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Petroleum royalties and regional development in Brazil: The economic growth of recipient towns

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ABSTRACT

In 1997, Brazil approved law n[er] 9478, establishing new rules for sharing petroleum royalties with Brazilian municipalities. The goal of this paper is to evaluate whether royalties distributed under the new law have contributed for the development of benefited municipalities. For that the difference-in-differences estimator (diff-in-diff) is used, which compares the evolution of the economic product into the municipality affected by the new law with the unaffected ones, by exploring the new legislation as an exogenous change. The data refer to the municipal gross domestic product (GDP) growth rate before and after the event. Results are surprising, showing that royalty receivers grew less than municipalities that did not receive such resources. The difference is small but statistically significant. In general, an increase of one real in royalties per capita reduces the growth rate of the municipal product in 0.002 percentile points.

Introduction

According to the Brazilian Constitution, the Federal Government is the single owner of onshore and offshore natural resources (Vilhena Filho, 1997, p. 46), but the production of such resources can be leased to private corporations. This legal arrangement is usual in many countries, with the purpose of avoiding common pool inefficiencies. As the sole owner, the government has the right to grab resource rents which are collected through a special fiscal regime over the production of nonrenewable resources, including oil and gas production.

By the middle of the 1990s, Brazil accomplished institutional changes in the regulation of its oil and gas industry. In 1995, a Constitutional Amendment eliminated the forty-year legal state monopoly over oil and gas production; two years later, the Parliament enacted the so-called "Petroleum Law",[1] which not only introduced meaningful changes in the regulation of this market, but also created new criteria for transferring resource rents to municipalities.[2] According to the new law, all concessionaires working on the production of oil and natural gas, both onshore and offshore, must pay royalties to the government. In general, these royalties consist in a 10% ad valorem tax over the gross value of production, but this rate can be reduced under very specific circumstances. After collecting royalties, the Federal Treasury distributes them to states and municipalities to offset possible adverse effects generated by productive activities.

The goal of this paper is to investigate whether royalties transferred under the new law have impacted on the economic growth of recipient municipalities in Brazil. We use the difference-in-differences estimator (diff-in-diff) which compares the economic growth of municipalities that received royalties – called the treatment group – with the performance of municipalities unaffected by the new law—the control group. In other words, this study aims at evaluating whether royalties have contributed to improve the gross domestic product (GDP) growth of municipalities eligible to receive these benefits compared to the non-eligible ones. This study contains two important assumptions: firstly, the eligible municipalities, as productive units, capture their mineral rents by collecting those royalties; secondly, the new law is assumed as an exogenous change that affected a specific set of municipalities. This investigation is relevant since the Brazilian Petroleum Law defines criteria and prohibitions for the application of these revenues.

The results suggest a surprising phenomenon: after the legal change, on average, the economic product of eligible municipalities grew less than the product of non-eligible ones. This investigation is relevant since Brazil is starting to discuss how to use efficiently its mineral rents, as giant oil and gas reserves were recently discovered in the oceanic pre-salt layer.

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[1] Law # 9478/1997.

[2] Loosely speaking, municipality (or Municipio or municipal district) is the main local circumscription in Brazil.

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This article is divided in seven sections, including this introduction. ''The Brazilian Petroleum Law'' section briefly describes how the Petroleum Law introduced important regulatory changes in Brazil, focusing on the new rules for sharing royalty revenues. ''Resource-dependence and economic performance: evidence and explanations'' section presents a summary report on evidence about the relationship between resource-dependence and economic performance. ''Methodology'' section describes the diff-in-diff estimator, showing how it isolates the effect of treatment (royalty revenues) on the economic growth of municipalities. ''Data'' section describes the data and ''Results'' section presents the results. The last section brings some concluding remarks.

