have mixed results in terms of the distance to the production frontier. For the period 2010-2012, a positive and significant effect was observed in the agriculture, manufacturing, and trade sectors; meanwhile, for the period 2013-2015, a negative effect was observed in the construction sector. These results could be associated with the share of the income generated in other countries and the behavior of the exchange rate, and their impact on firm performance. It is worth noting that during the period 2010-2012, the exchange was relatively stable; whereas, in the period 2013-2015, the exchange rate devalued significantly as a result of the drop in oil prices.

Technical efficiency measures were calculated for each firm using the estimations of the production frontiers for each economic sector. Table 4 provides the means and standard deviations of the efficiency measures for the periods 2010-2012 and 2013-2015 calculated by economic sector, size of the company, for different ranges of the debt to assets ratio, and the net profit margin. Results indicate that in both periods, firms of the construction and the agriculture, forestry, and fishing sectors have, on average, the highest technical efficiency (62 % and 61 % in the period 2010-2012, respectively; 79 % and 61 % in the period 2013-2015, respectively), whereas the trade sector, in both periods, registered the lowest average efficiency (19 % and 17 %, respectively). The low efficiency of the trade sector, compared to the other sectors, could be explained by the particularities of this sector, whose main activity is distribution, rather than the production of goods; it should be recalled that in this sector, the input mix could be different from the other sectors. It is also worth noting that in all economic sectors, efficiency measures display great dispersion among firms, which is higher during the first period. There is also a shift to the right in the efficiency of some sectors between periods and less dispersion among firms in the second period. The dispersion of efficiency measures obtained from specific frontier confirms the heterogeneity in the performance of companies in the country (see Figure 2 and Table 4).

When firms are classified by size, based on the company's assets, it was observed that in all economic sectors in both periods, larger firms had better performances, compared to medium and small ones. As presented in Table 4, the greatest differences were registered in the construction, commerce, and services sectors. For instance, for the period 2010-2012, the average technical efficiency measures for small firms in these sectors were 30.3%, 5.7% and 29.6%, respectively; while for large firms were 76.1%, 40.5%, and 74.8%, respectively. As pointed out by Melo-Becerra and Orozco-Gallo (2017), smaller production units generally exhibit higher levels of inefficiency due to the lack of scale economies. In general, results also indicate that when companies are ranked using the debt to assets ratio, on average, the efficiency measures increase with this ratio, which may be associated with the fact that larger firms can have more access to credit which can be used to carry out investment projects. In contrast, in the agricultural sector, efficiency decreases as the debt to assets ratio increases. Overall, efficiency measures increase with the net profit margin in all sectors, except in the trade sector in the first period.

Next, by using the estimates obtained from the *J* sector-specific frontiers and the Battese and Coelli (1995) approach, we estimate the meta-frontier for the firms of the five economic sectors included in the analysis. This method's novelty is that existing literature generally employs total factor productivity analysis and specific indicators of the firms without comparing efficiency within the economic sector and between the sectors and the aggregate frontier for the economy. In the estimation, we used as environmental variables aggregate employment and production in each of the economic sectors, as well as the degree of specialization of each region at the sectoral level.[12] The first-order coefficients and the interaction terms of the meta-frontier were significant and had the expected signs. Regarding environmental variables, firms that belong to sectors with more share of employment and production in the economy perform better. Meanwhile, the specialization of each region across economic sectors negatively affects the efficiency measures suggesting that the differences in the efficiency of companies compared to the meta-frontier are mainly explained by the characteristics of the sectors to which the firm belongs, rather than by regional differences of where the firm is located (Table 5). This result could be linked to the agglomeration economics literature, considering that some benefits can be obtained when companies are located close to each other due to savings in transport costs, especially in a country like Colombia, which has deficiencies in the transportation infrastructure associated with its geography (Glaeser, 2010).[13]

Table 6 summarizes, for both periods, the statistics of the TGR that measures the distance from the *jth* sector-specific frontiers to the meta-frontier, the MTE that correspond to the distance from each company to the meta-frontier, and the TE derived from the production frontiers of each economic sector. The measures are shown by economic sector, firm size and ranges of

12 As in the case of the sector-specific frontiers, a positive coefficient has a negative effect on the meta- frontier production function.

13 We appreciate the suggestion of this link to an anonymous referee.

debt to assets ratios, and net profit margins of firms. Results indicate that the TGR is on average 39 %, the MTE 13 %, and the TE 37 %, suggesting that if firms perform at or approach the production frontier of their economic sector, they could accomplish important gains in terms of efficiency. These improvements could be expressed in less input use or higher revenues with positive effects on firm and sector productivity.

The results for the MTE and the TGR indicate that there is a significant margin for improving the performance of the firms under analysis. To achieve this goal, policies involving measures aimed at ameliorating the conditions in which all firms operate are required. For example, investment in infrastructure and human capital might favor the performance of all companies, regardless of the sector where they operate. For both periods, results indicate that companies in the construction and the agriculture sectors have, on average, the highest efficiency measures obtained from the sector-specific frontiers. Nevertheless, firms of these sectors get the lowest TGR, suggesting a greater gap between the best available technologies in the country and the production frontiers of these economic sectors. Conversely, firms operating in the trade and service sectors are, on average, closer to the best available production technology of the country. These results suggest that firms in the construction and the agriculture sectors may have drawbacks in production technologies compared to the other sectors, which may be associated with differences in human capital and infrastructure characteristics. These differences might define heterogeneous requirements and inputs mix. For instance, these economic sectors generally hire less-skilled employees compared to the other sectors. Consequently, it is worth fostering policies that encourage research and technical change considering the specific conditions of the different economic sectors.

Among all firms, larger and more profitable ones are more likely to operate near to the economic sectors' production frontiers and the meta-frontier. However, when calculating the distance from the sector-specific frontiers to the meta-frontier, TGR, by firm size or profitability, this relationship does not hold, suggesting that some small and low profitability firms are just as efficient as the largest and most profitable firms. Results also suggest that the adoption of the best available technology of the country largely depends on the economic sector where the company operates (see Table 6).

Quantile Regression Analysis

In this section, we present the results of the quantile regression analysis. This methodology considers the heterogeneity in the performance of firms, manifested in the dispersion of the efficiency measures, explained in the previous section. It also allowed us to assess the interaction between the variables under analysis, considering different segments in the distribution of the dependent variable. First, we assessed the effect of taxes on the efficiency measures obtained from the stochastic frontier analysis, using the pool of firms for the period 2010-2015.[14] Tables 7 and 8 report quantile regression results when the efficiency obtained from the sector-specific frontiers and from the meta-frontier were used as dependent variables. In both specifications, the payment of corporate taxes, which is the variable of interest, was included as a percentage of total assets to account for the heterogeneity in firm's size.[15] In the regressions, we also control for other firm characteristics such as: (i) the age of the firm, (ii) the squared age of the firm, (iii) the type of the company, (iv) a solvency index measured as the ratio of total assets to total liabilities, (v) if the company required a fiscal auditor, and (vi) the level of violence in the municipality where the firm is located.[16] Considering that taxes could affect some economic sectors more than others, we included in the specification interactions between tax payments and the economic sector where the firm operates.

