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Does Oil Dependence Affect Regional Wealth? A Regional Study for the Municipalities of the State of Rio de Janeiro

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ABSTRACT

The aim of this study is to analyze the regional effects of oil royalty dependence on the local economic development of municipalities of the Rio de Janeiro state. To do so, we used spatial econometric models to estimate the local and spillover effects of royalty dependence on the economic local product. The main results were derived based on the Spatial Autoregressive Combined model (SAC) estimated by Generalized Moments (GM). The study's contribution is to address the natural resource curse debate through its regional perspective by estimating the direct, spillover, and total effects of oil royalty dependence on economic product, which is a groundbreaking approach for the natural resource curse debate. The results show that both the direct and spillover effects are negative and significant, indicating that there is evidence of the presence of a regional natural resource curse in the municipalities of the Rio de Janeiro state.

Keywords: Spatial Econometrics, Natural Resource Curse, Econometrics, Spillover Effects, Spatial Panel Data Models, Method of Generalized Moments

JEL Classifications: C33, E69, N56.

1. INTRODUCTION

The economic product, known as GDP, may be explained in its simplest form by two factors, labor and capital. Through the years the economic theory has developed and many authors have contributed by highlight the role of other factors that matters to the growth, such as human capital, institutions and natural resource (Aghion and Howit, 2009). Even though many authors have addressed natural resources as one of the main production factor to economic product since Adam Smith, between 1960 and 1990 countries that used to depend more on natural exportations, grew less than the ones that did not use to depend on those kind of resources (Sachs and Warner, 1995). This negative relation became known as natural resource curse (Van der Ploeg, 2011).

Since Sachs and Warner's (1995) paper, many authors have been analyzing the reasons that might explain why countries intense in natural resource underperform in economic growth when compared to countries that are less intensive in such resources. There is a consensus about that natural resource abundance does not cause the curse, because the curse is related with the negative externalities of economic dependence on natural resources, highlighting the aspect of negative externalities in human capital, fiscal policy and politicians' acts (Daniele, 2011; Atkinson and Hamilton, 2003; Robinson et al., 2006).

The natural resource curse is more likely related to how countries decide to deal with natural resource wealth, how they create policies to manage those resources and how it is connected with other public policies, which means it is the country's decisions that turns the resources abundance a curse or a blessing (Lederman and Maloney, 2003). As the curse is caused by the individual characteristics of the countries, the role of institutions can might solve this controversial result. Sala-i-Martin and Subramanian (2012) found that after controlling the institutions effect on the economic growth, the natural abundance become positive related to growth. Therefore, the natural resource curse is a country matter, that is why natural resource abundance and dependence affects countries in different ways.

The literature about natural resource curse has recently started to analyze empirically the local signs of natural resource curse and its spillovers around the region they are located. Analyzing the local impacts of natural resource boom is important to understand how this boom affects people's well-being and local economic performance when the macroeconomic aspects, including institutions, are the same for everybody (Van der Ploeg, 2011; Allcott and Keniston, 2017).

Feyrer et al. (2017) analyzed the geographic effects of shale-energy production of the counties of the major producer states of USA from 2004 to 2012. According to their results shale oil and gas boom has been important to boost the economies of the producing counties, increasing wages, occupations and royalty paid to landowners. Those positive effects are not limited to the related oil sector, because the same effects were verified on other sectors than oil and gas. The benefits of the boom do not restrict to the local economies, because all the positive effects became bigger when considered counties considering a ratio of 100 miles from the producing county, so the boom is an important factor to help the regional development in USA. Allcott and Keniston (2017) have founded similar results, adding that the benefits are cyclical with the oil and gas boom and bust. In a more restrict sample, Richter et al., (2018) analyzed the counties of the North and South Dakota; they found that the shale oil and gas production increased the income, and diminished the unemployment and the poverty of both the local economies and of the entire region considering a ratio of 200 miles from the producing counties of North Dakota.

In the USA, the local literature has been finding local economic gains and positive spillovers due to the natural resource exploitation. For Brazil the studies have totally distinct results, because all papers have found negative impacts of the oil exploitation and of the royalties application on economic indicators, such as economic growth, social parameters, educational scores and more (Magalhães and Domingues, 2014; Postali, 2009; Caselli and Michaels, 2013; Postali and Nishijima, 2013; Monteiro, 2015).

Postali (2009) analyzed the impact of oil rents on the economic growth of benefiting municipalities from 1999 to 2005, finding evidence that royalties had reduced economic growth by an average of 0.22% when compared to non-receivers, which suggests some sort of natural resource curse within Brazilian municipalities during that period. From a social perspective, Postali and Nishijima (2013) concluded that municipalities that dependent mainly on oil royalties socially underperformed, because their social improvements, measured by the illiteracy rate, access to electricity, piped water, and waste collection were smaller than those of the non-eligible municipalities. Their results for the whole country suggest the presence of a "social natural resource curse."

Caselli and Michaels (2013) addressed the impact of oil rents on public expenditures such as educational, health, and public investments and found evidence that royalties increased public expenditures without a corresponding quality response. The authors ascribed these results to corruption, rent-seeking, and bad political choices. Monteiro (2015) showed that royalties increased expenditures in education, but its quality index was better in non-eligible municipalities.

The papers above mentioned have contributed, in different ways, to explaining a part of the natural resource curse in Brazilian municipalities due to the oil windfall, but none of them have accounted for spatial dependence, which implies an underlying assumption of contemporaneous autocorrelation equal to zero (Greene, 2012). However, as people, goods, and services move freely across municipality borders, the economic performance of neighboring municipalities may be correlated with each other (Arbia, 2006).

