The effects of oil royalties on regional inequality in Brazil

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Abstract

This article evaluates the impact of oil royalties on Brazil's production structure and their effects on regional inequality. An interregional input-output model was used, encompassing the 27 Brazilian states and 26 sectors, with base year 2008. The simulation strategy assumed 75% of these funds are channelled into education and 25% into the health sector, as mandated by Law 12.858/2013. To measure the effect of royalties on regional inequality, the Gini coefficient was calculated both ex-ante and ex-post with respect to the impact analysis. The main findings indicate that interregional and intersectoral spillovers are weak; but, in the Southeast and Northeast regions, the investment of royalties in education and health could help reduce intraregional inequality.

Keywords

Economic development, regional development, petroleum revenues, royalties, productivity, regional disparities, income distribution, input-output analysis, Brazil

JEL classification

R15

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I. Introduction

The expansion of the oil sector since the last decade has made Brazil the second largest oil producer in South America. According to Falcão (2013), this situation is explained by Brazil's control of its oil reserves and an appropriate refining structure. These provide competitive advantages, such as the domestic security of sectors related to transportation and electricity production that are vital for the economy. Industrial competitiveness is gained through participation in international trade with the direct export of oil and its derivatives.

Nonetheless, the increasing extraction of oil and natural gas promotes environmental degradation and impairs well-being in the producing localities and municipalities, or others that are directly or indirectly affected by it. Accordingly, economic compensation must be paid for this activity. Recently, the Brazilian federal government altered the institutional apparatus that regulates the royalties destined for the municipalities and states that extract or produce this resource or are affected by oil activity.

Pursuant to subsection II of article 45 of Law 9.478/1997 (the "Oil Law"), royalties are economic compensation paid each month by the concession-holders, based on their extraction and production of oil or natural gas. The changes promoted by the "Oil Law" include new criteria for calculating and distributing these revenues among the municipalities affected by oil and natural gas production. The new law hiked the royalty rate from 5% to 10% of the gross value of production (GVP).

The evolution of oil legislation shows how, the past, royalties have been channelled to various areas of the economy, such as infrastructure, sanitation, health and education. However, according to Law 12.858 on oil royalties, enacted in 2013, 75% of the funds must be allocated to education and 25% to health. The investment of oil revenues in education and health demonstrates the importance that the Brazilian government attaches to these sectors.

The last ten years have witnessed an intense debate on the effects of oil royalties in Brazil, especially now that drilling has started in the pre-salt layer. The expansion of the oil sector stimulated by the rise in international commodity prices, increased the collection of oil and natural gas royalties. This, in turn, increased the revenues received by the beneficiary municipalities. Between 2010 and 2016, royalty collection totalled R$ 92.3 billion.

Based on different empirical approaches, various studies have measured the effects of oil royalties on different areas of the economy. These include studies on the effects of royalties on development (Pacheco, 2003; Postali, 2009; Caçador and Monte, 2013; Schlindwein, Cardoso and Shikida, 2014); the impact of oil revenues on the municipalities' public finances (Silva, 2007; Ribeiro, Texeira and Guitierrez, 2009; Carnicelli and Postali, 2014); and the effect of such revenues on social indicators (Terra, Givisiez and Oliveira, 2007; Givisiez and Oliveira, 2011; Postali and Nishijima, 2011 and 2013; Tavares and Almeida, 2014; Reis, Santana and Moura, 2018).

However, the literature contains few analyses of the effects of oil royalties on regional inequality in Brazil. Most empirical studies, using econometric approaches, analyse the effects on variables such as gross domestic product (GDP), social indicators and public finances, while ignoring intersectoral or interregional effects, which is the focus of this paper. The objective of this article is, therefore, to evaluate the effects of oil royalties on the production structure of Brazilian states and on regional inequality. For this purpose, an interregional input-output model is used, comprising the 27 Brazilian states and 26 sectors, with base year 2008.

This study contributes to the empirical literature by offering unpublished findings on the effects of oil royalties on regional inequalities in Brazil, based on an interregional and multisectoral model.

The article is divided into six sections, including this introduction. Section II analyses the main effects of oil royalties on the economy, and section III presents the interregional input-output model and the impact analysis. The database and simulation strategy used are presented in section IV, while the results are discussed in section V. Some final thoughts and policy implications are set forth in the sixth and last section.

II. Economic effects of oil royalties

The potential effects of oil royalties on local development in the benefited municipalities and, consequently, their impact on the municipalities themselves have already been examined extensively in the literature, through various lines of research. While some studies analyse the effects of royalties on development, others consider their impact on municipal finances and social indicators.

The impacts of royalties on development have been studied by Pacheco (2003), Postali (2009), Caçador and Monte (2013), Schlindwein, Cardoso and Shikida (2014) and Magalhães and Domingues (2014), among others.

Based on the weight of oil royalties in the revenues of municipalities facing the Campos basin in the State of Rio de Janeiro, Pacheco (2003) confirmed that royalties and special participations are enabling additional investments in infrastructure in the municipalities considered and are used to provide local governments with the funds needed to satisfy the excessive demand for public services. Nonetheless, no concrete actions to promote the sustainability and diversification of the local production base, with a view to averting the economic decline derived from the depletion of hydrocarbon reserves, were identified.

Postali (2009) used a difference-in-differences econometric model to compare the trend of certain indicators in the municipalities affected and those not affected by adoption of the “Oil Law”, Law 9,478 of 1997. This study used data on the growth rate of municipal per capita GDP and the human development index (HDI) of the municipalities, both before and after the event. The author found a negative relation between the amount of royalties transferred to the municipality and the growth rate of its GDP.

In an empirical model estimated to assess whether royalties affected municipal development indicators, Caçador and Monte (2013) found that oil revenues did not contribute significantly to the improvement of local development indicators.