Results indicate that the ratio of corporate tax payment to assets has a negative effect on the technical efficiency of firms in both the *TE* and the *MTE*. These results are consistent across the different quantiles. As explained above, taxes might affect the performance of firms through different channels, such as the distortive effects on the allocation of inputs within and among firms and within and among economic sectors, affecting the transaction costs of firms and consequently their performance (Vartia, 2008). Corporate taxes, as part of the cost of capital, might also affect investment decisions by reducing the expected post-tax return of the firm—see for example Bartolini (2018), Lazar and Istrate (2018), and Maffini et al. (2019), and for Colombia, see Melo-Becerra et al. (2017).

To capture differential responses among firms of different economic sectors, we assessed the interaction terms, calculated as the product between

14 In this exercise, we pooled together the efficiency measures obtained from the meta-frontier analysis. There is an efficiency measure for each firm and year; hence, we can consider only one period of analysis.

15 It is worth noting that in the meta-frontier estimations, effective marginal tax rates were used as environmental variables to control for the tax burden faced by firms. In this exercise, the amount of taxes paid is the variables of interest, which depends not only on the tax rate but also on the firm's profits and tax benefits.

16 The number of homicides per 100.000 inhabitants was used to measure the presence of violence in each municipality where firms are located.

the dummy variable of the economic sector and the tax payments to assets ratio. The analysis used the manufacturing sector as a reference category. Firms operating in the manufacturing sector compared to firms of the agriculture and construction sectors are in general expected to adopt better technologies and hire more qualified personnel, thereby achieving higher efficiencies measures. When the estimation was conducted using the *TE* of the firm as the dependent variable, results reveal for the first and second quantiles a stronger negative effect for firms belonging to the trade sector. In turn, in all quantiles, results indicate a less negative effect of corporate taxes for firms of the agriculture, construction, and service sectors. These findings can be explained by differences across economic sectors in the capital-labor relation and the portfolio of assets, among other characteristics of the firms, as well as for the tax benefits granted to firms of specific economic sectors that affect the firms' tax burden. For instance, the Colombian tax legislation offers a preferential tax rate of 9 % for hotel services, ecotourism services, and publishing companies.[17]

When estimations were carried out using the *MTE* as the dependent variable, results reveal a less negative effect in the upper quantile of the efficiency distribution for firms that operate in sectors other than manufacturing. In the middle quantile, similar results are observed except for firms of the construction sector where a stronger negative effect is found. In the lower quantile of the distribution, the interaction term was not significant for firms operating in the agriculture and trade sectors. The differences between the results obtained when using the *TE* and the *MTE* can be explained by the fact that a firm can be efficient when compared to the production frontier of its own sector, but not necessarily when compared to the meta-frontier of the set of companies in the country.

The coefficients of the control variables indicate that firms required to have a financial auditor, and large firms compared to medium and small firms have higher efficiency measures in the different quantiles of the distribution and for both measures of efficiency. According to Maffini et al. (2019), "smaller and private companies could be more financially constrained and a complex tax code may be less salient for them" (p. 364), which could affect the performance of smaller firms. Limited liability companies have a positive effect on the *TE* and the *MTE*. Thus, this type of company is more efficient when analyzing production technology with respect to the meta-frontier,

17 During the analyzed period, the general corporate tax rate fluctuated between 33 % and 34 %.

rather than within the economic sector production systems. In turn, the age of the firm has a negative effect on the performance, but the age squared has a positive effect, indicating that the effect of age could define a u-shape. An economic explanation for this relationship may be a weaker attachment to efficiency associated with tax changes by younger and older firms. Regarding the effect of violence, results indicate that efficiency measures obtained from the specific frontier and the meta-frontier are negatively affected by the presence of violence in municipalities where companies are located.

Second, we assessed the reverse relationship between efficiency and taxes (Table 9). The dependent variable was the ratio of corporate tax payments to assets, and the variables of interest were the TE and the MTE. We also control for firm characteristics and for the interaction terms between the economic sector and the efficiency measures. Results indicate that for all quantiles of the tax payments distribution, there is a positive relationship between corporate taxes and the TE, while the relationship with MTE is negative. These results suggest that when compared to firms of the same economic sector, firms with higher TE paid on average higher corporate taxes, but when compared to the set of firms of the country, firms with higher MTE paid lower taxes, suggesting important differences across economic sectors. The tax burden gap across firms together with the differences in efficiency indicate that companies located near to the meta-frontier pay less taxes in relation to their assets.[18]

Interesting results were found when analyzing the coefficients of the interaction terms by quantiles of the tax payments distribution. For instance, the coefficients of the interaction between the TE and the dummy variables of the economic sector indicate that in the lower quantile, the positive effect on taxes is higher in the trade sector and lower in the agriculture and construction sectors when compared to firms of the manufacturing sector. In the middle and upper quantiles, only the coefficient of the agriculture sector is significant and has a less positive effect on companies in this sector. In turn, the coefficients of the interaction between the MTE and the economic sector reveal that in the lower quantile, firms operating in the agriculture and construction sectors have a less negative effect on taxes. As in the previous case, only the coefficient of the agriculture sector is significant in the middle and upper quantiles and has a less negative effect compared to firms

18 It is important to recall that except for the tax benefits granted to specific economic sectors, the tax system applies equally to all firms. However, the effective marginal tax burden varies across firms due to differences in the portfolio of firms, the debt ratio, and other firms' characteristics that affect the marginal tax rate.

in the manufacturing sector. These results indicate that the performance of firms of the agriculture and construction sectors is the most affected by tax payments, which could be associated with the tax burden of these sectors. Indeed, firms of these two sectors have the highest effective marginal tax rates (Melo-Becerra et al., 2017).

The heterogeneous impact of taxes on efficiency and the reverse causality can make it difficult for some companies to approach the production frontier. As suggested by Bartolini (2018), these differences can prevent the reallocation of resources from less productive to more productive uses and hinder opportunities to acquire new technologies and innovative production processes. The author also suggests that companies near the production frontier may have an asset composition more favorable to the tax structure and have more possibilities of evading taxes.