This paper aims to address the regional perspective of the natural resource curse in Brazil, focusing on the municipalities of the Rio de Janeiro state. The municipalities of the state of Rio de Janeiro (RJ) gets the majority part of all oil royalties paid to municipalities in the country. From 2008 to 2017, the municipalities of the state of Rio de Janeiro received US$ 8.99 billion, meanwhile the rest of Brazilian municipalities received US$ 5.52 billion, it means that the oil rent is highly concentrated in the municipalities of state of Rio de Janeiro, representing 62% of all oil rents paid to municipalities in the country.

Our analysis focused on the state of Rio de Janeiro because it is the main oil production in Brazil and, therefore, its municipalities are the major beneficiaries of oil rents. Moreover, considering other municipalities from other states could create a noisy on estimations because we would have to control the likely effects of having several institutions acting on the municipalities. Thus, as our main interest was controlling those influences of differences of institutional quality, we focused on municipalities that are under the same institutional state authorities, making sure that our results are not affect by those noises.

We contribute to the literature by adding spatial dependence into the analysis of natural resource curse in Brazil, an overlocked factor until now. Thus, in accounting for this new element, this study aims to broaden the natural resource literature threshold by estimating the local and spillover effects of oil royalty dependence on per capita local product, as measured by the municipal per capita GDP.

The paper is structured into more five sections. After this introduction, there is an overview of the oil royalty system in Brazil, followed by a brief literature review on theories of the natural resource curse. We then present our empirical strategy, the results and, in closing, concluding remarks.

2. OVERVIEW OF OIL REVENUES IN BRAZIL

The approval of Brazilian oil law in 1997 completely transformed the Brazilian oil sector landscape. The law broke the monopoly of

Petrobras on oil production, allowing private foreign companies to operate according to a concession system that had once been forbidden. Moreover, the law introduced a new fiscal benchmark to the sector, focusing on increasing the governmental budget (Lei No, 1997).

The new fiscal benchmark is based on four types of rent: (1) royalty; (2) special participation; (3) signature fee; and (4) occupation fee. The signature fee is paid at once because it is a bid that the company must pay to win the concession. The occupation fee is a kind of rent that the company must pay because it occupies a governmental area. The royalty is a fee of 10% of gross production. Both the royalty and occupation fees are mandatory for every single contract. The Special Participation is an extra rate for oil wells that surpass expected productivity. The rate ranges from 0% to 40% depending on the pit productivity and the lasting time of production, and it is payable on the net production (Lei No, 1997).

The law established the oil rent prices based on a basket of several international oil prices, which once was determined by the Petrobras. The royalty is a fee of 10% on the gross oil revenue. The royalty measure also considers the rent from natural gas, but the gas price does not have an internationally define price. In both cases, the fee is the same.

The royalties paid are divided among the federal government, states, and municipalities. Municipalities received the largest part of the resource, keeping 34% of the total paid from 2008 and 2017 (Lei No, 1997; 2010). During this period, the municipalities received US$ 11 billion, while the municipalities of the Rio de Janeiro state kept US$ 7 billion of the total. Graph 1 show the oil royalty payments for the Brazilian municipalities aggregated by state to highlight the concentration in Rio de Janeiro.

The oil law did not specify the destiny of revenues; only Rio de Janeiro state had guidelines from the Auditors Court restricting the payment of public debt or current expenditures such as payroll. However, in 2013, law #12.858 created a couple of rules for oil rent applicability, highlighting: (1) 50% of the social fund must go to public education until the basic educational targets have been achieved; (2) 75% of any resources paid to any governmental entity must be applied to education and the rest (25%) to public health; (3) any type of public service can be paid with these resources, as well any kind of public service, especially payroll.[1]

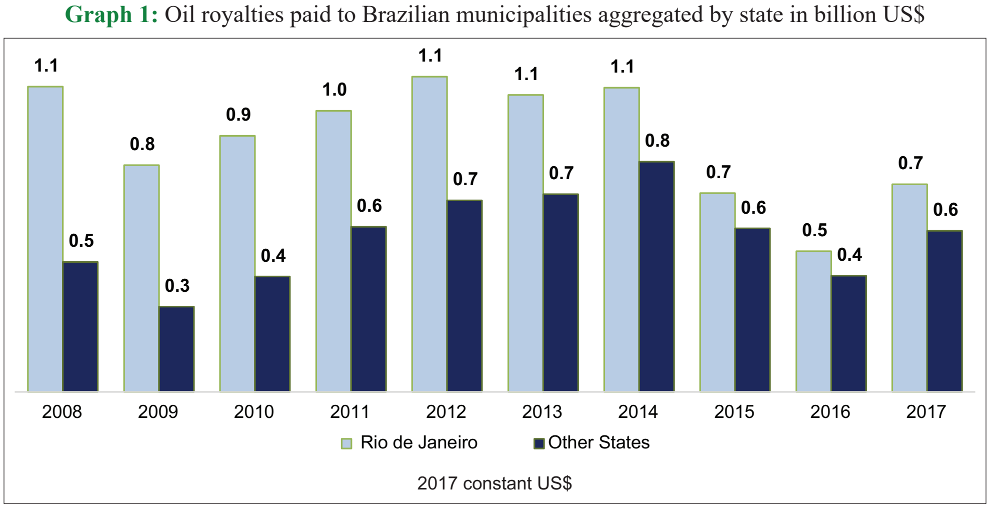
Therefore, the Brazilian oil sector has seen many changes in its law and regulation in the last 10 years. The last change, the law #12.858/2013 determine how the oil rent must be expanded, however it does not consider the empirical evidence that the oil rent has been generating negative effects on local economies (Caselli and Michaels, 2013; Monteiro, 2015; Postali, 2009; Postali and Nishijima, 2013), which might be a sign of natural resource curse.

