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Tax effort and oil royalties in the Brazilian municipalities

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Abstract

This paper estimates a stochastic production frontier, to investigate whether municipalities covered by oil royalties in the last decade have reduced their tax effort in Brazil. The issue is relevant to the prospect of a substantial increase in these revenues and the new rules for distribution of the funds, established by Law No. 12.734/2012. The inputs were provided by personnel and capital expenditures, whereas the product was defined as the municipal tax collection. With the purpose of overcoming the endogeneity problems due to reverse causality of output on inputs, we used the lagged independent variable as instruments in the inefficiency equation. The data set is composed of a panel of Brazilian municipalities from 2002 to 2011. The results indicate that oil revenues have a negative impact on the estimated efficiencies, signaling reduced fiscal effort by the benefiting municipalities.

JEL classification: H21; H71; Q38

Keywords: Oil windfalls; Stochastic frontier analysis; Tax effort; Municipalities; Endogeneity

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Resumo

Este artigo estima uma fronteira estocástica de produção a fim de investigar se os municípios beneficiados com royalties do petróleo na última década reduziram seu esforço tributário no Brasil. O tema é relevante devido à perspectiva de aumentos substanciais nestas receitas e às novas regras para distribuição destes recursos, definidos pela Lei 12.734/2012. Os insumos foram definidos pelas despesas de pessoal e de capital, enquanto o produto foi definido como a arrecadação tributária municipal. Com o propósito de contornar potenciais problemas de endogeneidade devido à possível causalidade reversa de produtos nos insumos, as defasagens das variáveis independentes foram usadas como instrumento na equação de ineficiência. O banco de dados é composto por um painel de municípios brasileiros observados de 2002 a 2011. Os resultados indicam que as receitas do petróleo possuem um impacto negativo significativo nas ineficiências estimadas, sinalizando uma redução do esforço fiscal nos municípios beneficiados.

Palavras-chave: Rendas do petróleo; Análise de fronteira estocástica; Esforço fiscal; Municípios; Endogeneidade

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1. Introduction

Law 9478/97, also known as “The Oil Law,” regulates the collection and sharing of oil rents between the Brazilian federated entities. A significant portion of these rents is distributed to a subset of states and municipalities that must fulfill some requirements, like proximity to producing areas or being affected by the activities of the oil industry.¹

Despite the magnitude of oil windfalls available to those municipalities for over a decade, few studies assess the local impacts of these rents, particularly regarding the incentives to invest them in promoting municipal development. It is noteworthy that the Brazilian law proposes to channel oil revenues into investment and vetoes their use for payroll and debt service. Thus, it is important to analyze whether royalties² have generated positive changes in the realities of the benefiting municipalities.

Different studies suggest that there is no conclusive evidence on the impact of oil royalties on eligible localities. Depending on the chosen economic indicator, the evidence is favorable or contrary (or null) to the increase in local welfare. Some studies find positive impact on socio-economic development and on local welfare (Navarro, 2003; Alexandre, 2003; Gomes, 2007; Postali and Nishijima, 2013) whereas others do not observe significant differences in the evolution of social indicators between beneficiaries and non-beneficiaries (Reis, 2005; Giviez and Oliveira, 2008; Postali and Nishijima, 2011; Caçador and Monte, 2013). Mixed evidence depending on the social indicator under analysis are found in Postali and Nishijima (2008) whereas Postali (2009) concludes for negative impact of royalties on economic growth of beneficiaries.

The guidelines for investing oil windfalls motivated some studies that found evidence of positive relationship between these revenues and capital expenditure (Bregman, 2007), global investment (Leal and Serra, 2002) and social spending without significant improvements in public services (Caselli and Michaels, 2013). Regarding the political effects,³ some studies show that oil royalties give electoral advantages for incumbent mayors (Monteiro and Ferraz, 2010), because they impact positively on the likelihood of reelection (Silva et al., 2013).

Regarding fiscal impacts, some studies have sought to verify whether oil revenues impair the fiscal discipline of the benefiting municipalities. The issue is very sensitive, as oil windfalls tend to be volatile, because they are closely linked to prices and production of hydrocarbons. Since the benefiting localities observe a positive shift in their budget constraints, they may be tempted to relax the incentive to collect their own taxes and/or to overspend (the flypaper effect). Preliminary evidence with data up to 2005 suggest that municipalities covered by oil revenues do reduce fiscal effort and overspend as consequence of royalties (Postali and Rocha, 2009; Queiroz and Postali, 2010); also, benefiting municipalities increase the number of civil servants (Monteiro and Ferraz, 2010).