Concluding Remarks

This paper studied the relationship between corporate taxes and the performance of Colombian firms in five economic sectors, namely agriculture, construction, manufacturing, trade, and services. The performance of firms was measured as the technical efficiency obtained from the sector-specific production frontiers and the meta-frontier, using the set of firms in the country. Then, by means of quantile regression analysis, we evaluated if tax payments have an impact on the performance of firms and whether more efficient companies pay more or less taxes. The empirical analysis used a panel data structure of firms for two periods, 2010-2012 and 2013-2015. During these periods, the national government introduced three major tax reforms in 2009, 2012, and 2014, which adjusted the corporate tax base, rate, and the tax benefits granted to firms.

Efficiency measures from the production frontiers of each sector and the meta-frontier indicate that firms have an important margin to improve their performance. Indeed, results indicate that companies operating in the construction and agriculture sectors have, on average, the highest efficiency measures (62 % and 61 % in the period 2010-2012, respectively; 79 % and 61 % in the period 2013-2015, respectively). Results from the meta-frontier indicate that firms in some economic sectors could be benefiting from better production conditions because of advantages in labor, infrastructure, and tax burden. To improve the performance of companies, policies should consider actions within economic sectors and policies that help reduce the technology gap between the frontiers of the different economic sectors and the meta-frontier. Regarding the effect of corporate taxation on firm performance and the reverse causality, results indicate that corporate taxes negatively affect the efficiency measures obtained from the production frontiers of the economic sectors and from the meta-frontier. These results could be explained by the effect that taxes have on the inputs reallocation within and between firms and within and across economic sectors and by the effect on the expected post-tax return of investment. In turn, results show that firms with higher *TE* paid on average higher corporate taxes, but firms with higher *MTE* paid lower taxes, suggesting differences in the tax burden of firms across economic sectors. These differences hinder the reallocation of resources from less productive to more productive uses and make it difficult for companies to approach the potential production of the economy.

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Table 1. Descriptive Statistics

Variable	Units	Agriculture, forestry and fishing		Manufacturing		Construction		Wholesale and retail trade		Services	
		Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
2010-2012											
Revenue	Billions of dollars $	27.9	65.1	61.0	177.0	71.4	139.0	58.2	125.0	37.0	72.3
Materials	Billions of dollars $	12.4	35.9	28.0	92.2	16.7	39.3	19.9	62.7	11.3	24.8
Labor	Billions of dollars $	3.6	5.8	2.6	6.0	10.1	18.9	1.4	4.3	7.2	26.6
Interest payments	Billions of dollars $	0.4	0.7	0.8	2.2	1.0	2.9	0.7	1.9	0.4	1.3
Environmental variables first stage											
Marginal effective tax rate	Percentage	27.7	4.2	25.8	3.7	25.1	3.2	25.1	3.1	24.9	4.0
Total assets	Billions of dollars $	15.6	27.0	26.5	76.6	22.0	60.0	9.2	21.5	10.6	15.5
Debt ratio	Percentage	39.3	22.8	46.1	18.3	57.8	18.3	51.7	19.4	48.2	23.5
Income generated abroad (Yes = 1)	Dummy	0.5	0.5	0.7	0.5	0.4	0.5	0.6	0.5	0.4	0.5

Variable	Units	Agriculture, forestry and fishing		Manufacturing		Construction		Wholesale and retail trade		Services	
		Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
Environmental variables second stage											
Employment	Per 1.000 hab.	3.606	32	2.572	85	1.144	80	5.286	204	3.814	83
Production	Billions of dollars $	40.791	732	91.511	2.519	44.855	3.518	114.054	4.882	67.884	3.213
Regional Production	Billions of dollars $	2.003	2.252	14.975	6.679	5.330	2.709	22.026	11.659	16.697	9.272
Observations	Number	480		3.078		174		309		165	
2013-2015											
Revenue	Billions of dollars $	20.1	51.5	21.5	52.9	56.1	106.0	23.9	37.6	21.6	24.7
Materials	Billions of dollars $	8.8	28.0	9.4	25.3	10.3	20.9	4.9	9.6	5.3	7.8
Labor	Billions of dollars $	1.9	2.9	1.3	2.0	9.2	23.4	0.6	0.7	3.8	6.5
Interest payments	Billions of dollars $	0.4	0.7	0.4	1.1	0.8	1.6	0.3	0.5	0.4	0.5
Environmental variables first stage											
Marginal effective tax rate	Percentage	26.4	4.1	23.2	3.4	22.7	3.5	22.3	3.4	22.1	4.2

Variable	Units	Agriculture, forestry and fishing		Manufacturing		Construction		Wholesale and retail trade		Services	
		Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
Total assets	Billions of dollars $	12.6	21.8	8.9	27.0	18.2	49.7	3.3	5.9	9.9	15.6
Debt ratio	Percentage	43.1	24.6	48.0	18.9	53.2	20.1	55.1	19.3	51.2	21.8
Income generated abroad (Yes = 1)	Dummy	0.4	0.5	0.6	0.5	0.3	0.5	0.5	0.5	0.4	0.5
Environmental variables second stage											
Employment	Per 1000 hab.	3.529	24	2.575	31	1.299	63	5.893	111	4.247	100
Production	Billions of dollars $	46.366	1.354	97.563	1.933	53.785	3.861	130.547	4.224	79.439	2.574
Regional Production	Billions of dollars $	2.559	2.449	15.604	6.043	5.596	2.703	28.777	12.711	15.749	11.617
Observations	Number	444		2.325		213		180		192	

Note. Monetary variables deflated by the consumer price index (CPI) provided by DANE and expressed in constant 2015 pesos, except for production and regional production variables, deflated by the GDP deflator (2015=100). 1 billion = 1,000,000,000

Source: Authors' calculations based on Superintendencia de Sociedades de Colombia, Melo-Becerra et al. (2017), and DANE.

Table 2. Estimated Parameters for the Production Frontiers by Economic Sector, 2010-2012