3. NATURAL RESOURCE CURSE LITERATURE: THEORY AND EMPIRICAL EVIDENCE

The contribution of natural resources to the economic welfare has been discussed since Adam Smith's classic work in the nineteenth century, "*An Inquiry into the wealth of nations*" (Badeeb et al., 2017). In the mid-20th century, Prebish (1950) and Singer (1950) observed that commodity prices grew less than the prices of industrialized goods, so that countries more dependent on the primary sector presented lower productivity, worsening their economic growth. Prebisch-Singer's hypothesis became even more likely right after Corden and Neary (1982) proposed the Dutch Disease idea, according to which natural resource-rich countries would suffer from a chronic economic low growth. The Dutch Disease rationale is based on big-push two-sector models, in which a resource boom would drain productive factors from the dynamic industrial sector to a traditional decreasing return sector (responsible for producing the primary good). Historically, the hypothesis was inspired in the hike in natural gas prices in the sixties, which led the Netherlands to specialize in gas.

1 For more information on oil revenues, see Giambiagi and Lucas (2013).

Graph 1: Oil royalties paid to Brazilian municipalities aggregated by state in billion US$



Source: Made by the authors with survey data (considering US$ 1 = R$ 3.8)

This specialization changed the profile of Netherland's exports, appreciated its currency exchange rate (due to the commodity boom), and started a deindustrialization process, which harmed its economic growth. Gelb (1988) introduced the idea that countries highly dependent on primary goods would economically underperform compared to industrialized ones. Auty (1993) named this phenomenon a natural resource curse, attributing the negative externalities to natural resource specialization (Davis and Tilton, 2005).

After Auty (1993), the economic research[2] started to look for empirical evidence to explain the so-called curse. Through econometric studies, Sachs and Warner (1995;1999; 2001)[3] concluded that countries dependent on natural resources used to grow less than those that were more independent. The explanation is based on the Dutch Disease three-sector model (natural resource tradable, non-resource manufacturing, and non-tradable sectors), in which the resource boom would shift capital and labor from the dynamic manufacturing sector to the resource tradable sector, leading the economy to specialize in this activity. Also, the non-tradable sector would be fostered, leading the exchange rate to appreciate and, consequently, deindustrialize the economy (Sachs and Warner, 1995).

SW's seminal papers have initiated a heated debate about the impacts of natural resources on producing economies. Many papers have agreed with SW's results by re-testing SW's natural resource dependence variable. Brückner (2010), for instance, concluded that countries dependent on primary goods grew less than the countries less the dependent on such goods by testing SW's same natural dependence variable. The author verified a more negative impact of natural dependence on economic growth (measured by PPP GDP[4]) after controlling for differences in non-tradable prices among countries.

However, further econometric methods applied to SW's data led researchers to question the actual nature of the resource curse and the explanation for the phenomenon gradually shifted from the productive dynamic to institutional factors. Lederman and Maloney (2003) stated that natural resource dependence had a positive correlation with economic growth when countries' idiosyncrasies were controlled for fixed effects. They also criticized the measure of resource dependence used by SW (percentage of commodities in the country's exports), because it would capture concentration of natural resources in a country export. Also Gylfason (2001) opened a new pathway for this literature by analyzing the impacts of natural dependence on the transmission channels of the curse. According to the author, the lower economic growth was a result of poor human capital in the resource-dependent countries. On the other hand, Stijns (2006) showed that natural resource abundance is positively related to educational investments because it creates possibilities for funding them. Daniele (2011) found that dependence on natural resources negatively impacts human capital, despite natural abundance having positive effects on human development. In the literature pathway of Gylfason (2001), other authors found similar results (Papyrakis and Gerlagh, 2004; 2007; Blanco and Grier, 2012; Cockx and Francken, 2016).

Atkinson and Hamilton (2003) attributed the weak economic growth of resource-dependent countries to a mix of bad public policies that lowered their genuine savings. Gylfason and Zoega (2006), Bond and Malik (2009), and Boos and Holm-Müller (2013) concluded the same thing, pointing out the slow development of financial systems in natural resource-dependent countries. Robinson et al., (2006) linked the curse to the lack of institutions able to control politicians' discretionary acts, mainly because politicians rule for their own interest in order to remain in power. Bornhorst et al., (2009) identified that resource-dependent economies replaced non-resource revenues with resource ones, so resource rents negatively affected their fiscal policy.

In another branch of the literature, the political aspect of the natural resource curse seems to be the key point to explain the misfortune, because politicians are encouraged to keep institutions weak (Davis and Tilton, 2005; Robinson et al., 2006). Empirical papers have confirmed this resource curse hypothesis. Sala-i-Martin and Subramanian (2012), after controlling for the institutional quality of the countries, found a positive correlation between natural resource dependence and economic growth. Brunnschweiler and Bulte (2008), Brunnschweiler (2008), and Alexeev and Conrad (2011) are some of the papers that found similar results.

To sum up, the evidence that resource-rich countries face low economic performance compared to non-rich ones led researchers to test several hypotheses, from Dutch Disease to institutional ones. The most recent evidence, confirmed by more up to date econometric techniques, seem to link the curse to weak institutions, with variations in the channels of transmission.

4. DATA AND EMPIRICAL STRATEGY

4.1. Data

Our dataset gathers information of 92 municipalities of the state of Rio de Janeiro from 2008 to 2017, which consists in a balanced panel data of 920 observations. In Brazil, municipalities are commonly split into more than one over time because of adverse incentives generated by Brazilian fiscal federalism, which assigns federal funds to new localities and interferes in data quality (Caselli and Michaels, 2013). From 2008 to 2017, there were no new municipalities created in the state of Rio de Janeiro. Thus, the initial 92 cities from 2008 are still the same 92 cities from 2017, therefore our data are free of this disturbance.

The dependent variable is the local economic product per capita – our proxy for the local level of economic development. We measure the local economic product by the per capita GDP of the municipalities in state of Rio de Janeiro. Cavalcanti et al. (2019) use the same proxy to measure the local economic development in his study.