Based on the creation of a socioeconomic development index (SDI) through multivariate analysis, Schlindwein, Cardoso and Shikida (2014) refuted the hypothesis that the development indicator of the Lindeiros do Oeste Paranaense municipality accompanies royalty collection. In other words, they challenged the idea that the larger the amount of revenue received, the higher the SDI of the municipalities. Furthermore, the correlation between SDI and royalty collection was negative in all municipalities; that is, the increase (decrease) in SDI values is correlated with the decrease (increase) in the amount of royalties.

Magalhães and Domingues (2014) estimated the effects of pre-salt layer oil extraction on the Brazilian economy, using a dynamic computable general equilibrium (CGE) model for the first time in a study on the Brazilian economy. This model is particularly suitable in terms of bilateral oil trade. The key finding is that the effects on Brazilian GDP and investment are positive and significant. However, the sectoral impact of pre-salt layer oil extraction is highly heterogeneous. While there are several sectors that benefit, there is also a group of activities that lose shares in Brazil’s GDP and exports, in a Dutch disease effect. The explanation for this finding lies in the effect of the concentration of factors of productive in oil extraction, the rise in input prices (such as capital and labour) and export revenues affecting the balance of payments. As a result, the Brazilian economy becomes more dependent on the oil production sector, and the revenues from these exports dominate the country’s foreign trade.

Studies on the impact of oil revenues on municipal public finances include Silva (2007), Ribeiro, Texeira and Guitierrez (2009), Carnicelli and Postali (2014) and Reis and Santana (2015).

According to Silva (2007), the track record of oil-producing municipalities is characterized by advances and setbacks in the performance of public finances and the provision of public goods and services. While advances lead to improvements in the performance of public finances and the quality of the public goods and services delivered, setbacks lead to inefficiency in the provision of goods and services and the capture of public funds.

In contrast, Ribeiro, Texeira and Guitierrez (2009) sought to identify the effects of royalty revenues received by municipal governments in the State of Espírito Santo on their respective per capita GDP. Data were collected from the state's 78 municipalities in 1999–2004. An econometric model using multiple regression based on balanced panel data was used to estimate relations between the variables. In other words, two models were used to test the elasticity of municipal per capita GDP with respect to royalties. The main finding is that there is no evidence of effects on per capita GDP in the municipalities analysed.

The method applied in the study by Carnicelli and Postali (2014) is doubly robust, based on a panel of municipalities between 2000 and 2009. The method consists of two stages. First, the probabilities of receiving oil revenues conditional on observable variables were estimated. In the second stage, a panel of fixed effects was estimated for the set of observations belonging to a common base constructed from the propensity scores estimated in the first stage. It was found that, although the municipalities hire additional civil servants in the presence of oil revenues, the average expenditure on personnel does not increase in the cities included in the treatment group.

Reis and Santana (2015) analysed the effects of using oil royalties to fund the public investments of Brazilian municipalities in 1999–2011, using the panel data econometric model. The study starts from the variables "Budget income", "Royalties" and "Capital expenditures" of the respective municipalities, obtained from secondary sources. The results show that municipalities that are more dependent on royalties increased their capital expenditures as royalties increased, from both a per capita and a fiscal ratio perspective.

The effects of oil royalties on social indicators have been studied by Terra, Givisiez and Oliveira (2007), Givisiez and Oliveira (2011), Postali and Nishijima (2011), Tavares and Almeida (2014) and Reis, Santana and Moura (2018), among others.

Terra, Givisiez and Oliveira (2007) analysed the redistributive potential of oil revenues by studying the pattern of inter-urban public investments in the Brazilian municipality that benefited most from oil revenues, namely Campos dos Goytacazes in the State of Rio de Janeiro. Their analysis revealed that budgetary slack in this "nouveau riche" municipality has not been exploited as a mechanism for reducing inter-urban inequalities; on the contrary, it is reinforcing them.

The method applied in the research by Givisiez and Oliveira (2011) includes compiling historical series of education indicators, based on school censuses and Prova Brasil. The authors compared the evolution of a defined group of municipalities with that of a control group, through logistic regressions. The results refute the hypothesis put forward in the paper, by indicating that the budgetary advantages of the municipalities in question were not reflected in better education indicators.

Postali and Nishijima (2011) used the FIRJAN Municipal Development Index (IFDM) as a measure of social development, to verify whether the royalties distributed under Law 9.478 of 1997 helped to improve the social indicators of the municipalities considered in 2000–2007, relative to the national average. The results showed that oil revenues did not have a significant impact on the social indicators of health and education in the beneficiary municipalities; but, surprisingly, they did generate negative effects on their formal labour sectors.

The study by Tavares and Almeida (2014) found that oil royalties increased education and health spending in the beneficiary municipalities by an average of R$ 2 billion and R$ 1.97 billion, respectively, in 2000–2009. However, the impact of royalties did not translate directly into increased social development as measured by the human development index (HDI). Based on a panel data econometric approach, Reis, Santana and Moura (2018, p. 89) note that the Brazilian municipalities most dependent on oil royalties reduced their health and education shares of public expenditures on average between 1999 and 2011.

In short, the aforementioned studies show that the investment of oil royalties does not produce clearly positive effects in terms of development, social indicators or public finances in the beneficiary municipalities. In some cases, the effects are even strongly negative. In general, studies on oil royalties use econometric approaches to analyse their impact on the economy.

No studies that use input-output models to measure the effects of these revenues on the Brazilian economy were found in the literature. Moreover, research on the economic or social effects of oil royalties does not include an analysis of the effects on income distribution. This article contributes to the empirical literature on royalties by offering new findings for the debate, focusing on regional income distribution. The following section develops the interregional input-output model and the impact analysis.

III. Interregional input-output model and impact analysis

1. Interregional input-output model

The interregional input-output model, also known as the "Isard model" (Isard, 1951), requires a large amount of data, either real or estimated, mainly on intersectoral and interregional trade flows. The interregional system shows the trade relations existing between regions, in terms of exports and imports, which are expressed through flows of goods and services that are destined for both intermediate consumption and final demand (Guilhoto and others, 2010).