Variables	Agriculture, forestry and fishing		Manufacturing		Construction		Wholesale and retail trade		Services	
	Parameter estimates	Standard errors	Parameter estimates	Standard errors	Parameter estimates	Standard errors	Parameter estimates	Standard errors	Parameter estimates	Standard errors
Constant	0.428	11.850	1.001	15.425	0.169	0.132	1.854	0.190***	0.546	0.222**
Materials (m)	0.449	0.027***	0.503	0.009***	0.315	0.044***	0.194	0.035***	0.441	0.032***
Labor (l)	0.321	0.027***	0.190	0.011***	0.274	0.044***	0.246	0.062***	0.162	0.040***
Interest payments (i)	0.062	0.019***	0.072	0.008***	0.144	0.030***	0.161	0.047***	0.084	0.034**
m^2	0.115	0.012***	0.118	0.005***	0.155	0.039***	0.089	0.013***	0.195	0.023***
l^2	0.052	0.020**	0.131	0.008***	0.241	0.039***	0.142	0.048***	0.163	0.032***
i^2	0.008	0.005	0.027	0.002***	0.043	0.011***	0.059	0.017***	0.037	0.015**
m x l	-0.095	0.010***	-0.081	0.004***	-0.088	0.032***	-0.084	0.023***	-0.136	0.014***
m x i	-0.008	0.009	-0.025	0.002***	-0.008	0.020	-0.024	0.012**	-0.077	0.015***
l x i	-0.004	0.008	-0.011	0.003***	-0.058	0.022***	-0.049	0.025*	0.017	0.021
Environmental variables										
Constant	0.562	11.850	1.375	15.425	1.037	0.204***	3.085	0.242***	0.818	0.267***
Marginal effective tax rate (METR)	-0.664	0.185***	-0.879	0.077***	-2.405	0.554***	-1.091	0.592*	-0.635	0.300**
Total assets	-0.082	0.023***	-0.154	0.008***	-0.214	0.052***	-0.303	0.060***	-0.269	0.037***

Variables	Agriculture, forestry and fishing		Manufacturing		Construction		Wholesale and retail trade		Services	
	Parameter estimates	Standard errors	Parameter estimates	Standard errors	Parameter estimates	Standard errors	Parameter estimates	Standard errors	Parameter estimates	Standard errors
Debt ratio (%)	0.013	0.109	-0.313	0.051***	-1.054	0.303***	-1.383	0.311***	-0.038	0.175
Income generated abroad (yes = 1)	-0.097	0.044**	-0.062	0.015***	-0.011	0.101	-0.499	0.095***	-0.067	0.065
σ^2	0.178	0.012***	0.138	0.004***	0.185	0.031***	0.572	0.052***	0.113	0.013***
γ	0.001	0.488	0.045	3.658	0.580	0.160***	0.927	0.071***	0.342	0.219*
σ_u^2	0.000	0.087	0.006	0.504	0.107	0.043**	0.530	0.067***	0.039	0.026
σ_v^2	0.178	0.088**	0.132	0.504	0.078	0.024***	0.042	0.040	0.074	0.025***
Log-Likelihhod	-267.490		-1317.710		-77.628		-337.960		-51.114	
Observations	480		3078		174		309		165	

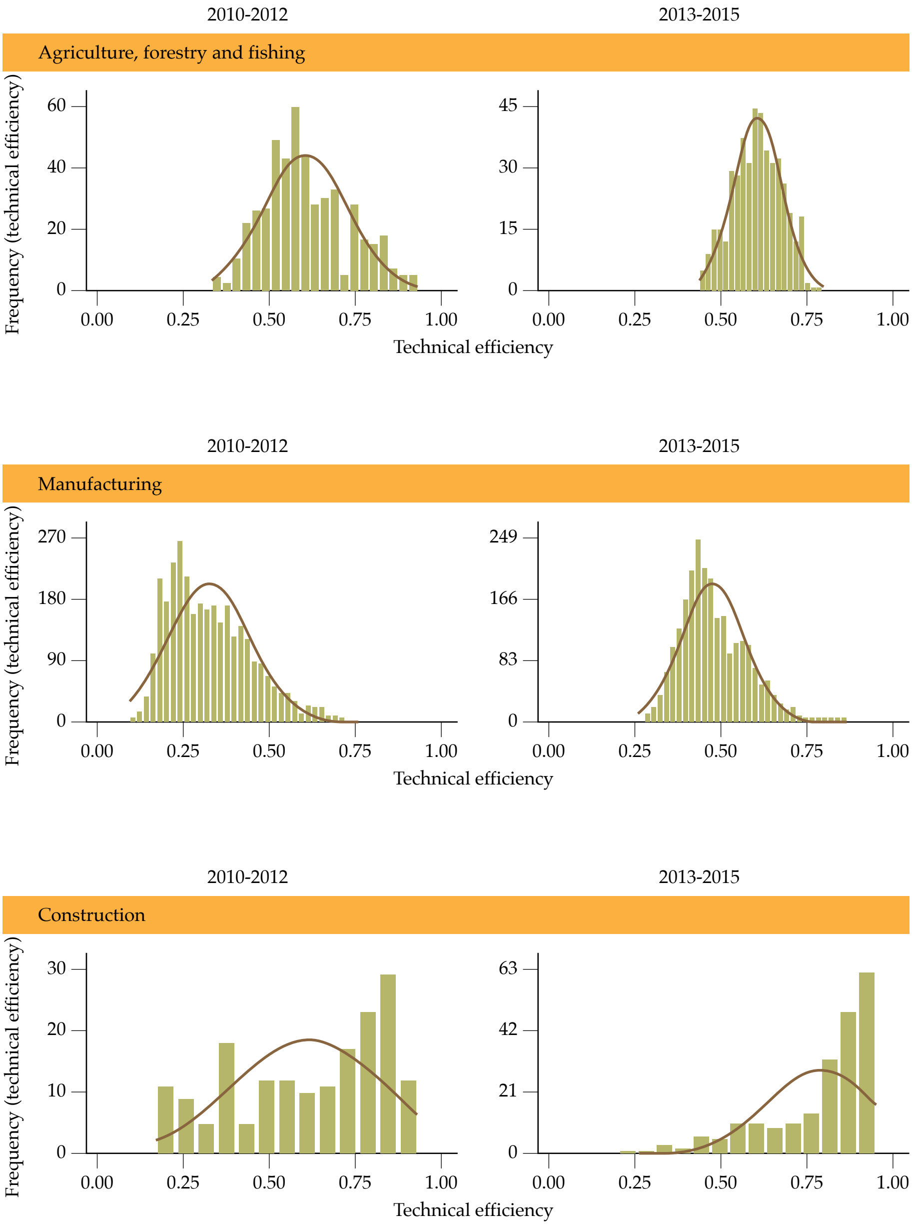
Note. Time variables and their interaction-terms were included in the frontier regression but are not presented in tables because of space limitations.
***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.