Our main independent variable is dependence on oil royalties, which is calculated based on the ratio of oil royalty and the

2 See, for instance, Frankel (2010) and Van der Ploeg (2011) for good surveys.

3 Henceforth, Sachs and Warner will be referenced by SW.

4 Purchasing Power Parity GDP.

municipal product. Because the royalty is priced based on several international oil prices, and oil production is not regulated by the government, the variable is strictly exogenous[5]. The royalty measure used in this study contains the royalties of both oil and natural gas. The royalty calculation is expressed by the following equation given by the ANP:

$$\text{Royalty} = \text{Royalty aliquot} \times \text{Oil production value} \quad (1)$$

$$\text{Oil production value} = (\text{Oil production vol.} \times \text{Oil price}) + (\text{Nat. gas vol.} \times \text{Nat.gas price}) \quad (2)$$

We expect that the dependence on oil royalty is negative related with the per capital GDP, based on two facts: (1) all literature review explored in this paper points out this negative relationship; and (2) The negative correlation between dependence on royalty and per capita GDP showed in the first section of this paper.

Even though the royalties are the main interest in this study, we controlled other aspects that could impact the local level of economic product. Based on the theoretical model that orientate our empirical strategy, we used the educational level of employers to proxy the human capital in which municipality. We classified the employers by their level of education, dividing them by illiterate, not finished elementary school, finished elementary school, graduated at high school and graduated in university or more. To account the stock of capital we used the public investment per capita, because there is no official investment variable calculated for municipalities in Brazil (a variable that encompasses both the private and the public investment in the city). We expect that both human capital and investment be positive related with local economic product.

The GDP and population were obtained on IBGE database, the Brazilian Institute for Geography and Statistics.[6] The oil royalties we extracted from the Brazilian oil agency (ANP; Brazilian acronym).[7] All variables about employers we collected by the microdata of the Ministry of Economy from the RAIS database.[8]

5 The Brazilian oil sector is regulated by the Oil National Agency, however, the production is not. Which means the government does not control the amount of oil produced in Brazil; the government just regulate the rules that affect production. Therefore, it is an indirect influence on production, which is common for every producer pitch.

6 https://sidra.ibge.gov.br/home/pimpfrg/nordeste

7 http://www.anp.gov.br/royalties-e-outras-participacoes

8 http://pdet.mte.gov.br/microdados-rais-e-caged

Table 1 presents a statistical summary of the variables used in this study. The per capita local GDP and local investment per capita are expressed in Brazilian currency (R$) in constant prices of 2017. All variables related with workers are expressed by units. Dependence on oil royalties is expressed in percentage.

All monetary values are expressed in constant R$ of 2017.

4.2. Empirical Strategy

This study aims to analyze how the dependence on oil royalty affects all municipalities of the state of Rio de Janeiro. Our analysis starts by the following empirical benchmark relation:

$$GDPpc_{it} = f(Dependence_{it}) \quad (3)$$

where $GDPpc_{it}$ is the economic product per capita, $Dependence_{it}$ is the oil royalty dependence measured by the ratio of oil royalty received and the economic product of the municipality *i* at time *t,* and β represents the parameter to be estimated. The linear form of eq. (3) is given by:

$$GDPpc_{it} = \beta_1 \, Dependence_{it} + \mu_i + \vartheta_t + \varepsilon_{it} \quad (4)$$

The μ_i term captures the idiosyncrasies of the municipalities not observable that are constant through time, such as: cultural issues, climate aspects, geographical position, etc. ϑ_t captures the time variant characteristics, for instance, the oil price level, Brazilian interest rate, etc. ε_{it} is the error of the econometric model.

The economic product is a function of labor and capital, which means material capital, natural resources, human capital and others (Aghion and Howit, 2009). The neoclassical production function underlies our choice of variables that explain the local per capita product in our analysis, justifying our main variable of dependence on natural resource, because the natural resource stock of capital is a main factor to the economic product (Aghion and Howit, 2009). Even though our main interest is nested in analyze how the municipalities are affected by the dependence on oil royalty, we have to consider other factors that explain the economic product, which are human capital and the material stock of capital. Thus, eq. (3) should consider the effect of these variables on GDPpc. These variables are important to the model, and not inserting them in the model would implicate in the error of omitted variables (Greene, 2012). In that perspective, our main relation expressed by eq. (4) is modified to:

Table 1*:* **Descriptive statistics of variables used in the study**

Statistics	Per capita GDP	Dependence Oil Royalties	Investment Per Capita	Workers iliterate	Workers not finshed elementary school	Workers finshed elementary school	Workers finshed high school	Workers graduated in University or more
n. obs	920.00	920	920	920	920	920	920	920
Minimum	8,874.78	0.00	0.00	0.00	154	158	247	19
Maximum	502,951.20	0.13	3,680.21	9,163	479,411	797,903	1,903,103	859,208
Mean	42,865.61	0.02	322.07	134.73	8,895.89	14,745.40	31,891.74	11,647.79
Stdev	55,396.58	0.02	378.30	632.76	44,565.76	76,024.82	174,382.90	75,540.57
Median	23,969.04	0.01	196.51	34.00	1,551.50	2,045.50	4,012.00	1,074.50

Source: Data survey

$$\begin{aligned}GDPpc_{it} &= \beta_1 Dependence_{it} + \beta_2 workers\ iliterate + \\ &\beta_3\ workers\ not\ grad\ at\ elementary\ school + \\ &\beta_4 workers\ grad\ at\ elementary\ school + \\ &\beta_5 workers\ grad\ at\ high\ school + \\ &\beta_6 workers\ grad\ at\ university\ level + \\ &\beta_6 investment\ per\ capita + \mu_i + J_t + \varepsilon_i\end{aligned} \quad (5)$$

Eq. (5) expresses the full relation that we describe our empirical model to be estimated. Nevertheless, classic econometric models demand some assumptions to generate consistent and efficient estimators, which are: strictly exogenous independent variables; homoscedasticity; non-autocorrelation; and full rank of independent variable matrix (Greene, 2012). In that perspective, because we are working with data of municipalities we believe that there is spatial relation between municipalities, which can mislead classical econometric assumptions, making the estimators inefficient (Elhorst, 2014).