This paper aims to contribute to the fiscal branch of the aforementioned literature. It proposes to investigate further the effect of royalties on the municipal tax effort. The methodology aims to estimate an efficient tax frontier to assess whether oil revenues can explain the distance of the municipality from this frontier.⁴ The topic is relevant because the fiscal relaxation may contribute to the progressive weakening of the local tax base, creating a vicious circle of increasing dependence on federal and state funds.

Studies on the relationship between federation and incentives for spending and taxing gained momentum after the Constitution of 1988 in Brazil,⁵ which allocated larger shares of public funds to states and municipalities, without

¹ According to the Oil Law, 10% of the gross value of production of oil and natural gas should be collected by the National Treasury as royalty revenues. Beyond royalties, there is also a “Special Tax” – a resource rent tax levied on highly productive projects. In 2012, new rules on the distribution of royalties were approved (Law 12731/12), favoring non-producing localities at the expense of the current beneficiaries.

² From now on, by “royalties,” we mean “royalties plus special tax.”

³ The political consequences of local expenditures in Brazil were studied by Meneguín and Bugarin (2001) and Meneguín et al. (2005), both collecting evidence on the linkage between public spending, voting and political power. There are strong evidence that high spending increases the likelihood of electing political allies or reelecting the incumbent mayor (Sakurai and Menezes Filho, 2008) and that the municipal budgets exhibit opportunistic and partisan cycles (Sakurai and Menezes Filho, 2011). Also Firpo et al. (2014) link local political power to public spending, concluding that federal deputies use amendments to reward their localities.

⁴ Queiroz and Postali (2010) estimate a stochastic frontier with data up to 2005 using GDP and population as inputs. However, in order to make economic sense in a production function, inputs should be a variable under control of policymaker. The present paper meets this objective by introducing capital and personnel expenses in the production function.

⁵ Countries organized as fiscal federalism aim to equalize the fiscal capacities between their regions (Dahlby and Wilson, 1994; Oates, 1999). The evidence suggests that the separation between the power to tax and the decision to spend in the presence of grants coming from upper levels of government under a federated system induces an increase in the size of local public budgets through distortive taxes and overspending (Winer,

the corresponding responsibility for the supply of goods and services (Cossio, 1998). The system was designed to reduce regional income inequalities (Mendes, 2005). However, there are wide evidence that the access to federal funds lead the Brazilian federative entities (states and municipalities) to underutilize their own tax base (Shah, 1994) and to reduce the fiscal effort (Cossio, 1998; Ribeiro and Shikida, 2000; Reis and Blanco, 1996; Ribeiro, 1998; Schwengber and Ribeiro, 1999; Marinho and Moreira, 1999; Veloso, 2008; Carvalho, 2008). Another distortive effect of federal grants on the behavior of local governments is the flypaper effect,⁶ whose evidence for Brazil are reported by Cossio and Carvalho (2001), Mattos et al. (2011) and Sakurai (2013).

Although oil revenues in Brazil – royalties and special tax – are assigned following a different compensatory logic, they can generate the same inefficiencies arising from the usual fiscal grants. Moreover, they present a distributional profile, in order to benefit the producing municipalities and/or the localities affected by activities related to the oil industry.

This paper aims to investigate this hypothesis – that oil revenues are reducing the fiscal effort of the benefiting municipalities – through the estimation of an efficient tax production frontier based on Battese and Coelli (1995). We include political variables in the inefficiency equation, with the purpose of assessing whether partisan preferences of locals help to explain inefficiency scores. As an additional contribution, we address the endogeneity of inputs by adopting the lagged independent variable in the production function as instrument to correct the bias of reverse causality and/or simultaneity between inputs and outputs.

This paper is structured as follows, besides this introduction. Section 2 presents the methodology; and Section 3 provides the data and results. The final section presents some concluding remarks.