According to Miller and Blair (2009), equation (1) summarizes the basic structure of the model, which presents the intersectoral and interregional flows of goods for two regions, L and M, with n sectors. In matrix form, these flows can be represented as follows:

$$Z = \begin{bmatrix} Z^{LL} & \vdots & Z^{LM} \\ \cdots & \cdots & \cdots \\ Z^{ML} & \vdots & Z^{MM} \end{bmatrix} \quad (1)$$

where: Z^{LM} and Z^{ML} represent interregional flows and Z^{LL} and Z^{MM} represent intraregional ones. The matrix of intraregional technical coefficients (A^{LL}) for two sectors can be defined as $A^{LL} = Z^{LL}(X^{L})^{-1}$ and $A^{MM} = Z^{MM}(X^{M})^{-1}$. The first formulation would be valid for A^{LM} while the second would be valid for A^{ML}; that is, varying only the value of the corresponding production (X).

The solution of the basic model (equation (2)) required for the interregional analysis proposed by Isard (1951) results in the following interregional Leontief system:

$$X = (I - A)^{-1}Y \quad (2)$$

where the Leontief inverse matrix is specified as $(I - A)^{-1}$. Although equation (2) represents the same solution as the standard input-output model, the interregional model has advantages over regional models, mainly by capturing the effects in each sector and region, and modelling of interregional flows (Miller and Blair, 2009).

2. Impact analysis

Impact analysis aims to measure the shock generated by exogenous changes in final demand (Y) or in each of its components (household consumption, government expenditures, investments and exports) on total production, employment, imports, wages and value added, among variables.

This study calculates the impact of oil royalties on total production, employment, income and tax revenue of the Brazilian states. The calibrated magnitude of the shock (ΔY) in the simulation is defined from the values of royalties in each state. Hence:

$$\Delta X = (I - A)^{-1} \Delta Y \tag{3}$$

$$\Delta V = \hat{v} \Delta X \tag{4}$$

where ΔX and ΔY are $(n \times 1)$ vectors that represent the effects on the volume of production and the variation in final demand, respectively; while V is an $(n \times 1)$ vector representing the impact on any of the variables mentioned above, namely value added, employment, wages and taxes, among others. In addition, $\hat{v}$ is a diagonal (nxn) matrix in which the elements of the main diagonal are, respectively, the coefficients of value added, employment, wages and taxes, among other variables. The coefficients are obtained by dividing the value of these variables, for each sector, (e_i) by the total production (x_i) of the corresponding sector. In other words:

$$v_i = \frac{e_i}{x_i} \tag{5}$$

Hence, to estimate the impact on the total production volume and each of the variables analysed, all the elements of the vectors ΔX and ΔV are added together.

An increase in sectoral production in a given region of Brazil has an impact on the production of various industries outside the locality of origin, which are referred to as interregional spillovers (Sesso Filho and others, 2006, p. 2).

IV. Database and simulation strategy

1. Database

The main database used is the Brazilian interregional input-output table, with base year 2008, obtained from the Regional and Urban Economics Lab (NEREUS) of the University of São Paulo (Guilhoto and Sesso Filho, 2005; Guilhoto and others, 2010). This matrix consists of 26 sectors and 27 Brazilian states. The data on oil royalties were extracted from the InfoRoyalties site of Universidade Cândido Mendes (UCAM).[1]

2. Simulation strategy

The simulation strategy is based on Law 12,858 on oil royalties, which was adopted in 2013 and provides that 75% of royalties must be invested in education and 25% in health. Thus, only these two sectors (education and health) will suffer variations in their respective final demands. For this purpose,

[1] See [online] http://inforoyalties.ucam-campos.br/.

a simple average of the amounts of royalties received by the states in 2013, 2014, 2015 and 2016 is calculated, which represents an annual shock in the system.

In order to make the analysis more robust, sectoral deflators were constructed from data on sectoral gross value-added obtained from the information bulletin on Brazil's system of national accounts in 2016, published the Brazilian Geographical and Statistical Institute (IBGE, 2018) for the activities "Private and public education" and "Private and public health".[2] The aim of this procedure is to deflate the royalty values for the base year of 2008, in order to make them compatible with the prices prevailing in the base year of the matrix[3].

Could regional income disparities in Brazil be reduced if oil royalties were in fact allocated to education and health, as recommended by Law 12.858/2013? In an attempt to answer this question, this study adopted the methodology used by Domingues, Magalhães and Faria (2009) and Ribeiro and others (2018 and 2017). This entailed calculating the Gini coefficient from the distribution of state GDP both before and after the effects of oil royalties.

The rationale involves calculating the Gini coefficient to verify whether it has increased or decreased. An increase would indicate income concentration, while a decrease would suggest deconcentration. The index can be expressed mathematically as follows:

$$G = 1 - \sum_{k=0}^{k=n-1} \left(X_{k+1} - X_K\right)\left(Y_{k+1} + Y_k\right) \quad (6)$$

where: G = is the Gini coefficient; and X and Y are cumulative proportions of the population and GDP variables, respectively.

V. Results and analysis

This section makes an exploratory analysis of the data on oil royalty collection, the results of simulations using the interregional input-output model, and the effects of oil royalties on regional inequality. The simulation results initially analyse the macroeconomic effects in the macroregions and states; and, in a second stage, they present the sectoral effects. Lastly, the results on regional inequality are presented, based on the calculation of the Gini coefficient both ex-ante and ex-post with respect to the impact analysis, in order to observe whether royalties contribute to the regional concentration or deconcentration of income.