According to Lesage and Fischer (2008) the economic product is usually spatially correlated, and this correlation can be expressed as $cov(y_i,y_j) = E(y_i y_j) – E(y_i)\ E(y_j) \neq 0, I \neq j$ (Arbia, 2006). We tested if there is spatial correlation on estimated errors of eq. (5) by estimating Moran's I of the residuals from the basic OLS model.

The Moran's I test on OLS model residuals rejected the null hypothesis rejected of non-autocorrelation with at 1% of significancy, which means that the estimated errors of eq. (5) is spatially correlated.[9] Table 2 shows the LM test of spatial model specifications, indicating that the errors must be spatially lagged. Table 2 also indicates that the dependent variable must be spatially lagged. Thus, considering the results of Table 2 we inserted both the independent variable spatially lagged – $\rho WGDPpc_{it}$ – and the estimated errors spatially lagged – $\varepsilon_i = v_i + \lambda u_i$ – in eq. (5). Therefore, our final model is a Spatial Autoregressive Combined model (SAC) estimated by Generalized Moments (GM), which ensures that our estimates are not influenced by any endogeneity of our covariates. The SAC model to be estimated is expressed in the following equation:

$$\begin{aligned}GDPpc_{it} &= \rho WGDPpc_{it} + \beta_1 Dependence_{it} + \beta_2 workers\ iliterate_{it} \\ &+\beta_3 workers\ not\ grad\ at\ elementary\ school_{it} \\ &+\beta_4 workers\ grad\ at\ elementary\ school_{it} \\ &+\beta_5 workers\ grad\ at\ high\ school_{it} \\ &+\beta_6 workers\ grad\ at\ university\ level_{it} + GDPpc_{it} = \rho WGDPpc_{it} \\ &+\beta_1 Dependence_{it} + \beta_2 workers\ iliterate_{it} \\ &+\beta_3 workers\ not\ grad\ at\ elementary\ school_{it} \\ &+\beta_4 workers\ grad\ at\ elementary\ school_{it} \\ &+\beta_5 workers\ grad\ at\ high\ school_{it} \\ &+\beta_6 workers\ grad\ at\ university\ level_{it} \\ &+\beta_6 investment\ per\ capita_{it} + \mu_i + J_t + \lambda u_i + v_i\end{aligned} \quad (6)$$

9 The test returned a Moran's I of 0.18729 using the Contiguity Queen spatial Matrix.

Table 2: LM test for spatial model especifications

LM tests	Queen	Euclidian
Lmerr	68.86***	545.40***
Lmlag	153.97***	296.80***
Robust Lmerr	4.02**	356.88***
Robust Lmlag	89.12***	108.28***
SARMA	157.99***	653.68***

*, **, ***Respectively represent the statistical significance at 10%, 5%, and 1%. Estimated by the authors with survey data

where W term represents the spatial matrix, and ρ is the parameter to be estimated, which captures the impact of the neighbors on the per capita GDP of the local economy.[10]

5. RESULTS AND DISCUSSION

5.1. Exploratory Data Analysis

The first step to understand if there is any sign of natural resource curse in the municipalities of the state of Rio de Janeiro is an exploratory data analysis through the years. According to Figure 1, firstly analyzing the change on 2008 and 2017 pictures of royalty dependence, there is no significant change to see. Nevertheless, analyzing the change through 2008 and 2017 per capita GDP, it is clear to see that localities that did not depend on oil royalties increase their local product more than localities that depend on royalties, as the change in the color intensity shows.

Graph 2 confirms this negative relation, showing that there is a clear tendency on higher per capita GDP in 2017 used to depend less on royalties in 2008. This suggests that, through the years, the expressive amount of rent paid to those municipalities did not produce a significant impact on their economic product, which contradicts expectations, since it should have generated investment and local opportunities, boosting economic growth and local wealth (Caselli and Michaels, 2013; da Mata et al., 2017)

5.2. Econometric Results

After exploratory data analysis, we start the causality evidence by econometric models. The Table 3 presents the estimated parameters of direct, spillover, and total effects of the model presented in eq. (6).

The estimated coefficient of the direct effect, which captures the impact of a city's oil dependence on its own per capita product, shows that an increase of 1 p.p. in dependence reduces the per capita product by R$ 4,444.74, on average. Our result is relatively different from the pattern found in the literature, because we measure the impact on economic product and not on the economic growth. Postali (2009) found that royalties diminished economic growth by 0.22% on average from 1999 to 2005. Therefore, royalty dependence has not only been harming economic growth, as the literature has always proposed, it is also diminishing the local aggregated product as well.