The Brazilian Petroleum Law

The Brazilian Parliament approved the Petroleum Law in 1997, but two years earlier, a Constitutional Amendment had already broken the legal state monopoly over oil and gas production. Before the Amendment, only state-owned Petrobras was allowed to operate this kind of activity in Brazil. The law represented a meaningful change in the Brazilian oil industry: firstly, the state monopoly was replaced by a concession system, in which domestic and foreign private firms can also be responsible for productive activities (exploration and production), competing with Petrobras. Secondly, the law introduced a special fiscal regime on oil production, aiming at collecting the resource rents for the government, which has the right to capture them as the resource owner.[3] But the novelty that matters for this study is the creation of new rules to guide the distribution of these rents to localities that fulfil some requirements regarding the sheltering of productive facilities.

The Brazilian Petroleum Law defines four basic types of fiscal charges on oil and gas exploration: (i) the signature fee; (ii) royalty rates; (iii) special participations and (iv) occupation fee. Royalties and the occupation fee are obligatory in every lease contract. Special participations are levied only on highly productive fields.

The signature fee is the winning bid in the lease auction managed by ANP—the National Petroleum Agency. There are also other criteria for assigning concessions to private investors, like minimum investment programs and commitments with local suppliers. The fee must be paid immediately at the commencement of the lease contract.

The royalty is a monthly ad valorem tax, of 10% of gross revenue, priced according to an averaged basket of international oil prices. The rule for natural gas is more complex, due to the absence of a developed international market, but the royalty rate is the same (10%). The ANP can reduce the royalty rate to 5%, if geological risks and poor productive conditions justify such a measure. The royalty revenues are shared among the Brazilian states, municipalities, the National Treasury and public R&D funds.

Special participations are extra fiscal charges over highly productive projects. The tax is calculated for each lease according to progressive rates over the net revenue, i.e., the gross revenue minus royalties, exploratory investments, operating costs, depreciation and other legal taxes. The government seeks to capture higher portions of the rent from highly profitable projects. There are six rates: zero (exemption), 10%, 20%, 30%, 35% and 40% of net revenue according to a rule that considers the volume of extraction, the well's depth and the field's age. Resources collected by special participations are shared among states, producer localities and Federal Government.

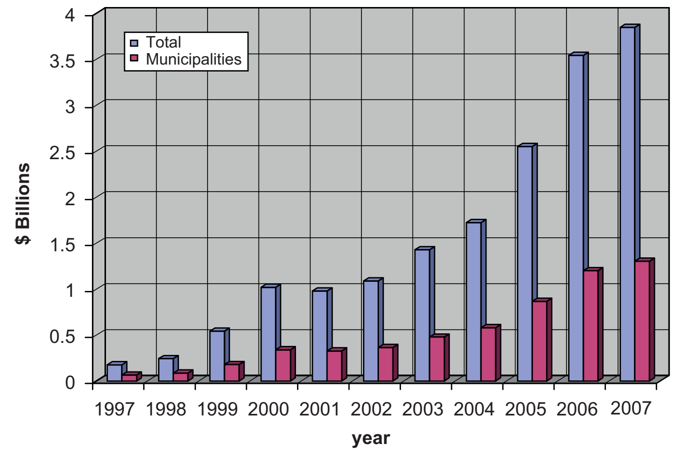

Fig. 1. Royalty revenues and portion shared with municipalities in Brazil, in billions of US dollars. *Source*: ANP.

Finally, the occupation fee is a rent paid to the government on the basis of area of a project. The concessionaire must pay this tax in the beginning of each year.

The Federal Government has transferred royalties to localities since at least 1986, but only after the Petroleum Law was approved, in 1997, did these resources increase substantially. Serra (2003) suggests several reasons for this. Firstly, the royalty rate was raised from 5% to 10% of gross revenue. Secondly, new rules for sharing revenues were created, which enlarged significantly the volume of royalties in the hands of municipalities[4] as well as the other benefitting districts.