2. Methodology

Aigner et al. (1977) originally developed the Stochastic Production Frontier method to study the technical efficiencies of firms. The fundamental idea is to estimate a frontier that represents the potential (or optimal) production of a particular set of productive units and observe how each one is positioned relative to this frontier. Considering $i = 1, \dots, I$ firms, the basic model is:

$$y_i = f(X_i; \beta) + V_i - U_i \quad (1)$$

where X_i is the vector of inputs, y_i is a measure of product, and β is the vector of parameters to be estimated, which describes how production responds to changes in inputs. The production unexplained by the model (random error) is decomposed into two parts. The U_i component reflects the fact that the product of each unit has its upper bound on the production frontier and possesses non-negative truncated distribution ($U_i \geq 0$); usually, one assumes a half-normal distribution, such that $U_i \sim N^+(\mu, \sigma^2)$. V_i is a random component that is assumed to be independent and identically distributed (i.i.d.), representing shocks beyond the unit's control, such that $V_i \sim N(0, \sigma_v^2)$ and $CoV(V_i, U_i) = 0$. The V_i component means that the frontier itself may vary randomly between firms or over time for the same firm.

The rationale behind the stochastic frontier model can be employed to study a “tax production function.” The tax capacity of a governmental entity can be estimated according to factors that are under its control (U_i) or beyond it (V_i). Thus, the efficiency measure can be derived from U_i , as follows⁷:

$$TE_i = \frac{y_i}{E[y_i|U_i = 0]} = \frac{y_i}{f(X_i; \beta)} \quad (2)$$

Since U_i has non-negative distribution, $TE \in [0, 1]$. Fig. 1 allows us to observe the efficiency measures. The greater the distance U_i , the closer to zero the technical efficiency TE . This means that the municipality producing y_i would be able to “produce” more taxes with the same amount of input X_i .⁸

1983; Logan, 1986; Smart, 1998; Keen and Kotsogiannis, 2002, 2004; Goodspeed, 2002; Lucas, 2004; Aragon and Gayoso, 2005; De Mello, 2008; Sanguinetti and Tommasi, 2004; Buettner, 2006; Dahlberg et al., 2008; Smart, 2007).

⁶ The flypaper effect is the evidence that intergovernmental grants have a greater effect on expenditures than an equivalent increase in the income of the taxpayers of the benefiting localities. For detailed theoretical and empirical references, see Gamkhar and Shah (2006), Inman (2008), Dahlby (2011).

⁷ For a formal definition of technical efficiency, as well as for both the input- and the output-oriented version, see Kumbhakar and Lovell (2000, p. 43).

⁸ Similarly, one could define an input-oriented efficiency measure, that is, the amount by which the input X_i could be reduced without reducing the observed output y_i .

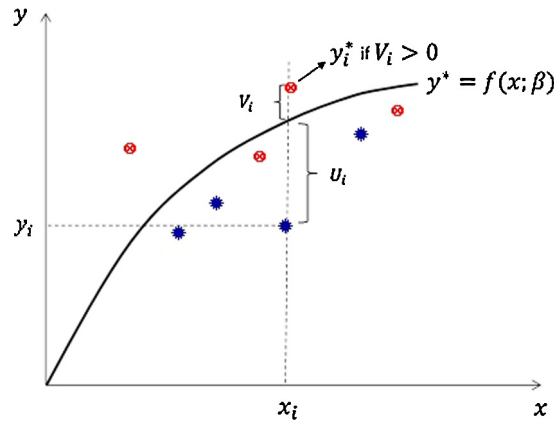


Fig. 1. Stochastic production frontier.

Moreover, as $U \rightarrow 0, TE \rightarrow 1$, indicating that the unit (municipality) is close to the tax-efficient frontier. The frontier’s position varies stochastically according to the random error V . If V is positive, the stochastic frontier exceeds the value of the deterministic one. This is represented by the solid curve, which does not consider the occurrence of exogenous shocks. The opposite occurs if V is negative. The position of the stochastic frontier as $V \neq 0$ is indicated by \otimes . In Fig. 1, municipality i ’s position is above the deterministic frontier, indicating that the unit experienced a positive shock.