Table 3. Estimated Parameters for the Production Frontiers by Economic Sector, 2013-2015

Variables	Agriculture, forestry and fishing		Manufacturing		Construction		Wholesale and retail trade		Services	
	Parameter estimates	Standard errors	Parameter estimates	Standard errors	Parameter estimates	Standard errors	Parameter estimates	Standard errors	Parameter estimates	Standard errors
Constant	0.248	37.460	0.624	28.319	-0.122	0.139	1.516	3.129	0.599	73.296
Materials (m)	0.421	0.026***	0.523	0.011***	0.364	0.049***	0.159	0.047***	0.394	0.030***
Labor (l)	0.393	0.033***	0.228	0.014***	0.238	0.052***	0.183	0.080**	0.286	0.032***
Interest payments (i)	0.062	0.019***	0.046	0.009***	0.147	0.033***	0.283	0.055***	0.091	0.026**
m^2	0.193	0.018***	0.113	0.005***	0.181	0.044***	0.119	0.023***	0.145	0.028***
l^2	0.119	0.027***	0.118	0.012***	0.165	0.048***	0.115	0.072	0.153	0.022***
i^2	0.026	0.006***	0.019	0.003***	0.046	0.013***	0.085	0.017***	0.031	0.011**
m x l	-0.143	0.015***	-0.097	0.006***	-0.101	0.042**	-0.047	0.032	-0.153	0.022***
m x i	-0.019	0.011*	-0.004	0.004	0.003	0.021	-0.018	0.020	0.009	0.015
l x i	0.010	0.011	-0.002	0.005	-0.025	0.021	-0.057	0.025*	0.001	0.019
Environmental variables										
Constant	0.618	37.460	0.852	28.319	0.564	0.239**	1.974	3.113	0.931	73.296
Marginal effective tax rate (METR)	-0.662	0.181***	-0.533	0.073***	-1.852	0.739**	-1.656	0.537***	0.163	1.158
Total assets	-0.029	0.024	-0.105	0.010***	-0.152	0.072**	-0.187	0.072***	-0.199	0.024***

Variables	Agriculture, forestry and fishing		Manufacturing		Construction		Wholesale and retail trade		Services	
	Parameter estimates	Standard errors	Parameter estimates	Standard errors	Parameter estimates	Standard errors	Parameter estimates	Standard errors	Parameter estimates	Standard errors
Debt ratio (%)	-0.240	0.099**	-0.143	0.051***	-1.518	0.654**	-0.013	0.371	-0.119	0.146
Income generated abroad (yes = 1)	-0.017	0.041	-0.037	0.015**	0.469	0.210**	0.078	0.099	-0.121	0.048**
σ^2	0.159	0.011***	0.119	0.003***	0.256	0.047***	0.387	0.041***	0.084	0.009***
γ	0.017	5.085	0.008	3.129	0.289	0.181*	0.510	2.112	0.020	13.737
σ_u^2	0.003	0.808	0.001	0.373	0.074	0.058	0.197	0.818	0.002	1.159
σ_v^2	0.156	0.808	0.118	0.373	0.182	0.028***	0.190	0.816	0.083	1.159
Log-Likelihhod	-221.712		-825.993		-135.736		-169.797		-35.095	
Observations	444		2325		213		180		192	

Note. Time variables and their interaction-terms were included in the frontier regression but are not presented in tables because of space limitations.
***$p < 0.01$; **$p < 0.05$; *$p < 0.1$..


2010-2012
2013-2015
Agriculture, forestry and fishing
Frequency (technical efficiency)
60
40
20
0
45
30
15
0
0.00
0.25
0.50
0.75
1.00
Technical efficiency
2010-2012
2013-2015
Manufacturing
Frequency (technical efficiency)
270
180
90
0
249
166
83
0
0.00
0.25
0.50
0.75
1.00
Technical efficiency
2010-2012
2013-2015
Construction
Frequency (technical efficiency)
30
20
10
0
63
42
21
0
0.00
0.25
0.50
0.75
1.00
Technical efficiency

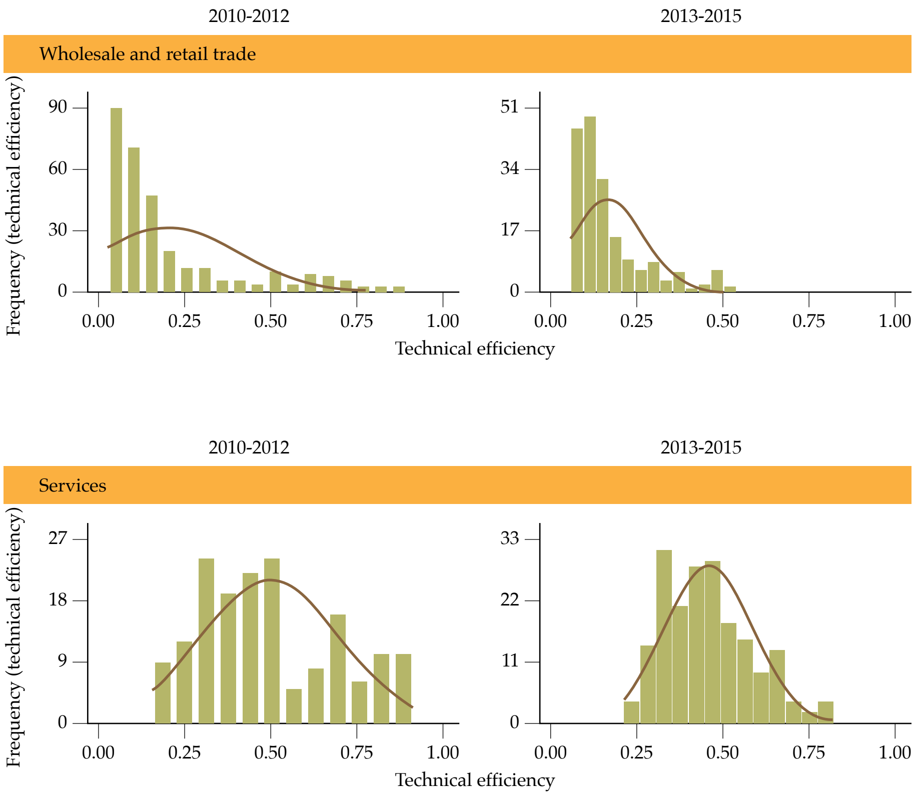


Figure 2. Frequency Distributions of Technical Efficiency by Economic Sector

Table 4. Technical Efficiency by Characteristics

Variables/Range	Agriculture, forestry and fishing		Manufacturing		Construction		Wholesale and retail trade		Services	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
2010-2012										
By economic sector	0.609	0.124	0.326	0.120	0.617	0.220	0.194	0.203	0.497	0.200
By company size										
Small	0.469	0.056	0.194	0.030	0.303	0.084	0.057	0.030	0.296	0.077
Medium	0.569	0.079	0.276	0.049	0.516	0.172	0.140	0.134	0.463	0.102
Large	0.725	0.105	0.436	0.093	0.761	0.130	0.405	0.224	0.748	0.108
Debts to assets ratio (%)										
< 4.6	0.600	0.114	0.324	0.126	0.590	0.209	0.108	0.126	0.483	0.186
>= 4.6 < 14.7	0.626	0.127	0.313	0.119	0.583	0.235	0.204	0.225	0.533	0.222
>= 14.7 < 27.5	0.611	0.126	0.325	0.120	0.661	0.209	0.196	0.209	0.471	0.185
>= 27.5	0.599	0.129	0.345	0.112	0.647	0.229	0.247	0.209	0.501	0.209
Net profit margin (%)										
< 0.8	0.590	0.105	0.326	0.113	0.488	0.218	0.171	0.164	0.469	0.240
>= 0.8 < 2.5	0.589	0.129	0.310	0.111	0.608	0.213	0.271	0.243	0.433	0.151
>= 2.5 < 5.1	0.624	0.125	0.320	0.118	0.639	0.192	0.168	0.182	0.517	0.187
> 5.1	0.662	0.142	0.349	0.131	0.658	0.250	0.128	0.163	0.557	0.200