The new law also changed rules for investing royalties. According to the previous rule (from 1986), these resources could be invested only in energy, environmental management, sewage and roads. The law from 1997 does not establish any specific type of investment, widening considerably the set of possibilities. However, city halls are not allowed to use royalties for ordinary expenditures, such as wage and debt interest payments. Finally, as Serra (2003) notes to calculate royalty revenues, the new law introduced the *reference price*, an average of international oil prices. This measure represents an important change, since royalty revenues have become very sensitive to the oscillation of oil prices. Before the new law, indemnities[5] were calculated based on controlled prices in refineries. Since Petrobras used to fix the price on a discretionary basis,[6] those resources were completely insensitive to changes in international prices. Moreover, the volume of royalties available for municipalities also increased for two reasons: the progressive rise in oil prices after 2000 and the abrupt change in the exchange policy in 1999, when the Brazilian currency started to float and devalue (royalties are priced in dollars).

These legal changes generated a substantial increase in royalty revenues to eligible municipalities (whose set was also enlarged), which had also acquired more freedom to allocate them. In fact, royalties in the hands of municipalities have been increasing since 1999, as shown in Fig. 1.[7]

[3] According to Hartwick (1977), these rents should be invested to avoid welfare losses. Basically, the owner must be compensated due to the depletion effect, since the resource is a capital stock.

[4] Special participations are also shared, but less than two dozens of municipalities are eligible for receiving them.

[5] Royalties were called indemnities before 1997.

[6] The government used to freeze oil prices in refineries in order to control the inflation.

[7] Converted by the annual average exchange rate ''Reais''/$.

There are few studies analyzing the relationship between royalty revenues and local development in Brazil. Leal and Serra (2002) investigate the destination of royalties in municipalities in the northern part of Rio de Janeiro state. They show that eligible municipalities invested above the average within Rio de Janeiro state, but the investment/royalties ratio was systematically below one. Through a fiscal study, Costa Nova (2005) concluded that selected eligible municipalities in Bahia state did not succeed in increasing key social indicators faster than non-eligible ones, despite the surplus in their budgets due to royalties.

While these studies have the unquestionable merit of analyzing the budgetary data and its relationship with royalty revenues for specific cities, there has been lack of investigation in a national basis, involving all municipalities that receive such revenues. Moreover, based on those studies, it is impossible to evaluate the true impact of royalties on municipal performance in terms of GDP growth, since unobservable local characteristics are also important factors that impact on the evolution of the local product.

The relationship between economic performance and resource rent is widely studied in the literature, with intriguing empirical evidence. The next section approaches this subject.

Resource-dependence and economic performance: evidence and explanations

The economic literature has always been concerned how natural resources, growth and welfare are related each other. Since resources are undoubtedly a capital stock to endowed countries, the conventional (neoclassical) hypothesis links the abundance of them to potential wealth, through a production function (Davis and Tilton, 2005, p. 234). This view is confirmed by a plenty of examples of developed countries whose endowment acted favorably towards development in the past, like United States, as well as more recently, like Australia and Canada (Wright and Czelusta, 2006). Developing countries, like Chile, Peru and Botswana were able to grow on a sustainable basis by developing their mineral sectors (Wright and Czelusta, 2006).

An alternative view started to emerge by the end of the 1980s (e.g.: Auty, 1990) questioning the assumed positive effect of resource-abundance on development. This view seemed to be confirmed by empirical evidence that the GDP growth rates of resource-rich countries were lower than the non-endowed ones. The phenomenon was called "*natural resource curse*", which expresses the assumed low economic performance of countries highly dependent on natural resources, mainly the developing ones. Examples of such evidence can be found in Sachs and Warner (1995, 1999, 2001), Sala-I-Martin (1997) and Mehlum et al. (2006), among others. However, recent studies (like Lederman and Maloney, 2006) have objected the curse, based on other statistic techniques as well as on different measures of resource-dependence. Since then, researches have been focusing on other explanatory factors, like institutions, dysfunctional policies, human capital, debt overhang and technological progress.