Battese and Coelli (1995) develop a stochastic frontier model for panel data in which the inefficiency terms are parameterized from a set of explanatory variables. Thus, y_{it} is the production of unit $i, i = 1, \dots, I$, at time $t, t = 1, \dots, T$. If X_{it} is the $(1 \times K)$ vector of inputs and β is the $(K \times 1)$ vector of parameters to be estimated, the model can be expressed in the following functional form:

$$y_{it} = \exp(X_{it}\beta + V_{it} - U_{it}) \tag{3}$$

V_{it} are i.i.d. random errors such that $V_{it} \sim N(0, \sigma_V^2)$. U_{it} are non-negative random components that possess normal distribution truncated at zero, representing the technical production inefficiencies. They are expressed by:

$$U_{it} = Z_{it}\delta + W_{it} \tag{4}$$

Thus, $U_{it} \sim N(Z_{it}\delta, \sigma_W^2)$, where Z_{it} are the explanatory variables of technical inefficiencies and δ is an $(M \times 1)$ vector of coefficients to be estimated. $W_{it} \sim N(0, \sigma^2)$ is a random variable truncated at point $-Z_{it}\delta$.⁹

As regards the tax problem, there are two distinct types of variables. The impact of each input X_{it} on tax collection y_{it} depends on the magnitude of the coefficient β , which indicates whether these variables expand or contract the frontier, i.e., whether they increase or decrease the municipal tax collection. Z_{it} are variables that may explain the distance between the observed tax collection and the estimated efficient frontier, while δ are the corresponding coefficients to be estimated. If $\delta > 0$, the variable contributes to distancing the municipal tax revenue from the efficient frontier, while a negative sign implies that the variable acts to reduce inefficiency. In the case under study, the oil royalties are the variable of interest among the set of covariates.

The model defined by Eqs. (3) and (4) can be linearized and synthesized according to the following system:

$$\ln y_{it} = X_{it}\beta + V_{it} - U_{it} \tag{5}$$

$$U_{it} = Z_{it}\delta + W_{it} \tag{6}$$

As Battese and Coelli (1995) highlight, both equations must be estimated simultaneously by maximum likelihood. The reason is that a two-stage procedure with ordinary least squares is inconsistent, because in the first stage, the

⁹ As Kumbhakar and Lovell (2000, p. 43) argue, since a panel has more information than cross-sectional data (for which the stochastic frontier models were originally developed), it allows the relaxation of some of the strong assumptions on the distribution of the error components. In addition, some estimation techniques in the panel do not require the assumption of independence between the error component and the independent variables, so that the repeated cross-sections can replace it. Finally, the estimation in the panel allows consistent estimates of the coefficients as $T \rightarrow \infty$ (Kumbhakar and Lovell, 2000, p. 96).

inefficiency components are estimated as a regression error, i.e., under the assumption that they are white noise. However, the second-stage estimation involves specifying a regression model to explain such effects, violating *ex post* the assumption that they are i.i.d. in the previous stage. Thus, following Battese and Coelli's (1995) recommendation, the equations are simultaneously estimated by maximum likelihood.¹⁰

The technical efficiency (TE) of each municipality i in year t can be defined by the ratio y_{it}/y_{it}^* , where y_{it}^* is the estimated tax revenue on the efficient frontier ($U_{it} = 0$). Therefore:

$$TE_{it} = \frac{\exp(X_{it}\beta + V_{it} - U_{it})}{\exp(X_{it}\beta + V_{it})} = \exp(-U_{it}) = \exp(-Z_{it}\delta - W_{it}) \quad (7)$$

The technical efficiencies TE measure the distance of each municipality from the efficient frontier and vary, by design, between zero and one. The closer to one, the more efficient the municipality and, therefore, the higher its tax effort. For example, if $TE = 0.75$, then this municipality collects 25% less than it would obtain if the internal sources of inefficiency were corrected.

In studies on tax efficiency, the advantage of the stochastic frontier method over classical regression is the possibility of estimating potential revenues, taken as the upper bound for tax collection. Without this, the alternative procedure would be to compare the position of decision-making units with respect to the unconditional average of tax revenues, which is a worse reference for efficiency.