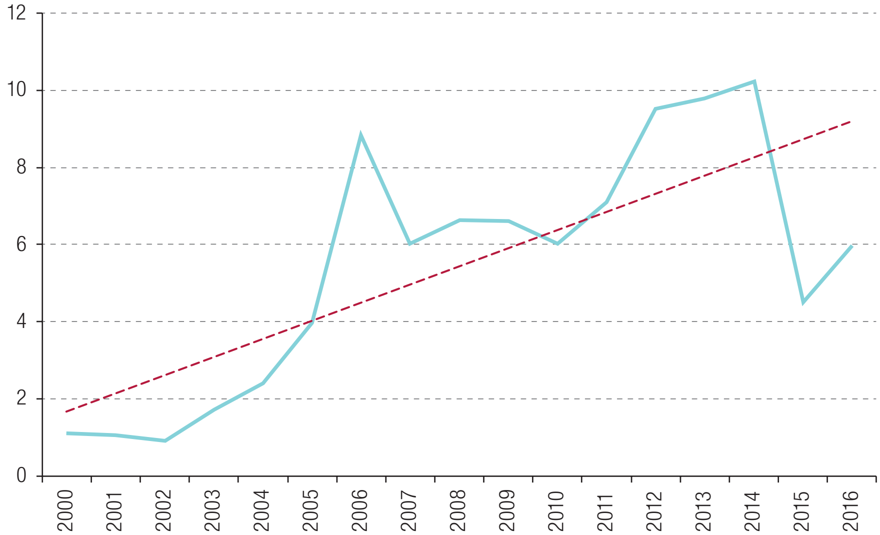
1. Exploratory analysis

Figure 1 shows the annual collection of oil royalties 2000–2016. In this period, revenue collection fluctuated; for example, between 2007 and 2009, it declined owing to the global economic crisis, low oil prices and the appreciation of the real against the dollar. In 2016, royalty revenues shrank by 29% to their lowest level since 2009.

[2] In this database, gross value added is available at current and constant prices for a set of 51 economic sectors spanning 2000–2016. Before calculating the sectoral deflators, the activities "Private education" and "Public education" and "Private health" and "Public health" were aggregated into "Private and public education" and "Private and public health", respectively. This was necessary to obtain the same sectoral aggregation as used in the input-output table.

[3] The sectoral deflators are presented in annex A1.

Figure 1
Brazil: annual oil royalty collection, state data, 2000–2016
(Billions of reais of 2008)

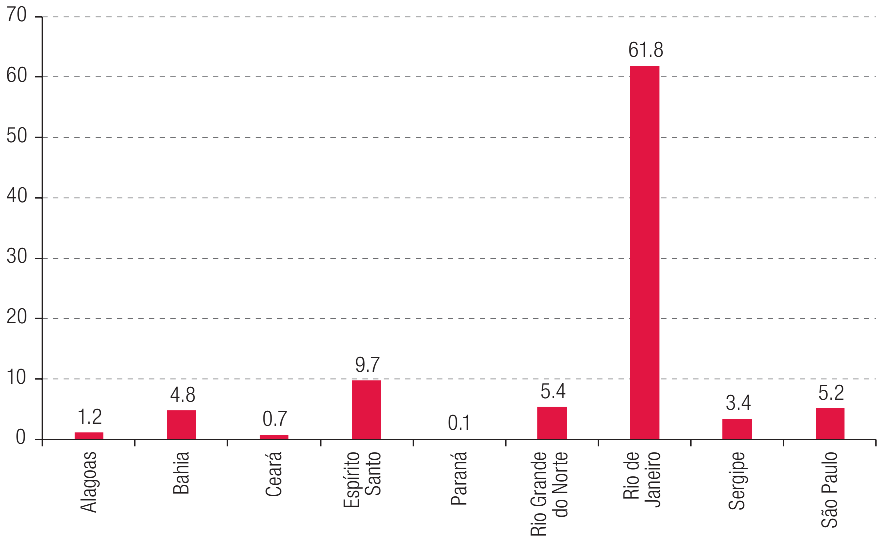


Source: Prepared by the authors on the basis of Info Royalties of the University of Cândido Mendes (UCAM) [online] http://inforoyalties.ucam-campos.br/.

In the period spanned by figure 1, there was a significant rise in the price of oil (commodity cycle), caused mainly by burgeoning demand from China and India (Jimenez and Tromben, 2006). However, according to Sessa, Simonato and Domingues (2017), commodity exports (including oil) contributed to real growth of 0.7% of Brazilian GDP between 2005 and 2011.

Figure 2 shows the sum total of royalty collection in 2000–2016. The State of Rio de Janeiro received the largest amount, absorbing an average of 95% of all oil royalties in Brazil. In contrast, the State of Paraná receives a small portion of these resources, and in 2010–2012 it received nothing.