Given the first group of studies, the literature always tried to provide an economic rationale for the alleged curse. A common explanation links the resource curse to the 'Dutch disease', i.e., a chronic competitiveness loss faced by resource-dependent economies resulting from the overvalued exchange rate. The term "Dutch disease" firstly appeared to describe the impact of natural gas discoveries on the Dutch economy by the 1960s, when the subsequent export boom contributed to overvalue the exchange rate.[8] As a consequence, the competitiveness of manufactured exports was negatively impacted and the economic growth was impaired. Although there are several variants, "Dutch disease" started to represent the general description of similar phenomena regarding the adverse effect of overvalued currencies on the economic dynamism.

Besides the Dutch disease hypothesis and its variations, several other explanations have emerged in the literature to explain the resource curse (Davis and Tilton, 2005). Some examples are investment crowding out, the peculiar production path of nonrenewable resources, differentiated growth path of resource-endowed countries, institutional quality, declining terms of trade, volatility of markets and misuse of rent.[9]

After observing empirically that resource-rich countries exhibit growth rates below the world average between 1970 and 1990,[10] Sachs and Warner (1999) link the phenomenon to the effect of a big push in a resource-based economy. They suggest a dynamic Dutch disease model, assuming a two-sector economy: traded goods and non-traded goods. If the production function exhibits increasing returns to scale in the former, a resource boom reduces the economic growth, since it generates a positive demand shock in the latter, which requires a shift in the labor factor towards this sector to sustain the higher consumption (by definition, non-traded goods are produced only locally). Consequently, the traded sector loses scale, which impairs the economic growth, and the economy can deep in a de-industrialization process. The empirical analysis comprehends eleven Latin American countries. Life expectancy, institutional quality and public savings are used for controlling purposes in the econometric estimates. They find evidence on a negative relationship between resource intensity (measured by the exports/GDP ratio) and GDP growth.

Under the same line of investigation, Sachs and Warner (2001) collect evidence that countries highly dependent on natural resources exhibit modest GDP growth rates compared to the non-endowed ones, even when estimates are controlled for commodity prices. They also add geographic control variables, like the percent of land area within 100 km from the sea, distance to the closest major port, the fraction of land area in the Earth tropics and a malaria index. The explanation for the resource curse is also based on the Dutch disease.

Among explanations based on growth models, Rodriguez and Sachs (1999) link the low performance of petroleum exporting countries to the trend to "live beyond their means". These countries would be inclined to an excessive consumption/capital ratio (overshooting) provoked by high resource rents, mainly when these rents are invested in domestic assets. The authors assume an extended Ramsey model with natural resources, in which positive export shocks overshoot the capital stock and, consequently, the income per capita increases above the average. As a result, the transition to the steady state would exhibit negative growth rates in these economies, on average. They calibrate a dynamic general equilibrium model with Venezuelan data, whose results explain Venezuela's growth path right after the oil shocks during the 1970s.

Based also on the unsustainable over-consumption, Neumayer (2004) also analyzes the alleged curse. By arguing that the gross domestic product is not a good indicative of rent in resource-endowed countries, the author proposes the net domestic product as a 'genuine measure of rent', estimated according to a proxy of Hotelling's user cost (Hotelling, 1931). The argument states that the resource-endowed countries exhibit high depreciation rates

[8] For a survey about the Dutch disease, see Stevens (2003).

[9] Davis and Tilton (2005) provide a list of possible reasons for the resource curse with a rich discussion about the strength and the weakness of each explanation.

[10] Sachs and Warner (1995).

due to the depletion effect, since a significant share of their capital is composed of natural resources. So, when the measure is based on the gross product, the depreciation is accounted as rent, signaling erroneously to policy makers a non-optimal level of sustainable consumption. The results confirm the resource curse when the net product is used as dependent variable (instead of the gross product), but the estimated coefficients are lower.

Sachs and Warner's results, as well as the subsequent akin literature, awakened some controversy. Since Davis (1995), researchers have been questioning the economic explanation for the resource curse, by arguing that these studies omitted important explanatory variables. Moreover, other statistical techniques and new length of time lead to new findings suggesting that the existence of the resource curse may be a misleading conclusion, since the adverse effect of resource on the economic performance would come from non-economic mechanisms.