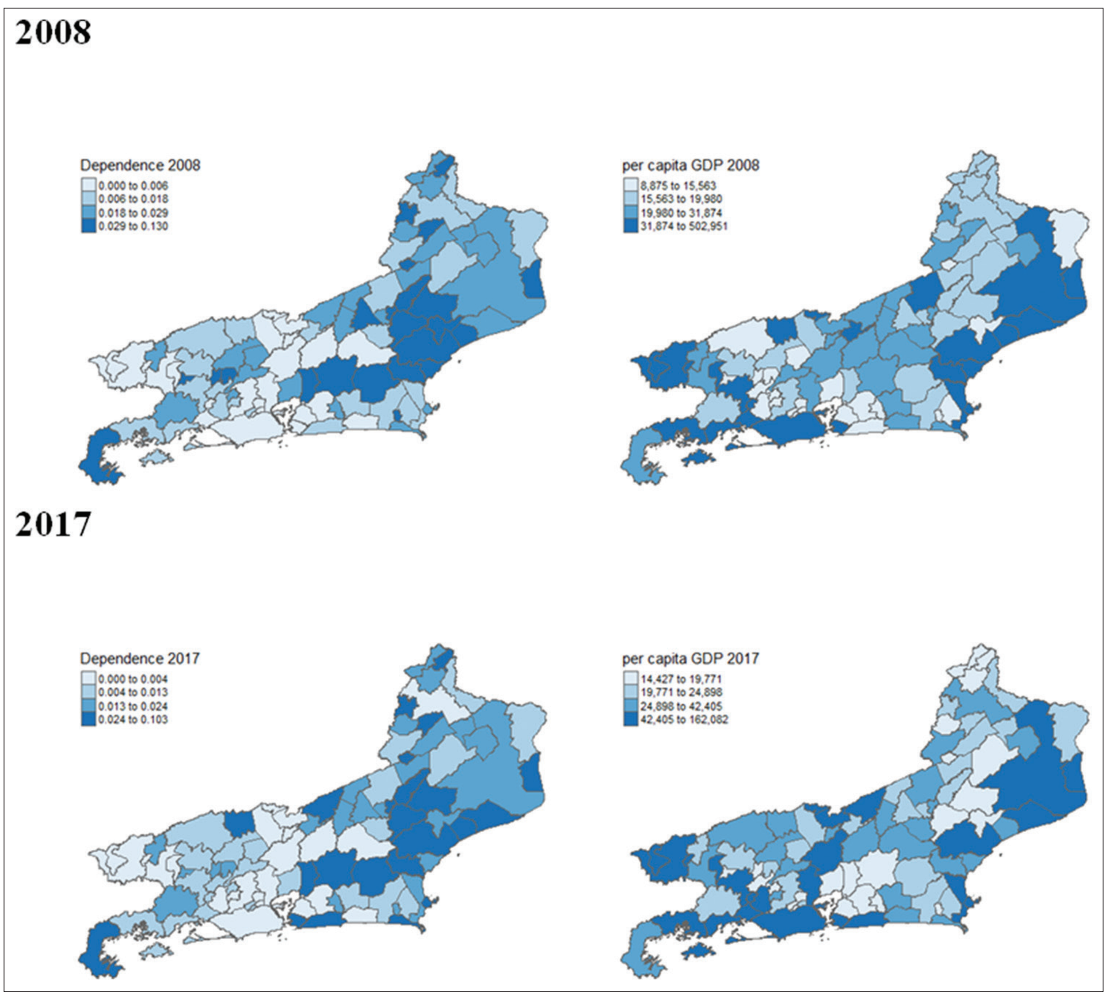
10 We did not apply exhaustible tests to check the best spatial matrix to account spatial dependence because it does not represent a significantly influence in results; therefore, we opt by the queen contiguity matrix normalized by the row. For more information see (LeSage and Pace, 2014).

Table 3: Results of SAC model estimated by GM

Dependent variable: Per capita economic local product (per capita GDP)			
Variables	**Direct**	**Indirect**	**Total**
Oil royalty dependence	−4,444.74***	−3,416.52***	−7,861.26***
	(890.95)	(992.07)	(1,688.34)
Number of ilitrate workers	16.85*	12.95	29.80*
	(9.31)	(7.83)	(16.79)
Number of workers not grad. at elementary	1.93**	1.48**	3.41**
	(0.86)	(0.74)	(1.55)
Number of workers not grad. at high school	−1.86***	−1.43*	−3.29***
	(0.67)	(0.59)	(1.22)
Number of workers grad. at high school	0.36*	0.28*	0.64*
	(0.19)	(0.16)	(0.34)
Number of workers grad. at university	−0.29	−0.23	−0.52
	(0.29)	(0.24)	(0.53)
Per capita investment	79.81***	61.35***	141.16***
	(4.38)	(13.55)	(14.59)
ρ	0.47***		
	(0.06)		
Error spatially lagged		Yes	
Individual effect		Yes	
Time effect		Yes	
Observations		920	

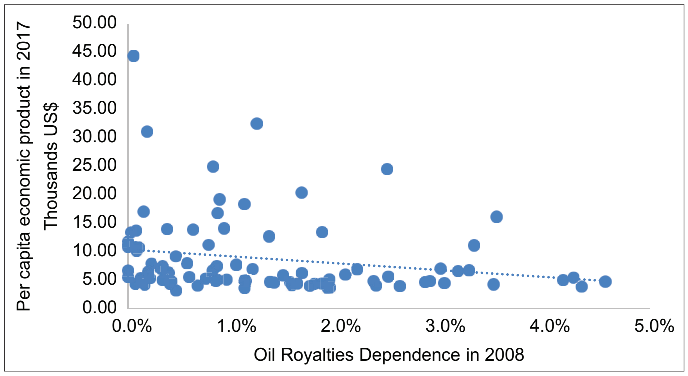
Standard deviations in parenthesis. *, **, ***Respectively represent the statistical significance at 10%, 5%, and 1%

Figure 1: Economic product per capita and oil royalty dependence in 2008 and 2017



Source: Made by authors using survey data

Graph 2: Scatter plot of per capita economic product of municipalities of the Rio de Janeiro state and royalty dependence in 2008



Source: Created by the authors from survey data

As the oil royalty is given by the oil production, the dependence measure can represent oil sector dependence, which brings our result in line with the point of view of Lederman and Maloney (2003) that sector dependence harms economic growth; in our case, it also harms economic overall product. Our result also corroborates that of Sachs and Warner (1995; 1999; 2001), who found negative effects of primary good exports.