3. Data and results

In order to estimate the tax production function, it is necessary to select some measures of inputs that reflect the municipal effort in collecting taxes. This paper employs the personnel expenditures as a proxy for labor and the capital expenditures as a proxy for capital in the tax production function. The idea is to capture the municipal effort in managing the activities related to tax collection. Papers that employ the efficient production frontier to assess tax collection usually base the inputs on fiscal capacity, that is, on local economic variables (GDP, population, etc.), without taking into account the effort of the government. This paper adopts a different strategy and employs another set of inputs, following the argument that they indirectly reflect the level of effort made by municipal administrations to collect taxes. Given the available information, both capital and personnel expenditures are direct functions of the inputs employed in tax collection.¹¹ However, due to legal restrictions, in Brazilian municipalities, the mayor observes the fiscal revenue before implementing personnel and capital expenditures, which would make such variables endogenous. Moreover, some normative restrictions (like Fiscal Responsibility Act) forbid the free float of personnel and capital expenditures. This could introduce a bias of reverse causality in the estimates, since the estimated tax collection affects the Municipal outlay. In order to overcome this problem, the lagged personnel and capital expenditures are used as instruments for personnel and capital expenditures, respectively. This allows correcting the bias of reverse causality and simultaneity that comes from the aforementioned restrictions, under the identification hypothesis that the past inputs (expenditures) are uncorrelated with unobservable determinants of present output (taxes).

The measure of product is the local tax revenue. It is noteworthy that the GDP per capita was inserted into the inefficiency equation. This variable aims to control for the fiscal capacity. Some of the aforementioned studies use it as input for tax production, but, since the estimation is made simultaneously by maximum likelihood, the net effect of regressing it in the inefficiency equation is equivalent, despite the difference in economic interpretation: instead of input for tax collection, the idea is to assess whether the fiscal capacity shifts the score of efficiency relative to the frontier.

The specification of the production function is an important issue. According to Sauer et al. (2006), the functional form must possess certain desirable properties and the most important ones are theoretical flexibility and global consistency. A flexible functional form should be able to mimic arbitrarily different productive structures from an appropriate choice of parameters.¹² On the other hand, a functional form has global consistency if it allows the reproduction of the theoretical properties of an expected economic relationship, from the appropriate choice of

¹⁰ The expressions for the log-likelihood function as well as for the partial derivatives with respect to the parameters to be estimated can be found in Battese and Coelli (1993).

¹¹ The ideal would be the use of personnel expenditures and investment in activities directly linked to the management of revenues by the municipal power, but this level of information is not available in our database.

¹² For a more detailed discussion on the role of flexibility, see Sauer et al. (2006).

parameters. The theoretical consistency requires that the production function is: (i) monotonically non-decreasing in inputs; (ii) single-valued for each observation; and (iii) quasi-concave, which means a convex production-possibility set. The theoretical consistency must be the only restriction imposed on the production function, the functional form of which should be as flexible as possible.

The two most common functional forms used for the production function are Cobb–Douglas and Translog (Coelli et al., 2005, p. 211). Translog¹³ is more flexible than Cobb–Douglas, but the latter more easily meets the conditions for global theoretical consistency, just requiring the estimated coefficients to be non-negative. For Translog, verifying the consistency conditions is a much more complicated task.¹⁴ Our Translog estimates did not meet such criteria and, for this reason, only the results for Cobb–Douglas are presented.

Considering the two inputs described above, the Cobb–Douglas production function can be expressed by¹⁵:

$$\ln RTrib_{it} = \beta_0 + \beta_1 \ln DespCap_{it} + \beta_2 \ln DespPess_{it} + V_{it} - U_{it} \quad (8)$$

where $RTrib_{it}$ is the tax revenue of municipality i in year t , $DespCap$ is the capital expenditure and $DespPess$ is the personnel expenditure. β_0 , β_1 , and β_2 are the parameters to be estimated and the global consistency conditions require that $\beta_1 \geq 0$ and $\beta_2 \geq 0$. The proposed inefficiency equation is given by:

$$\begin{aligned} U_{it} = & \delta_0 + \delta_1 \ln Roy_{it} + \delta_2 \ln PIBpc_{it} + \delta_3 \ln PIBpc_{it-1} + \delta_4 \ln Pop_{it} + \delta_5 \ln Pop_{it-1} + \delta_6 \ln TransUn_{it} \\ & + \delta_7 \ln TransUn_{it-1} + \delta_8 \ln TransEs_{it} + \delta_9 \ln TransEs_{it-1} + \delta_{10} Agric + \sum_{j=11}^{18} \delta_j DAno_{it} \\ & + \sum_{j=19}^{25} \delta_j DPartido_{it} + \delta_{26} ColGov + \delta_{27} ColPres + W_{it} \end{aligned} \quad (9)$$