The first wave of alternative explanations tries to establish the linkage between low performance of resource-rich countries and their institutional quality. Atkinson and Hamilton (2003) investigate the role of institutions in a panel of 91 countries observed during sixteen years, for several types of natural resources. They found that countries mostly affected by the resource curse also exhibited problematic fiscal profiles and small levels of domestic savings, so the resource rents would be wasted in the financing of ordinary governmental expenses. Conversely, countries that invested in physical and human capital were able to avoid a bad experience. The authors conclude that institutional quality is important to the proper allocation of resource rents, avoiding mismanagement and dissipation of revenues.[11]

Torvik (2002) develops a model that establishes the relationship between resource boom and incentives to rent-seeking in a context of fragile democratic institutions that makes the capture of public funds easier. The model assumes four sectors, among which a group of entrepreneurs that can engage in rent-seeking activities, due to the institutional weakness. The model concludes that although a resource boom tends to increase the country's income, it also makes rent-seeking more attractive to entrepreneurs, whose effects impact negatively on income and on welfare.

Kronenberg (2004) confirms the negative relationship between natural resource-abundance and economic growth, for the transition economies from the former Eastern Europe, whose countries were not included in samples of the previous studies. The basic education is added as a proxy for human capital. The conclusions suggest that the resource curse may hit other countries at other times as well. Major causes of the resource curse in developing countries are corruption and the low level of educational investments.

Mehlum et al. (2006) also link the resource curse to institutional weaknesses. The paper builds a model in which institutions are labeled in two categories: "producer friendly institutions" and "grabber friendly institutions" (e.g.: fragile laws, dysfunctional bureaucracy and corruption). The abundance of natural resources would push per capita income down in countries with a high degree of grabber friendly institutions. Conversely, producer friendly institutions tend to increase income. The study uses the same database as Sachs and Warner (1995), but it adds an institutional quality index.[12] Institutional disabilities explain an expressive part of the resource curse, since institutions in these countries are not able to prevent political groups from mismanaging rents.

A similar model is developed by Robinson et al. (2006), with the purpose of explaining the resource curse in a political basis. The model is based on a two-period extractive model in which a politician decides how much to produce in the current period and how to distribute resource rents, by evaluating the probability of being re-elected. In this framework, the value of being in power increases with a permanent or an anticipated resource boom that leads the politician to try to maximize the likelihood of re-election by employing more people in the public sector. This shifts the labor force from the (productive) private sector to unproductive tasks in the public sector. So, the resource boom may increase or reduce income depending on whether institutions are solid enough to prevent this opportunistic behavior. Vicente (2009) confirms empirically the evidence of such a political resource curse. The author explores the announcement of oil and gas discoveries in Sao Tome and Principe in the 1990s as an exogenous event. The study collected data through a survey about perceived corruption on public funds and rent allocation, and uses a standard difference-in-differences estimator to evaluate whether bigger oil reserves lead to the perceived misuse of public funds, by using the Cape Verde as control. The results suggest the evidence of higher perceived corruption regarding education, vote buying and customs.

Boyce and Emery (2007) provide an alternative explanation to reconcile the well-documented evidence that resource-rich countries tend to exhibit high per capita income and low growth rates. Based on the dynamics of optimal extraction of nonrenewable resources (Hotelling, 1931), they develop a two-sector model: the resource-based sector and the manufacturing-based one. By assuming that resource's owners maximize the rent over time, the authors demonstrate that the labor allocated to the resource sector is decreasing due to the progressive depletion, and the resource rent falls as time goes on. So, under certain circumstances (enough decreasing resource prices and relatively slow technological progress in the resource sector), the growth rate of manufacturing-oriented countries is higher than for resource-oriented ones. Therefore, the curse does not exist, because it would be a direct consequence of the extractive dynamics and depletion of natural resources. Evidence of the phenomenon within states of the USA is provided.