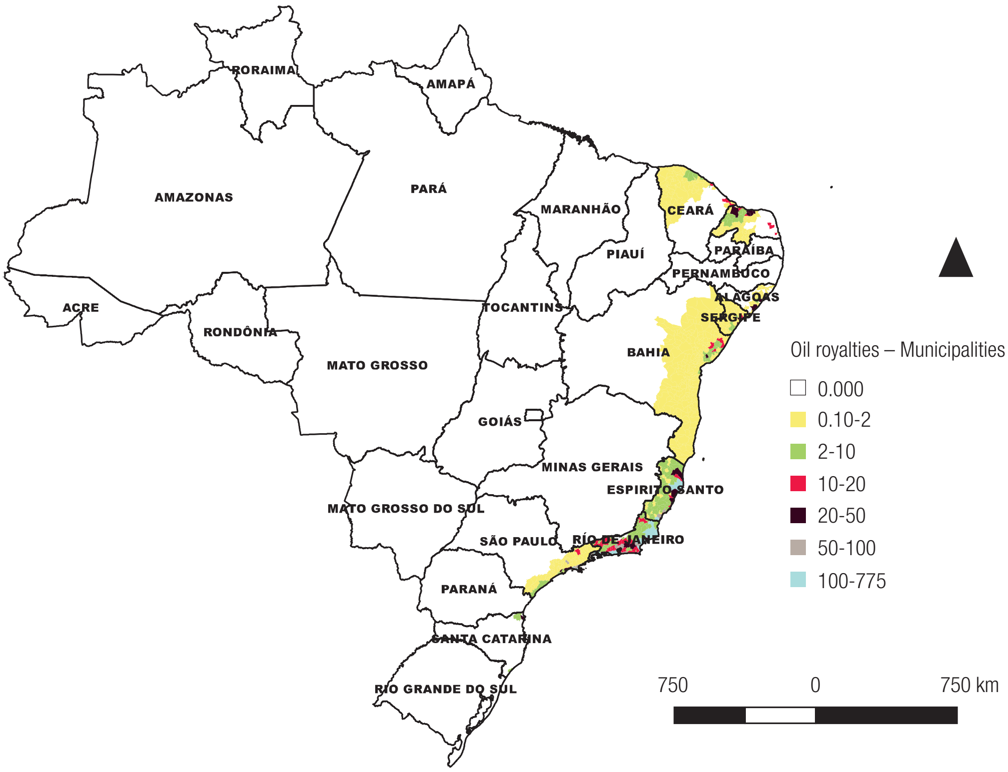
Figure 2
Brazil: total oil royalty collections, 2000–2016
(Billions of reais at 2008 prices)



Source: Prepared by the authors.

Only 969 or 17.4% of Brazil's 5,565 municipalities, distributed across nine states, receive oil royalties. Map 1 shows the spatial distribution of these revenues in 2013. It can be seen that royalties are concentrated on the coast, reflecting to the location of the offshore fields, which have the highest concentration of reserves in the country and, consequently, the highest rates of extraction and production of oil. The map also shows that all municipalities in the states of Sergipe, Espírito Santo and Rio de Janeiro receive royalties, although not all of them are producers.

Map 1
Brazil: spatial distribution of oil royalties, 2013
(Millions of reais at 2013 prices)



Source: Prepared by the authors.

The exploratory analysis identified the trend and distribution of oil royalties and the main royalty collecting states.

2. Analysis of the simulation results for the macroeconomic variables

As noted above, to evaluate the effects of oil royalties on the production structure of Brazil's states, an input-output table is used with base year 2008, covering 27 states and 26 sectors. For simulation purposes, the royalty values are considered as exogenous shocks on final demand. As noted in the previous section, the simulation strategy took into account the average value of oil royalties in 2013–2016 and was based on Law 12.858/2013, which requires 75% of these funds to be allocated to education and 25% to the health sector.

Table 1 shows the effects on the main macroeconomic variables considered in the model. These figures should be interpreted as potential effects relative to the base year of the matrix, 2008 (base-line scenario).

Table 1
Brazil: macroregional effects of oil royalties on selected macroeconomic variables
(Percentages)

Regions	Production	GDP	Income	Employment	ICMS[a]	IPI[b]
Brazil	0.050	0.070	0.110	0.070	0.050	0.040
North	0.010	0.004	0.003	0.004	0.010	0.010
Northeast	0.060	0.070	0.120	0.050	0.000	0.000
Centre-West	0.003	0.002	0.002	0.003	0.004	0.003
Southeast	0.080	0.100	0.170	0.120	0.070	0.050
South	0.010	0.010	0.010	0.010	0.010	0.010

Source: Prepared by the authors on the basis of the 2008 input-output table.
[a] ICMS = goods and services sales tax.
[b] IPI = tax on industrialized products.

The effects on the reference variables are greatest in the regions in which oil extraction takes place, in this case, the Northeast and Southeast. This is to be expected in the input-output simulations, owing to the linearity present in the model. Ribeiro and others (2013), Belo, Ribeiro and Simões (2017), and Ribeiro and others (2017) obtained similar results through input-output simulations for different recent applications. For that reason, this study makes a qualitative analysis to identify the distribution of the regional and sectoral effects.

In general, the low values of the impacts and spillovers, especially in regions that do not collect oil royalties, reflect the weakness of productive linkages with the simulated sectors (education and health), which minimizes the multiplier effects in the economy. These sectors belong to the services segment, most of which are targeted on final demand.

The magnitude of the effects on the macroeconomic variables relates directly to the structural coefficients of the model (Belo, Ribeiro and Simões, 2017). In other words, the coefficients of employment (ratio of the number of jobs to the gross value of sectoral production), income and GDP of the Northeast and Southeast regions would record higher values than those of Brazil as a whole. These regions have smaller economies, so they are more sensitive to impacts than the country at large. The taxation variables (goods and services sales tax (ICMS) and tax on industrialized products (IPI)) have structural coefficients below zero, which would generate relatively smaller effects in percentage terms.

If the oil royalties collected in the Northeast region were actually channelled into education and health they could have average annual impacts, between 2013 and 2016, of 0.06% on production, 0.05% on employment, 0.12% on income and 0.07% in GDP. In the Southeast region, the main recipient of oil royalties, this policy could have average annual impacts of 0.08% on production, 0.12% on employment, 0.17% on income and 0.10% on GDP. The other macroregions would report marginal impacts, mainly because they do not collect oil royalties themselves. Furthermore, as noted above, no significant spillovers are observed, owing to the weak productive integration of the sectors in question.

Recent studies published in the international literature provides evidence that oil activity affects employment and wages positively in some regions of the United States (Allcott and Keniston, 2018; Bartik and others 2017; Feyrer, Mansur and Sacerdote, 2017). These findings are therefore in line with the relative aggregate employment effects reported in table 1.

It should be noted that the impact on tax collection in the Southeast region is likely to be greater than in the Northeast region. According to Barros Júnior, Silva and Costa (2016), the ICMS rates applicable to interstate goods flows are 7% or 12%, depending on the states of origin and destination. The ICMS rate of 12% is destined for the South and Southeast regions, while the 7% rate is destined for the Northeast, North and Centre-West regions. Since the Southeast is the wealthiest and most productive region in Brazil and taxes are collected at the production stage, this region can be expected to benefit the most.