where Roy_{it} is the royalty revenue received by the municipality i in year t ,¹⁶ $PIBpc_{it}$ is the gross municipal product per capita, POP_{it} is the municipal population, $TransUn_{it}$ are financial grants from the federal government, and $TransEs_{it}$ are state grants. $Agric_{it}$ is the share of agricultural products in the gross municipal product, the goal of which is to control for the profile of the municipality (urban or rural). $DAno_{it}$ and $DPartido_{it}$ are, respectively, year dummies and dummies representing the political party of the mayor in office. These aim to control for potential inefficiencies resulting from partisan differences. $ColGov$ is a dummy equal to 1 if the major's party belongs to the coalition that elected the state governor and $ColPres$ is a dummy equal to 1 if the major's party belongs to the coalition that elected the President and zero otherwise. Both dummies are important to control for political alliances that may affect voluntary transfers to municipalities. The product per capita controls for fiscal capacity, whereas grants aim to control for revenues coming from upper governments. The population controls for the size of the municipality. In addition to the current level, the lagged values of such variables ($PIBpc_{it-1}$, Pop_{it-1} , $TransUn_{it-1}$, $TransEs_{it-1}$) were also included, in order to take into account the dynamic component of inefficiency, under the rationale that past values of the economic product, the population and the transfers may affect the current tax revenue as well as the inefficiency.

Table 1 summarizes the descriptive statistics of the variables used in the model. Noteworthy is the great dispersion of royalty revenues, a result of the large asymmetry in the distribution of these resources that prevails in the Brazilian federation.

¹³ A functional form is flexible of k -order if it allows the building of an approximate function of which the number of parameters sufficient for its value at a given point is equal to the arbitrary function until the k th derivative. Cobb–Douglas is flexible of first order, whereas Translog is flexible of second order. As evidenced by Coelli et al. (2005), the higher the degree of flexibility, the better, but it can generate estimation problems, such as collinearity and the curse of dimensionality.

¹⁴ See Sauer et al. (2006, pp. 147–148).

¹⁵ The general functional form of Cobb–Douglas is $y_{it} = ecp \left[\beta_0 \prod_{i=1}^n x_{it}^{\beta_i} \right]$, the linearized version of which is given by (5).

¹⁶ As there are many observations with a zero value, we actually calculated $\ln(1 + Roy) \approx \ln(Roy)$. The orders of magnitude of this variable allow such approximation.

Table 1
Descriptive statistics.

Variable	Mean	St. deviation	Min.	Max.
Tax Revenue (<i>RTrib</i>)	8401.91	155,650.97	0.00	15,021,430.78
Capital Expenditure (<i>DespCap</i>)	5045.03	32,747.56	1270.10	2,565,202.95
Personnel Expenditure (<i>DespPess</i>)	17,993.02	127,128.87	709.42	8,136,915.46
Oil Royalties (<i>Roy</i>)	561.26	10,931.36	0.00	1,230,973.11
Municipal Product per Capita (<i>PIBpc</i>)	10.57	309.85	0.72	50.67
Population (<i>Pop</i>)	34,332.31	204,151.58	0.00	11,316,119.00
Grants from Federal Govt. (<i>TransUn</i>)	13,047.81	43,139.75	0.00	1,725,472.90
Grants from State (<i>TransEs</i>)	11,089.74	90,985.02	0.00	7,748,201.47
Share of Agricultural Product (%) (<i>Agric</i>)	19.34	16.55	0.00	84.82
#Obs.	46,153			
#Municipalities	5559			

Sources: ANP, IBGE, RAIS, Finbra/STN. Calculated by the author. Monetary values in R\$1000.

The results are exhibited in Table 2. The conditions for theoretical consistency of the Cobb–Douglas production function are satisfied because the coefficients of both inputs¹⁷ are positive and statistically significant. This means that both expenses contribute to generating tax revenues for municipalities. With regard to the explanation for the inefficiencies (9), oil revenues have a negative impact on tax effort, very small though. Nevertheless, this impact is statistically significant at 1%. GDP per capita and population both have significant negative coefficients, indicating that the fiscal capacity and the size of the municipality contribute to increasing the efficiency in collecting tax, which is an intuitive result: collecting tax is easier for large, rich municipalities than for poor, small ones. The same conclusion can be noted for the lagged values of these variables.