Variables/Range	Agriculture, forestry and fishing		Manufacturing		Construction		Wholesale and retail trade		Services	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
2013-2015										
By economic sector	0.607	0.072	0.476	0.093	0.790	0.158	0.165	0.105	0.458	0.128
By company size										
Small	0.518	0.045	0.376	0.037	0.526	0.152	0.092	0.017	0.330	0.056
Medium	0.603	0.061	0.466	0.054	0.782	0.114	0.158	0.085	0.439	0.067
Large	0.662	0.051	0.591	0.075	0.887	0.068	0.293	0.123	0.589	0.107
Debts to assets ratio (%)										
< 5.6	0.584	0.076	0.473	0.094	0.773	0.170	0.158	0.105	0.443	0.133
>= 5.6 < 16.7	0.601	0.066	0.467	0.089	0.748	0.183	0.170	0.094	0.470	0.137
>= 16.7 < 29.5	0.623	0.071	0.479	0.093	0.809	0.148	0.163	0.100	0.461	0.114
> 29.5	0.621	0.069	0.484	0.095	0.837	0.101	0.168	0.115	0.455	0.120
Net profit margin (%)										
< 0.9	0.619	0.065	0.476	0.089	0.763	0.134	0.172	0.122	0.444	0.118
>= 0.9 < 2.8	0.593	0.065	0.463	0.092	0.775	0.142	0.160	0.110	0.473	0.130
>= 2.8 < 5.5	0.594	0.073	0.475	0.092	0.779	0.182	0.158	0.087	0.441	0.101
> 5.5	0.611	0.082	0.490	0.096	0.824	0.143	0.171	0.098	0.469	0.155

Note. Company size based on Colombian legislation (Law 904 of 2004) and classified as small for companies with assets between 0.3 and 3.2 billion expressed in constant 2015 pesos; medium (>= 3.2 < 19.3); and large (>= 19.3).

Table 5. Estimated Parameters for the Meta-Frontier

Variables	Meta-Frontier 2010-2012		Meta-Frontier 2013-2015	
	Parameter estimates	Standard errors	Parameter estimates	Standard errors
Constant	1.895	11.607	1.687	7.970
Materials (m)	0.439	0.005***	0.452	0.006***
Labor (l)	0.210	0.006***	0.229	0.008***
Interest payments (i)	0.097	0.004***	0.098	0.005***
m^2	0.128	0.002***	0.137	0.003***
l^2	0.126	0.004***	0.118	0.005***
i^2	0.031	0.001***	0.035	0.001***
m x l	-0.073	0.002***	-0.070	0.003***
m x i	-0.033	0.001***	-0.024	0.002***
l x i	-0.010	0.002***	-0.005	0.003**
	Environmental variables			
Constant	1.137	11.607	1.094	7.970
Employment	-0.941	0.015***	-1.063	0.017***
Production	-0.946	0.017***	-0.633	0.021***
Regional production	0.008	0.003***	0.019	0.004***
σ^2	0.065	0.001***	0.074	0.002***
γ	0.002	0.737	0.002	0.538
σ_u^2	0.000	0.048	0.000	0.040
σ_v^2	0.065	0.048	0.074	0.040
Log-Likelihhod	-225.545		-382.013	
Observations	4178		3327	

Note. Time variables and their interaction-terms were included in the frontier regression, but are not presented in tables because of space limitations.
****p* < 0.01; ***p* < 0.05; **p* < 0.1.

Table 6. Technology Gap Ratio (TGR), Sector-Specific Technical Efficiency (TE) and Meta-Frontier Technical Efficiency (MTE) by Characteristics

Variables / Range	TGR		TE		MTE	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
2010-2012						
Corporate sector	0.394	0.164	0.368	0.179	0.132	0.072
By economic sector						
Agriculture, forestry, and fishing	0.250	0.014	0.609	0.124	0.152	0.032
Manufacturing	0.379	0.008	0.326	0.120	0.124	0.045
Construction	0.091	0.006	0.617	0.220	0.056	0.020
Wholesale and retail trade	0.922	0.009	0.194	0.203	0.180	0.188
Services	0.413	0.005	0.497	0.200	0.206	0.083
By company size						
Small	0.408	0.167	0.211	0.096	0.076	0.025
Medium	0.400	0.178	0.324	0.146	0.115	0.049
Large	0.380	0.147	0.489	0.159	0.176	0.081
Debt to assets ratio (%)						
< 4.6	0.385	0.164	0.367	0.185	0.124	0.060
>= 4.6 < 14.7	0.393	0.158	0.361	0.185	0.130	0.077
>= 14.7 < 27.5	0.388	0.146	0.364	0.174	0.130	0.068
>= 27.5	0.409	0.185	0.378	0.172	0.142	0.082
Net profit margin (%)						
< 0.8	0.393	0.169	0.374	0.174	0.132	0.064
>= 0.8 < 2.5	0.402	0.183	0.355	0.175	0.132	0.090
>= 2.5 < 5.1	0.394	0.161	0.355	0.176	0.127	0.067
>= 5.1	0.386	0.140	0.386	0.190	0.136	0.065
2013-2015						
Corporate sector	0.331	0.148	0.495	0.152	0.150	0.044
By economic sector						
Agriculture, forestry, and fishing	0.285	0.017	0.607	0.072	0.173	0.023

Variables / Range	TGR		TE		MTE	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
Manufacturing	0.307	0.008	0.476	0.093	0.146	0.029
Construction	0.104	0.006	0.790	0.158	0.082	0.017
Wholesale and retail trade	0.893	0.014	0.165	0.105	0.148	0.095
Services	0.460	0.012	0.458	0.128	0.211	0.059
By company size						
Small	0.343	0.152	0.375	0.102	0.117	0.025
Medium	0.336	0.153	0.482	0.130	0.146	0.033
Large	0.312	0.132	0.622	0.134	0.183	0.052
Debt to assets ratio (%)						
< 5.6	0.335	0.156	0.490	0.156	0.148	0.045
>= 5.6 < 16.7	0.323	0.127	0.492	0.140	0.149	0.044
>= 16.7 < 29.5	0.330	0.147	0.499	0.153	0.149	0.042
>= 29.5	0.337	0.159	0.501	0.159	0.152	0.045
Net profit margin (%)						
< 0.9	0.339	0.145	0.490	0.138	0.153	0.043
>= 0.9 < 2.8	0.337	0.153	0.481	0.149	0.147	0.046
>= 2.8 < 5.5	0.332	0.162	0.492	0.162	0.145	0.043
>= 5.5	0.317	0.128	0.520	0.156	0.153	0.044