Figure 3 shows the effects of oil royalties on GDP and aggregate employment in the royalty-collecting states. It is worth noting that 97.4% of the effects on GDP are concentrated in these states, while just 2.6% spreads to the rest of Brazil; in other words, the impact in states that do not collect royalties themselves is marginal.

Figure 3
Brazil: effects of oil royalties on GDP and employment in royalty-collecting states
(Percentages)

Source: Prepared by the authors on the basis of the 2008 input-output table.

The effects of royalties on GDP and employment can be explained by the economic structure of the states analysed. Figure 3 shows that Espírito Santo, Rio de Janeiro, Sergipe and Rio Grande do Norte are the only states reporting above-average effects. According to the National Confederation of Industry, in 2016, the oil and natural gas extraction industry had a industrial GDP shares of 20.7% in Espírito Santo, 18.6% in Rio de Janeiro, 11.8% in Sergipe and 10.1% in Rio Grande do Norte (CNI, 2018). The oil industry is thus crucially important to the economy of these states, where the extraction of oil and natural gas has boosted this sector and, consequently, increased employment.

The states of São Paulo and Bahia, which have the largest and sixth largest economies in Brazil, respectively, would experience lower than average effects. Both have relatively more diversified economies and, therefore, are less dependent on the oil sector. In other words, although these states play an important role in the extraction and production of oil and natural gas, this is not their main economic activity. This confirms the relatively low impact of royalties on GDP and employment.

For the sectors specified in the 2008 input-output table, table 2 presents the effects of oil royalties on the sectoral GDP of the Brazilian states.[4] As expected, the greatest effects would be registered in the education and health sectors of the regions directly receiving the investments, namely Alagoas (0.5% and 0.25%, respectively), Bahia (0.76% and 0.31%), Ceará (0.09% and 0.05%), Sergipe (2.42% and 1.31%), Rio Grande do Norte (2.58% and 1.38%), Espírito Santo (6.46% and 2.70%), Rio de Janeiro (4.88% and 1.73%), São Paulo (0.19% and 0.07%) and Paraná (0.02% and 0.01%).

[4] The input-output model is constructed on the basis of the Leontief-type production function. In other words, it assumes fixed input proportions and constant returns to scale (Miller and Blair, 2009). Thus, sectoral effects on other variables, such as employment, will report the same values as shown in table 2 (impact on sectoral GDP).

Table 2
Brazil: effects of oil royalties on the sectoral GDP of the states, conclusion[a]
(Percentages)

Sectors	SE	RN	DF	GO	MT	MS	EN	MG	RJ	SP	PR	SC	RS
Agriculture, forestry, logging	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.02	0.00	0.01	0.00	0.00	0.00
Livestock and fishing	0.03	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.03	0.02	0.01	0.01	0.01
Mining	0.02	0.01	0.01	0.01	0.01	0.01	0.04	0.01	0.03	0.01	0.01	0.01	0.01
Food, beverages and tobacco	0.03	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.01
Textile, apparel and footwear	0.04	0.02	0.01	0.01	0.01	0.01	0.08	0.02	0.05	0.02	0.01	0.01	0.01
Wood, paper and printing	0.02	0.02	0.00	0.00	0.01	0.00	0.04	0.02	0.02	0.01	0.01	0.01	0.00
Petroleum, coke and alcohol refining	0.15	0.12	0.01	0.04	0.03	0.04	0.03	0.05	0.24	0.04	0.04	0.03	0.03
Other chemicals and pharmaceuticals	0.03	0.03	0.01	0.01	0.01	0.01	0.04	0.02	0.07	0.02	0.02	0.02	0.01
Articles of rubber and plastic	0.06	0.03	0.04	0.02	0.02	0.03	0.17	0.03	0.14	0.04	0.03	0.04	0.02
Cement and other non-metallic mineral products	0.18	0.14	0.02	0.03	0.03	0.04	0.08	0.07	0.10	0.04	0.04	0.04	0.02
Metallurgy	0.08	0.09	0.03	0.03	0.02	0.03	0.13	0.03	0.10	0.05	0.03	0.03	0.02
Machinery and equipment	0.04	0.02	0.01	0.01	0.02	0.01	0.02	0.01	0.03	0.02	0.01	0.01	0.01
Electrical and electronic equipment	0.02	0.02	0.01	0.01	0.01	0.01	0.05	0.01	0.03	0.01	0.01	0.00	0.01
Transport equipment	0.02	0.02	0.01	0.02	0.02	0.02	0.09	0.02	0.04	0.01	0.01	0.02	0.01
Miscellaneous industries	0.02	0.04	0.01	0.00	0.01	0.01	0.03	0.00	0.00	0.00	0.00	0.01	0.01
Electricity and gas, water, sewerage and street cleaning	0.13	0.06	0.02	0.05	0.06	0.08	0.42	0.07	0.21	0.08	0.07	0.04	0.06
Construction	0.18	0.34	0.00	0.02	0.01	0.01	0.40	0.02	0.37	0.04	0.02	0.03	0.01
Commerce	0.13	0.18	0.00	0.00	0.01	0.00	0.25	0.00	0.21	0.02	0.00	0.00	0.00
Transportation, warehousing and postal services	0.08	0.09	0.01	0.01	0.01	0.01	0.13	0.01	0.13	0.02	0.01	0.01	0.01
Private services	0.08	0.10	0.01	0.01	0.02	0.01	0.09	0.01	0.10	0.02	0.01	0.01	0.01
Financial intermediation and insurance	0.27	0.31	0.00	0.01	0.01	0.01	0.47	0.01	0.31	0.03	0.01	0.01	0.00
Real estate services and leasing	0.06	0.06	0.01	0.00	0.01	0.00	0.07	0.01	0.05	0.01	0.01	0.01	0.01
Accommodation and restaurant services	0.04	0.06	0.01	0.01	0.00	0.00	0.05	0.01	0.06	0.01	0.01	0.01	0.00
Private and public education	0.10	0.11	0.00	0.00	0.00	0.00	0.21	0.00	0.15	0.01	0.00	0.00	0.00
Private and public health	4.73	5.03	0.00	0.00	0.00	0.00	12.62	0.00	9.56	0.37	0.04	0.00	0.00
Public administration and social security	2.14	2.25	0.00	0.00	0.00	0.00	4.38	0.00	2.81	0.11	0.01	0.00	0.00