Grants from upper levels of government (state and federal) exhibit a curious result: whereas the current grants increase efficiency, their lagged values contribute to reduce it. This result illustrates the dynamic profile of grant-dependency. Municipalities benefiting from high financial transfers in the previous year do relax their fiscal effort in the following year.

Rural municipalities are less efficient than urban ones, since the variable representing the share of agricultural products in the gross municipal product is significantly positive. Rural municipalities are more dependent on federal and state funds. Since they have low tax base, they face greater difficulty to collect ISS and IPTU, the two most representative municipal tax.

The year dummies are negatively significant between 2005 and 2007, but positively significant from 2009 and 2011. This can be interpreted as a temporal decrease in inefficiency relative to 2003, representing a kind of learning curve for municipalities until 2007. After that, municipalities may have suffered setbacks as a result of the global crisis, but this hypothesis deserves better investigation.¹⁸ Dummies for the most representative political parties of the Brazilian system were inserted, relative to others. As can be seen, municipalities with mayors belonging to PSDB and DEM tend to be more efficient in tax collection than other associations.

Finally, political alliances with state and federal government impact positively on efficiency, since dummies representing political alignment of the major in office are negatively significant. This means that coalitions improve the efficiency in tax collection.

The fit of the model to the stochastic frontier follows the parameterization proposed by Battese and Corra (1977) such that $\gamma = \sigma^2 / (\sigma^2 + \sigma_V^2)$, where σ^2 is the variance of the inefficiency component U and σ_V^2 is the variance of the random error V . Thus, $\gamma \in [0, 1]$, indicating the adequacy of a stochastic frontier model vis-à-vis the usual econometric model. If $\gamma \rightarrow 1$, the variance of the inefficiency is significant, indicating that the frontier model is appropriate; if γ is not statistically different from zero, the variance of U is small compared with the total variance, so that a frontier brings

¹⁷ In a previous stage, both expenditures were regressed on their lagged values, used as instruments. The actual inputs in the production function are predicted values of these regressions.

¹⁸ After 2008, municipalities have experimented lower constitutional grants, as consequence of tax exemptions (mainly IPI) and called for changes in the percent of these transfers.

Table 2
Cobb–Douglas tax production function. Dependent variable: municipal tax revenues. Independent variables in log.

	Coefficient	Standard deviation
<i>X</i>		
<i>Constant</i> (β_0)	10.223***	0.167
<i>DespCap</i> (β_1)	0.217***	0.009
<i>DespPess</i> (β_2)	0.249***	0.009
<i>Z</i>		
<i>Constant</i> (δ_0)	14.882***	0.094
<i>Roy</i> (δ_1)	1.87E-09***	2.22E-10
<i>PIBpc</i> (δ_2)	-0.383***	0.023
<i>PIBpc</i> ₍₋₁₎ (δ_3)	-0.188***	0.023
<i>Pop</i> (δ_4)	-0.423***	0.018
<i>Pop</i> ₍₋₁₎ (δ_5)	-0.116***	0.018
<i>TransUn</i> (δ_6)	-0.361***	0.004
<i>Trans Un</i> ₍₋₁₎ (δ_7)	0.253***	0.004
<i>Trans Es</i> (δ_8)	-0.270***	0.004
<i>Trans Es</i> ₍₋₁₎ (δ_9)	0.047***	0.003
<i>AGRIC</i> (δ_{10})	0.774***	0.027
<i>Dummy 2004</i> (δ_{11})	-0.017	0.012
<i>Dummy 2005</i> (δ_{12})	-0.089***	0.015
<i>Dummy 2006</i> (δ_{13})	-0.210***	0.014
<i>Dummy 2007</i> (δ_{14})	-0.198***	0.014
<i>Dummy 2008</i> (δ_{15})	-0.014	0.021
<i>Dummy 2009</i> (δ_{16})	0.154***	0.014
<i>Dummy 2010</i> (δ_{17})	0.219***	0.015
<i>Dummy 2011</i> (δ_{18})	0.301***	0.016
<i>Dummy PMDB</i> (δ_{19})	0.103***	0.031
<i>Dummy PT</i> (δ_{20})	0.109***	0.028
<i>Dummy PSDB</i> (δ_{21})	-0.043***	0.010
<i>Dummy PDT</i> (δ_{22})	-0.017	0.013
<i>Dummy PTB</i> (δ_{23})	0.005	0.012
<i>Dummy DEM</i> (δ_{24})	-0.050***	0.014
<i>Dummy PL</i> (δ_{25})	-0.011	0.018
<i>ColGoV</i> (δ_{26})	-0.018***	0.008
<i>ColPres</i> (δ_{27})	-0.090***	0.030
σ^2	0.411***	0.003
γ	0.007***	0.001
Log-likelihood	-30,317.22	
λ test of the one-sided error	42,230.46**	

*** 1% significant.

** 5% significant.

no gains compared with a classical regression model. As can be seen in the results, although γ is low, it is statistically different from zero, which confirms the suitability of the frontier.