Table 7. Determinants of sector-specific technical efficiency by quantile regression, 2010-2015

Variables	Quantile 25		Quantile 50		Quantile 75	
	Parameter estimates	Standard errors	Parameter estimates	Standard errors	Parameter estimates	Standard errors
Dependent variable: Sector-specific technical efficiency						
Constant	44.433	0.991***	54.823	2.493***	65.149	1.329***
Tax payments to assets ratio	-0.119	0.014***	-0.190	0.030***	-0.187	0.027***
Mandatory statutory auditor (Yes=1)	4.446	0.521***	7.376	2.069***	2.721	0.736***

Variables	Quantile 25		Quantile 50		Quantile 75	
	Parameter estimates	Standard errors	Parameter estimates	Standard errors	Parameter estimates	Standard errors
Solvency ratio	0.345	0.087***	0.497	0.054***	0.310	0.054***
Years in business	-0.374	0.037***	-0.354	0.044***	-0.182	0.042***
Years in business-squared	0.005	0.001***	0.005	0.001***	0.002	0.001***
Stock corporations (Yes=1)	0.224	0.395	0.366	0.417	0.527	0.574
Small firms (Yes=1)	-20.128	0.548***	-22.246	0.926***	-24.012	0.848***
Medium firms (Yes=1)	-11.688	0.387***	-10.692	0.464***	-13.055	0.577***
Presence of violence	-0.054	0.007***	-0.136	0.009***	-0.069	0.013***
Taxation by economic sector interaction term						
Agriculture, forestry, and fishing	0.381	0.108***	0.579	0.207***	1.158	0.306***
Construction	0.138	0.022***	0.296	0.064***	0.531	0.124***
Wholesale and retail trade	-0.629	0.103***	-0.361	0.096***	-0.014	0.059
Services	0.267	0.055***	0.154	0.042***	0.076	0.069
Pseudo R2	0.226		0.179		0.213	
Observations			7381			

Note. Standard errors based on 20 bootstrap samples.
Source: Authors' calculations based on Superintendencia de Sociedades de Colombia, Instituto Nacional de Medicina Legal y Ciencias Forenses.
***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.

Table 8. Determinants of Meta-Frontier Technical Efficiency by Quantile Regression, 2010-2015

Variables	Quantile 25		Quantile 50		Quantile 75	
	Parameter estimates	Standard errors	Parameter estimates	Standard errors	Parameter estimates	Standard errors
Dependent variable: Sector-specific technical efficiency						
Constant	14.490	0.373***	16.631	0.397***	20.639	0.382***
Tax payments to assets ratio	-0.030	0.004***	-0.038	0.005***	-0.042	0.004***
Mandatory statutory auditor (Yes=1)	1.496	0.187***	2.032	0.229***	0.612	0.226***

Variables	Quantile 25		Quantile 50		Quantile 75	
	Parameter estimates	Standard errors	Parameter estimates	Standard errors	Parameter estimates	Standard errors
Solvency ratio	0.056	0.019***	0.081	0.019***	0.095	0.018***
Years in business	-0.089	0.017***	-0.096	0.020***	-0.140	0.018***
Years in business-squared	0.001	0.000***	0.002	0.000***	0.002	0.000***
Stock corporations (Yes=1)	0.202	0.112*	0.208	0.083**	0.521	0.105***
Small firms (Yes=1)	-6.531	0.142***	-7.182	0.179***	-7.319	0.150***
Medium firms (Yes=1)	-3.692	0.139***	-3.759	0.109***	-4.315	0.171***
Presence of violence	-0.016	0.002***	-0.021	0.002***	-0.018	0.002***
Taxation by economic sector interaction term						
Agriculture, forestry and fishing	0.027	0.027	0.072	0.016***	0.098	0.025***
Construction	-0.111	0.037***	-0.008	0.025	0.025	0.011**
Wholesale and retail trade	-0.002	0.009	0.015	0.010	0.135	0.040***
Services	0.166	0.029***	0.256	0.033***	0.391	0.040***
Pseudo R2	0.223		0.235		0.245	
Observations			7381			

Note. Standard errors based on 20 bootstrap samples.
Source: Authors' calculations based on Superintendencia de Sociedades de Colombia, Instituto Nacional de Medicina Legal y Ciencias Forenses.
***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.

Table 9. Determinants of Taxation by Quantile Regression, 2010-2015

Variables	Quantile 25		Quantile 50		Quantile 75	
	Parameter estimates	Standard errors	Parameter estimates	Standard errors	Parameter estimates	Standard errors
Dependent variable: Tax payments to assets ratio						
Constant	3.333	0.316***	9.958	0.910***	23.279	2.006***
Sector-specific technical efficiency	0.049	0.009***	0.104	0.012***	0.258	0.036***
Meta-frontier technical efficiency	-0.257	0.026***	-0.655	0.055***	-1.606	0.135***

Variables	Quantile 25		Quantile 50		Quantile 75	
	Parameter estimates	Standard errors	Parameter estimates	Standard errors	Parameter estimates	Standard errors
Mandatory statutory auditor (Yes=1)	0.661	0.161***	2.122	0.258***	4.582	0.613***
Solvency ratio	0.015	0.008*	0.032	0.012***	0.066	0.019***
Years in business	-0.020	0.010**	-0.097	0.022***	-0.221	0.055***
Years in business-squared	0.000	0.000	0.001	0.000***	0.002	0.001***
Stock corporations (Yes=1)	-0.222	0.078***	-0.096	0.132	0.662	0.442
Small firms (Yes=1)	-0.041	0.126	-1.150	0.424***	-3.711	0.824***
Medium firms (Yes=1)	-0.084	0.087	-0.962	0.247***	-2.417	0.572***
Presence of violence	0.003	0.001***	0.003	0.002	0.004	0.008
Sector-specific technical efficiency interaction term						
Agriculture, forestry, and fishing	-0.091	0.011***	-0.234	0.020***	-0.564	0.045***
Construction	-0.125	0.048***	-0.093	0.183	0.182	0.485
Wholesale and retail trade	1.678	0.927*	1.303	1.817	0.781	3.250
Services	-0.007	0.034	0.031	0.094	-0.027	0.211
Meta-frontier technical efficiency interaction term						
Agriculture, forestry, and fishing	0.246	0.041***	0.678	0.071***	1.691	0.162***
Construction	1.234	0.511**	0.647	1.794	-2.514	4.669
Wholesale and retail trade	-1.597	1.004	-0.874	1.959	0.432	3.496
Services	0.082	0.080	0.119	0.210	0.538	0.473
Pseudo R2	0.027		0.044		0.064	
Observations			7381			

Note. standard errors based on 20 bootstrap samples.
Source: Authors' calculations based on Superintendencia de Sociedades de Colombia, Instituto Nacional de Medicina Legal y Ciencias Forenses.
***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.