Source: Prepared by the authors on the basis of the 2008 input-output table.
[a] SE: Sergipe; RN: Rio Grande do Norte; DF: Federal District; GO: Goiás; MT: Mato Grosso; MS: Mato Grosso do Sul; ES: Espírito Santo; MG: Minas Gerais; RJ: Rio de Janeiro; SP: São Paulo; PR: Paraná; SC: Santa Catarina; RS: Rio Grande do Sul.

To examine the results shown in table 2 more effectively, the following criterion was adopted: the largest effects were selected considering all the states of the model; in other words sectors that would display the greatest variation relative to the base year of the input-output table. The following sectors are highlighted: financial intermediation and insurance; construction; cement and other non-metallic mineral products; petroleum refining, coke and alcohol; electricity, gas, water, sewerage and street cleaning; commerce; metallurgy; textile, apparel and footwear; transportation, warehousing and postal services; private services; and articles of rubber and plastic.

These activities are likely to be affected because of their commercial relations (direct and indirect) with the education and health sectors. According to this selection criterion, the greatest sectoral effects were also concentrated in the states that receive oil royalties. In other words, cross-sectoral spillovers are detected in these states.

The sectors that would be most affected are clearly those related to the distribution of oil royalties pursuant to Law 12.858/2013, namely education and health. However, private and public education would present the greatest variation of impact on GDP. At the national level, education is part of the government's policy agenda; and this sector has been highlighted as critical for the country's economic progress and fundamental for reducing inequalities. However, the greatest obstacle still lies in harnessing these expenditures into development (Tavares and Almeida, 2014). Terra, Givisiez and Oliveira (2007) and Oliveira and Silveira Neto (2016) confirm that spending on education makes it possible to regional income inequalities. These authors advocate increasing education investments in the poorest states and increasing investment in the highest levels of education.

In non-collecting states, oil royalties seem to have only marginal effects on the sectors. Thus, it is possible to determine that the education and health sectors have local dynamics. All of the results showed negligible spillover effects, in both inter-sectoral and interregional terms, owing to the weak linkages of these sectors.

To complement the findings in terms of the effects on GDP, it is worth noting that public revenues are responsible for the maintenance of state functions. According to Silva (2007), the track record of oil-producing states is marked by advances and setbacks in the performance of public finances and the provision of public goods and services. The expenditures generated depend directly on the revenues collected or captured through various modes of financing, as well as partnerships that generate resources for the public purse. Inefficiency in this allocation of resources can be considered a setback in the performance of a state's public finances.

3. Analysis of the results of the simulation for income concentration

What impact does the collection oil royalties have on regional inequality in Brazil? Considering the distribution of GDP in the 27 states, the variation in the Gini coefficient reveals the concentration of income. That is, if oil resources were allocated to education and health, they would help reduce regional disparities, but only marginally (-0.002%). Pamplona and Cacciamali (2017) confirm that the concentration of natural resources —such as oil— can be a blessing or a curse for a country's economy.[5] In the case of Brazil, this concentration could generate a decrease in interregional inequalities, albeit a marginal one.

Ribeiro and others (2017) obtained a similar result. According to these authors, tourism expenditures in the Northeast region of Brazil in 2011 helped to reduce intraregional inequalities, as the Gini coefficient decreased between the scenarios.

Given the concentration of oil revenues in just a few Brazilian states, the foregoing analysis needs to be deepened to assess the impact of royalties on regional inequality. Thus, table 3 reports the Gini coefficient of the Brazilian macroregions, calculated in the baseline scenario, prior to the impact, and in the scenario affected by oil royalties. Its relative variation between these two scenarios is also shown.

Table 3
Brazil: effects of oil royalties on intra-regional inequality

Regions	Gini Coefficient		
	Ex ante	*Ex post*	Variation *(percentages)*
North	0.7044	0.7044	-0.001
Northeast	0.6408	0.6408	-0.008
Centre-West	0.7020	0.7020	-0.001
Southeast	0.6436	0.6433	-0.052
South	0.4786	0.4785	-0.003

Source: Prepared by the authors on the basis of the 2008 input-output table.

[5] See this discussion in Magalhães and Domingues (2014).

Table 3 shows that only the Southeast and Northeast regions show slightly greater variations in the Gini coefficient, -0.052% and -0.008%, respectively. In the other regions, the Gini coefficient remains almost constant; in other words, it displays marginal variations around zero. It is interesting to note that the magnitude of the variation in the Gini coefficient was correlated with the main royalty-collecting regions. Thus, the larger the amount of oil royalties, the lower the intra-regional income concentration. For the case of Turkey, Aydin (2012) states that half of the oil royalties are transferred to low per-capita income provinces, which helps to distribute income.

These results are consistent with those reported in the literature. According to Guimarães Neto (2009), the deconcentration of income that took place in Brazil was far from signifying a redefinition of the traditional division of labour among Brazilian regions. Nonetheless, it did help to consolidate trends, the emergence of regional specializations outside the Southeast, and the implementation of new activities through which less industrialized economies interact with the rest of the national economy, such as the Northeast region.