Nevertheless, the literature has suggested other explanations for the negative relation between natural resource dependence and economic wealth. Albeit our findings have not reached the impact of oil dependence on other variables such as social expenditures, other Brazilian studies found that oil royalties negatively impacted educational quality, social development, and economic growth (Postali, 2009; Caselli and Michaels, 2013; Postali and Nishijima, 2013; Monteiro, 2015).

Still, our results and all cited papers lead to similar conclusions, which is that natural resource dependence harms economic success. None of these mentioned studies have analyzed the regional effect of natural resource dependence on economic wealth or growth. Accounting for spatial dependence in the results is the first contribution of this paper. In addition, we estimated the dependence spillover effect, capturing the effect of dependence in one city on its neighbor's per capita economic product, which is this paper's major contribution to the curse literature to our view.

The estimated coefficient of the spillover effect was negative and significant, meaning that 1 p.p. in dependence on royalties in one city diminishes its neighbor's per capita product by R$ 3,416.52. This suggests that the natural curse is spreading across the municipalities' borders and affecting surrounding cities.

The estimated total effect is negative and significant, representing that an increase of 1 p.p. in dependence drops the per capita economic product by R$7,861.26 of the dependent city. This negative total effect indicates that the dependent municipality's own dependence on royalties harms its wealth and impacts surrounding cities' per capita product as well; therefore, the negative spillover effect worsens the dependence effect on the original city because both cities impact each other. From these results, we can infer that the natural resource curse is not just a local phenomenon in municipalities of the Rio de Janeiro state. The robustness check of direct, spillover and total effects are available on Appendix 1-3. It is important to notice that all models corroborate the estimates of the SAC model estimated by GM.[11]

The natural resource curse literature greatly contributed to this study, showing the impact of individual effects on analysis, as with the paper of Lederman and Maloney (2003). We accounted for both individual and time fixed effects. The individual effect captures cities' heterogeneities that do not change over time, for instance cultural issues. The time effect captures aspects common to every city but change over time, as the oil price.

Other covariates are also considered in the study to account for adjacent effects that could impact per capita GDP. We controlled effects of workers education to proxy the impact of human capital in the local economic product. We also added the public investment in capital, because there is no measure to account the total investment on the municipal level in Brazil. By adding the public investment measure we intend to control the effects of the capital investment, which is a main production factor in the neoclassical production function (Aghion and Howitt, 2009); however, as we adopted the public investment, it can accounts for the effect of the size of the government in the local economy. Even though the measure of the size of the government is not perfect, it is important to account it somehow in the local economic product because there is a current debate about the role of government size on Brazilian economic development, and our result matches the recent debate (Tinoco and Giambiagi, 2018).

It is also important to say that a might cause of the natural resource curse on local economies could be the expenditure direction of law #12.858/2013 gives to oil rents. It does not mean that the paper suggest that the local economies should not invest on education or health systems, but the literature points that the oil revenues has not been positive about the educational and health indicators on those localities. It might be explained by the law been directing resources to areas that have no governance structure of expending, which means it add more resources on projects that were poorly designed or to institutions that are already consumed by corruption, intensifying a negative result to society. Nevertheless, it should be properly analyzed on further papers.

6. CONCLUDING REMARKS

This study analyzed the regional impact of oil royalty dependence on the welfare of the municipalities of the Rio de Janeiro state. Our proxy for economic welfare was the municipal economic product per capita and our variable of interest was royalty dependence, as measured by the ratio of oil royalty and local per capita product. To

11 The only estimate that had a different sign than others was the spillover effect of SDEM model; however, it was not statiscally significant. Moreover, the spillover effect usually has different sign than other spatial models due to its calculation, for more information see (Elhorst, 2014).

analyze the regional effect of oil dependence on municipal GDP per capita, we estimated an SAC model to obtain the direct, spillover, and total effects of dependence on the per capita product. All three estimated parameters were negative and statistically significant.

This paper's first contribution was addressing the local natural resource curse debate based on the product per capita and not on the economic growth; the former is widespread in specialized literature. The direct effect indicated that royalty dependence is diminishing the aggregated product, complementing and worsening literature findings till now, which means the royalty dependence negatively impacts the aggregated product and the growth of local economies.

The second contribution of this paper was accounting for spatial dependence in the results, a new methodological approach. The major contribution of this paper was to estimate the spillover effect of oil royalty dependence on per capita product. The spillover effect was negative and significant, suggesting that dependence in one city crosses the municipalities' borders and impacts neighboring cities' per capita product. Such a result indicates that there may be a regional natural resource curse in the municipalities of the Rio de Janeiro state.

The total effect aggregates the direct effect and the response of the spillover effect on the dependent city. The total effect estimated parameter was negative and statistically significant, indicating that dependence on oil is bad for the dependent city and surrounding cities, and these combined negative effects are even worse for the entire region. Thus, our results strongly indicate the presence of a regional natural resource curse in the municipalities of the Rio de Janeiro state.

The transmission mechanisms that spread the curse to neighboring cities was not a focus of this study, but it is a suggestion for further papers. Nevertheless, the literature generally points to the cause of the curse as economic dependence, rent-seeking, bad political decisions that lower the government's net savings, and bad investments in human capital. Due to specialization, many companies leave the production city because there is labor and capital migration to the natural resource sector, and companies that leave may be the ones that used to boost the local economy. Rent-seeking is likely to explain the regional curse because it may attract a bad kind of company to the region, which could expulse good companies owing to unfair competition, for instance. Another possible explanation is corruption and bad connections in the region. We have only highlighted the likely causes that explain the regional curse, but a study to analyze how local economies link to each other is mandatory to better understand this regional curse.

We indicate that the Brazilian federal government should redesign law #12.858, because it directs almost all the revenue of royalties to education and health; however, the known studies have found that royalties are not producing good results in such areas. Thus, the Brazilian government should save this money and expend more effort on designing institutional benchmarks to manage these resources in our view.