A. Appendix

Table A.1. Selected studies on the effect of taxes on corporate sector

Author(s)	Main goal	Sample	Analytical technique	Main findings
Bartolini (2018)	To investigate if effective taxation is negatively correlated with productivity.	Orbis database of firms across OECD (1995-2015). Observations = 1.914.231	Model with fixed-effects regression.	Firms at the productivity frontier pay less tax for each dollar of profits than the other firms in the sample due mainly to the high share of multinational firms and the composition of capital.
Lazar and Istrate (2018)	To investigate taxation as determinant of firm performance.	Non-financial Bucharest Stock Exchange listed companies (2000-2011). Observations = 537	Model with fixed effects regression.	The firm-specific overall effective tax rate has a negative effect on firm performance. Leverage negatively affects firm performance.
MacKinlay (2015)	To evaluate the role of taxes in firms' debt issuance decisions.	Non-financial firms in the Compustat universe (1988-2019). Observations = 1.642	Conditional logit framework.	The effect of taxes on firms' overall debt usage was insignificant. Rather than influencing the total debt in firms' capital structure, taxes affect the relative composition of debt.
Schwellnus and Arnold (2008)	To analyze the link between corporate taxation and economic growth, measured by productivity and investment.	European OECD firms from the Amadeus database (1996-2004). Observations = 287.727	OLS autoregressive distributed lag process.	Provided evidence of substantial negative effects of corporate taxation on two of the main drivers of economic growth: productivity and investment.
Vartia (2008)	To provide new information on how different tax policies can affect investment and productivity.	Industry level data from the OECD productivity database (1983-2001). Observations = 4.191	OLS and generalized method of moments estimation.	Found evidence that corporate taxes reduce investment by increasing the user cost of capital. Tax incentives for research and development (R&D) are found to have a positive effect on productivity.
Kaunitz and Egebark (2017)	To study the causal effects of a sudden payroll tax reduction on firm performance.	Swedish firm-level data from Statistics Sweden and the Statistical Business Register (2003-2012). Observations = 95.500	Difference-in-differences approach.	Found that under a payroll tax reduction scheme which lowered labor costs for young workers, firm exit and profit were not affected, which hold both for low- and high-profit firms.

Author(s)	Main goal	Sample	Analytical technique	Main findings
Dabla-Norris et al. (2017)	To study the link between tax compliance costs and firm performance.	Tax Administration Quality country-level Index merged with firm-level data from the World Bank Enterprise Surveys (2013-2016). Observations = 11.354	Difference-in-difference approach.	Results show that a stronger tax administration can exert a positive effect on the productivity of small and young firms. Better tax administration attenuates the productivity gap of small and young firms relative to larger and older firms.
Orjinta and Agubata (2017)	To contribute to the debate by evaluating the impact of taxes in firms' debt decisions.	Panel data from the published financial statement of quoted non-financial firms in Nigeria (2007-2016). Observations = 450	Pool OLS and weighted least squares regression.	Found a strong and positive effect of taxation on companies' capital structure. Empirical results identify a statistically significant positive effect of the relative tax benefit (interest tax and tax shield) of debt on the companies' debt ratio.
An (2012)	To determine if tax treatments offered to foreign investment enterprises responded by raising debt ratios.	Chinese Industrial Enterprises Database (2002-2008). Observations = 319.767	Difference-in-differences approach.	Found that foreign investment enterprises have responded to the law by raising debt ratios, which means that taxation plays an important role in the choice of capital structure.
Fama and French (1998)	To measure tax effects in the pricing of dividends and debt.	Compustat firms (1965-1992). Observations = 2.400 per annual.	Cross-sectional regression.	Found no hint of a negative personal tax effect in the pricing of dividends, and results produce no indication that debt has net tax benefits.
Gemmell et al. (2018)	To test whether aspects of the domestic policy environment affect the productivity catch-up of firms.	Firm-level data from the Amadeus database for 11 European countries (1996-2005). Observations = 226.468	OLS regression.	Higher rates of corporate taxation slow the rate of convergence for small firms, who are likely to be the most constrained from making productivity-enhancing investments. Small firms are affected, whereas large firms are not.

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Mukherjee et al. (2017)	To exploit staggered changes in state-level corporate tax rates to show if an increase in taxes reduces future innovation.	Firm-level patent data from the National Bureau of Economic Research matched with Compustat (1990-2006). Observations = 47.632	Difference-in-differences approach.	Found evidence that firms respond to tax increases by filing a lower number of patents, investing less in R&D, and bringing fewer new products into the market, which, taken together, suggests that higher corporate taxes indeed reduce innovator incentives and discourage risk-taking.
Zwick and Mahon (2017)	To study the effect of taxes on investment and how it varies across firms.	Firm-level panel from the cross-sectional Statistics of Income (1996-2010). Observations = 820.769	Difference-in-differences approach.	The first empirical finding is that bonus depreciation has a substantial effect on investment. Second, small firms respond 95 percent more than big firms. Third, firms respond strongly when the policy generates immediate cash flows, but not when cash flows only come in the future.
Djankov et al. (2010)	To present new cross-country evidence for the effects of corporate taxes on investment and entrepreneurship.	Mid-size domestic firm from Price water-house Coopers accountants and tax lawyers (2004). Observations = 85 countries.	Simple cross-country regressions.	Found evidence that effective corporate tax rates have a large and significant adverse effect on corporate investment and entrepreneurship. Corporate tax rates are correlated with investment in manufacturing but not services, as well as with the size of the informal economy.
Maffini et al. (2019)	To analyze the effects of tax incentives on companies' investment spending.	UK corporation tax returns dataset merged with Fame information for UK companies (2002{2003 to 2006{2007). Observations = 17.365.	Difference-in-differences approach.	Found that access to more generous capital allowances increases firms' investment by between 2.1 and 2.5 percentage points. Did not find evidence of a cash flow effect. The increase in investment was mainly due to the reduction in the user cost of capital following the reform.

Note. The Organization for Economic Cooperation and Development (OECD), Ordinary Least Squares (OLS).