Another confirming test of the adequacy of stochastic frontier is the likelihood ratio statistic λ , which tests the joint null hypothesis $H_0 : \gamma = \delta_1 = \dots = \delta_{27} = 0$. It is significant at the 5% level, considering the critical values found by Kodde and Palm (1986, p. 1246),¹⁹ which means that the one-sided error assumption for U_{it} is valid (Eq. (4)).

Table 3 reports the estimated technical efficiency of the top 20 beneficiaries of oil revenues, in gross values, considering the average for 2002–2011. They are ranked by oil revenues. The scores of some big beneficiaries are well above the national average (0.05), which is very low. Campos dos Goytacazes, the most benefiting from royalties,

¹⁹ This statistic has a mixed χ^2 distribution with degrees of freedom given by the number of restrictions imposed on the model (in this case 28).

Table 3
Estimated technical efficiency of the top 20 beneficiaries. Average 2002–2011. Royalties in R\$ millions.

State	Municipality	Royalties	TE
RJ	Campos dos Goytacazes	920.65	0.54
RJ	Macaé	379.80	0.52
RJ	Rio das Ostras	267.21	0.36
RJ	Cabo Frio	157.12	0.46
RJ	Quissamã	93.20	0.31
RJ	São João da Barra	89.66	0.18
RJ	Casimiro de Abreu	64.48	0.19
ES	Presidente Kennedy	58.47	0.10
RJ	Rio de Janeiro	51.86	1.00
AM	Coari	51.14	0.20
RJ	Armação dos Búzios	49.85	0.16
RJ	Angra dos Reis	49.65	0.62
SP	São Sebastião	48.02	0.45
ES	Linhares	41.10	0.30
RJ	Niterói	39.84	0.85
RJ	Duque de Caxias	30.00	0.89
RJ	Carapebus	29.34	0.08
RJ	Parati	29.18	0.09
RJ	Magé	25.49	0.21
RN	Mossoró	25.00	0.37
Average Brazil			0.05

Source: Estimated by the author.

exhibit technical efficiency of 0.54 whereas Rio de Janeiro is on the efficient frontier (score = 1.00). The table allows concluding that the benefiting municipalities are more efficient than the national average, but oil revenues impact negatively on such scores.

4. Concluding remarks

This study aimed to investigate the hypothesis that Brazilian oil windfalls may be leading the benefiting municipalities to relax their fiscal effort. To fulfill this goal, we estimated a Cobb–Douglas stochastic production frontier, the regularity conditions of which are more easily met. We used the model of Battese and Coelli (1995), which allows the joint estimation of the production function and the inefficiencies, parameterized in explanatory variables, among which are the oil revenues. To overcome possible bias of reverse causality of inputs and outputs, we adopted the lagged independent variable as instruments; also, the inefficiency equation employs lagged economic product, population and grants with the purpose of controlling for the dynamic components of tax collection.

The results show that oil royalties reduced the tax effort of the benefiting municipalities, to the extent that there is a negative and statistically significant relationship between these revenues and the estimated inefficiencies.

Such results suggest that the current discussion on more equitable distribution of royalties between the Brazilian states and municipalities should be conducted with caution, since a considerable portion of Brazilian localities suffer from low fiscal capacity, due to regional inequalities. The increase in oil revenues may contribute to reducing the incentive to collect taxes, generating a vicious circle of dependence on federal funds, which is a chronic problem in Brazil. This problem is particularly relevant in the context of pre-salt, due to the expected boost in such revenues.

Of course, this study has limitations and several extensions are possible. In particular, other production functions can be estimated, including further control variables. The effects on expenditures can also be studied. Nevertheless, we believe we have taken an important step in understanding the impact of oil revenues on local realities and in designing mechanisms for the effective use of these rents in the coming years.

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