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APPENDIX

Table A1: Direct Effect of OLS, FE, SLX, SAR, SEM, SAC, SDM and SDEM models

Dependent variable: Per capita economic local product								
Variables	**OLS**	**FE**	**SLX**	**SAR**	**SEM**	**SAC**	**SDM**	**SDEM**
Roygdp	−310.70	−7,447.10***	−7,515.10***	−4,487.81***	−4,554.00***	−3,802.93***	−4,615.61***	−4,733.30***
	(825.10)	(1,084.00)	(1,100.00)	(937.31)	(937.29)	(891.43)	(970.80)	(972.70)
Ilit.	14.08	15.64***	0.15	13.59	13.91	11.32	11.90	12.07
	(9.83)	(9.36)	(0.09)	(9.55)	(9.15)	(8.31)	(9.14)	(9.12)
Elincomp	2.20**	0.56	0.00	1.79*	1.71*	2.15**	1.69*	1.54
	(0.98)	(0.74)	(0.01)	(0.89)	(0.92)	(0.93)	(1.00)	(0.99)
Elcomp	−2.14***	−0.54	0.00	−1.72**	−1.65**	−2.03***	−1.58**	−1.46*
	(0.76)	(0.56)	(0.01)	(0.69)	(0.71)	(0.72)	(0.77)	(0.76)
Hscomp	0.85***	0.12	0.00	0.41**	0.40**	0.52***	0.40**	0.39*
	(0.20)	(0.14)	(0.00)	(0.20)	(0.19)	(0.18)	(0.19)	(0.20)
Univcomp	−1.22***	0.03	0.00	−0.43	−0.42	−0.56*	−0.45	−0.45
	(0.30)	(0.23)	(0.00)	(0.31)	(0.29)	(0.29)	(0.30)	(0.30)
Pcinvest.	97.04***	37.10	0.36***	78.58***	78.39***	76.54***	78.51***	78.15***
	(4.14)	(2.76)	0.03	(4.23)	(4.21)	(4.50)	(4.71)	(4.40)
ρ				0.122***		0.46***	0.12***	
				(0.04)		(0.05)	(0.00)	
λ	No	No	No	No	Yes	Yes***	No	Yes*
Ind effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Tm effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observ.					920			

λ= Errors spatially lagged. Standard deviations in parenthesis. *, **, *** respectively represents the statistical significance at 10%, 5% and 1%

Table A2: Spillover Effect of OLS, FE, SLX, SAR, SEM, SAC, SDM and SDEM models

Dependent variable: Per capita economic local product					
Variables	**SLX**	**SAR**	**SAC**	**SDM**	**SDEM**
Oil royalty dependence	−3,330.40	−608.64**	−2,910.21	−626.10**	894.57
	(2,397.10)	(279.26)	(923.52)	(265.90)	(2,008.30)
Number of ilitrate workers	0.21	1.84	8.67	1.61	49.29***
	(0.17)	(1.65)	(6.79)	(1.47)	(15.23)
Number of workers not grad. at elementary	0.01	0.24	1.64	0.23	0.92
	(0.01)	(0.16)	(0.82)	(0.17)	(1.55)
Number of workers not grad. at high school	−0.01	−0.23*	−1.55	−0.21*	−1.60
	(0.01)	(0.14)	(0.66)	(0.14)	(1.20)
Number of workers grad. at high school	0.00	0.06	0.40	0.05	0.46
	(0.00)	(0.04)	(0.16)	(0.04)	(0.34)
Number of workers grad. at university	0.00	−0.06	−0.43	−0.06	−0.36
	(0.00)	(0.05)	(0.24)	(0.05)	(0.55)
Per capita investment	0.15	10.66***	58.57	10.65***	−4.37
	(0.05)	(4.47)	(11.61)	(3.96)	(7.55)
Error spatially lagged	No	No	Yes	No	Yes
Individual Effect	Yes	Yes	Yes	Yes	Yes
Time Effect	Yes	Yes	Yes	Yes	Yes
Observations			920		

Standard deviations in parenthesis. *, **, ***Respectively represents the statistical significance at 10%, 5% and 1%

Table A3: Total Effect of OLS, FE, SLX, SAR, SEM, SAC, SDM and SDEM models

Dependent variable: Per capita economic local product					
Variables	**SLX**	**SAR**	**SAC**	**SDM**	**SDEM**
Oil royalty dependence	−10,845.50	−5,096.45***	−6,713.14	−5,241.71***	−3,838.73***
	(1,297.10)	(1,088.21)	(1,731.51)	(1,134.00)	(1,035.60)
Number of ilitrate workers	0.36	15.43	19.99	13.51	61.36
	(0.08)	(10.99)	(14.96)	(10.46)	(6.10)
Number of workers not grad. at elementary	0.01	2.04**	3.79	1.92*	2.46
	(0.01)	(1.02)	(1.71)	(1.15)	(0.57)
Number of workers not grad. at high school	−0.01	−1.95**	−3.58	−1.79**	−3.07
	(0.00)	(0.80)	(1.34)	(0.88)	(0.43)
Number of workers grad. at high school	0.00	0.47**	0.92	0.45**	0.85
	(0.00)	(0.23)	(0.34)	(0.22)	(0.14)
Number of workers grad. at university	0.00	−0.49	−0.99	−0.51	−0.81
	(0.00)	(0.35)	(0.52)	(0.34)	(0.25)
Per capita investment	0.51	89.24***	135.12	89.16***	73.78***
	(0.02)	(7.08)	(14.06)	(6.67)	(3.15)
Error spatially lagged	No	No	No	Yes	Yes
Individual effect	Yes	Yes	Yes	Yes	Yes
Time effect	Yes	Yes	Yes	Yes	Yes
Observations			920		

Standard deviations in parenthesis. *, **, ***Respectively represents the statistical significance at 10%, 5% and 1%