Following the logic of table 3, table 4 presents the results of the variation in the Gini coefficient calculated from the sectoral distribution of GDP in the baseline scenario and the scenario affected by royalties. The sectors that would display an increase in the Gini coefficient —thus contributing to an increase in regional disparities— are highlighted in bold. Brazil displays the largest sectoral increases in the mining (28.1%), machinery and equipment (22.2%), petroleum refining and coke (18.4%) and other chemical and pharmaceutical products (18.4%).

Table 4

Brazil: effects of oil royalties on sectoral concentration-Gini coefficient of sectoral GDP

(Percentages)

Sectors	Gini Coefficient		
	Brazil	Northeast	Southeast
Agriculture, forestry and logging	-23.55	**0.00**	-37.76
Livestock and fishing	-15.79	-21.15	-10.20
Mining	**28.09**	-8.58	**0.01**
Food, beverages and tobacco	**0.77**	-21.57	-28.72
Textile, apparel and footwear	**5.13**	-6.02	-19.42
Wood, paper and printing	**11.51**	**3.61**	-29.32
Petroleum, coke and alcohol refining	**18.43**	**0.12**	-9.54
Other chemicals and pharmaceuticals	**18.44**	**17.11**	-9.19
Articles of rubber and plastic	**8.96**	-0.03	-12.82
Cement and other non-metallic mineral products	**14.68**	**0.04**	-46.17
Metallurgy	-1.92	-12.47	-0.01
Machinery and equipment	**22.22**	0.15	-15.93
Electrical and electronic equipment	**6.36**	-0.11	**9.00**
Transport equipment	-0.57	**19.36**	**12.52**
Miscellaneous industries	**11.52**	**0.09**	-16.95
Electricity and gas, water, sewerage and street cleaning	-6.55	-29.04	-40.85
Construction	-28.25	-48.61	-0.18
Commerce	-27.70	-0.05	-0.17
Transportation, warehousing and postal services	-7.56	-12.37	-0.05
Private services	-11.26	-0.08	-0.20
Financial intermediation and insurance	**13.80**	-0.95	-0.02
Real estate services and leasing	-21.28	-0.03	-0.01
Accommodation and restaurant services	-2.06	-7.93	-0.14
Private and public education	-33.38	-2.99	-7.63
Private and public health	-23.39	-57.10	-2.50
Public administration and social security	**0.00**	**0.00**	-0.01

Source: Prepared by the authors on the basis of the 2008 input-output table.

In the other sectors, the Gini coefficient fall; that is, they could contribute to the reduction of regional disparities if the revenues from royalties were allocated to education and health. This can be seen in the sectors of the Southeast and Northeast regions, most of which would contribute to the intraregional deconcentration of revenues.

Contrary to the pattern prevailing in the Northeast, the deconcentration of income in the main industrial sectors in the Southeast region must be related to the fact that the largest industrial park in the country is located there. Greater investment in education tends to generate employment and income opportunities in the Southeast region, thereby helping to reduce income concentration.

The analysis of the Gini coefficient is important for targeting the design of public policies at regions with high levels of inequality. This analysis makes it possible to identify the sectors that could contribute to an increase or decrease in regional disparities, from the addition of oil royalties to states' revenues.

VI. Final remarks

This study set out to evaluate the effects of oil royalties on the Brazilian production structure and regional inequality. To that end, simulations were used with an interregional input-output model specified for the 27 Brazilian states, considering Law 12,858/2013, which requires 75% of these funds to be allocated to education and 25% to health.

As expected, the main results found greater effects in the royalty-receiving regions, the Southeast and Northeast. The sectors considered in the simulation, education and health, have few linkage effects, and this is reflected in weak spillovers, both in intersectoral and interregional terms. Although Rio de Janeiro accounts, on average, for 95% of total oil royalties collected, these have relatively less impact than in other states (Rio Grande do Norte and Espírito Santo) owing to the greater diversification of its economy.

It should be noted that, since all the values of the shocks were positive, all the effects would also be positive; that is, there would be no "losers". This represents a constraint on the results and occurs because in input-output models there is no substitution between factors of production; in other words the supply curve is perfectly elastic. For this reason, an attempt was made to conduct the analysis qualitatively, for example by evaluating the distribution of the effects at the regional and intersectoral levels.

In terms of the effects of oil royalties on regional inequality, it is possible to evaluate what would happen if these resources were, in fact, allocated to education and health. The results obtained show that the allocation of royalties to education and health could contribute to reducing intraregional inequalities in the Southeast and Northeast regions.

It is therefore important not to use royalties to cover current expenses, but instead channel them into sectors that represent investments that can compensate future generations for the extraction of resources by the current generation. Investing them in sectors such as education and health, which represent an investment in human capital, as well as in infrastructure and science and technology, which can provide increases in physical capital, is a desirable course of action. The evidence of this study with respect to the allocation of oil royalties to education and health shows that the country should continue on this path.

It is therefore of utmost importance that society and public managers be convinced of the importance of using resources in accordance with the law. It is important to maintain and improve oversight of the way both collecting municipalities and states use the funds, in order to ensure that current legislation is complied with; in other words, that these resources are fully channelled into education and health.

For future studies, it is proposed to evaluate the effects of these resources in the long run, which is interesting especially because of the time it takes for investments in the education sector to bear fruit. This will be done by developing a dynamic CGE model that explicitly takes account of changes in relative prices and capital accumulation over time.

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Annex A1

Table A1.1
Brazil: sectoral deflators, with base-year 2008

Activities	2008	2009	2010	2011	2012	2013	2014	2015	2016
Private and public education	1.00	0.89	0.80	0.67	0.61	0.51	0.44	0.40	0.37
Private and public health	1.00	0.92	0.87	0.81	0.70	0.60	0.53	0.49	0.47

Source: Prepared by the authors on the basis of Brazilian Geographical and Statistical Institute (IBGE), *Sistema de Contas Nacionais: Brasil 2016*, 12 March 2018 [online] https://biblioteca.ibge.gov.br/visualizacao/livros/liv101620_informativo.pdf.