More recently, researchers have been showing more skepticism about the resource curse, as they adopt new statistical tools and other measures of resource-dependence. Lederman and Maloney (2006) work with the same data set used by Sachs and Warner (1999), but the panel was updated until 2000. In order to control for unobservable characteristics of each country, the authors use a fixed effects model with new controls, like a Herfindahl-Hirshman Index (HHI) for exports, a measure of capital accumulation, and the level of intra-industry trade. The GMM estimates aim at controlling for possible endogenous effects. The study finds that the HHI for exports impacts negatively on growth, leading to the conclusion that previous studies would mix up the export concentration with the resource-dependence. With those controls, the alleged resource curse disappears.

Manzano and Rigobón (2006) also use panel data with fixed effects to evaluate the impact of resource-dependence on the GDP performance. Their results show that the resource curse disappears when a credit constraint is among the explicative variables. In the 1970s, endowed countries contracted high levels of debt by giving resources as collateral after commodity prices had climbed; during the slowdown in the 1980s, those countries faced problems due to a high stock of debt without a suitable cash flow to pay it. In this context, the weak growth of resource-rich countries would be a consequence of debt overhang.

[11] In this sense, this conclusion confirms the Hartwick's rule (Hartwick, 1977) that states that nonrenewable resource rents must be invested (and not consumed) to avoid intergenerational welfare loss.

[12] This index is calculated by the *Political Risk Services* and is composed by the average of five indexes regarding law enforcement, quality of bureaucracy, corruption and sovereign risk.

Bravo-Ortega and Gregorio (2005) approach the importance of human capital and its relationship with natural resources and growth. The paper develops a model that predicts a negative relationship between resource-abundance and growth, due to the progressive decline of the labor force working on the resource sector as the country develops. However, this effect is decreasing as the endowment of human capital grows. By adding a term that captures the interaction between human capital and natural resources in regressions, the authors found a threshold level of human capital, above which the resource-abundance impacts positively on GDP growth.

Summing up, the relationship between resource-dependence and growth is a warm debate and this small survey does not cover it all. Previous evidence of the resource curse is being questioned by recent contributions that take into account non-economic factors and new measures of resource-dependence.

Methodology

The empirical strategy consists in studying the effect of royalty revenues on eligible municipalities by comparing the growth of their economic products[13] with the growth of non-eligible ones, before and after the Petroleum Law was enacted. We assume that the new law is an exogenous event, since it changed significant rules on collection and distribution of royalties to benefit local districts, increasing substantially their revenues.

The term 'exogenous event' refers to a change in the legislation to be explored to identify the impact of royalties on local growth. It is the main strategy of identification of the diff-in-diff estimator, like the one used here. This means that the reasons that led to the approval of the new law are unrelated to the explanatory variables. Since the Petroleum Law meant a meaningful transformation in the regulatory framework of the oil industry in Brazil (including new municipalities that started to receive royalties and new rules for calculating them), the interpretation that the new law is exogenous is a weak assumption to be adopted.

Two main rules define whether a municipality is entitled to receive royalties or not, and its corresponding revenue: (i) the municipality must be considered a 'producer locality' and (ii) the municipality must be directly or indirectly impacted by oil and gas production. The current criteria that guide the royalty sharing have serious distortions (Serra, 2003). The largest volumes of royalties are driven to producer municipalities. When the tract occurs offshore, the municipality is eligible as a producer, according to the projections of its geographical contour over the sea, and the revenue of royalties it is entitled to receive is proportional to the production of the wells within this projection. Thus, depending on the shape of its coast, the municipality includes more or less wells under its area, receiving royalty revenues accordingly. Regarding the second rule, all activities of embarkation and disembarkation (including transportation by pipelines) are included in the criteria of eligibility.

The identification strategy employs the difference-in-differences estimator (Meyer, 1995),[14] to compare the effect of an event over a group – called the treatment group – with the performance of an unaffected one—the control group. In this case, we aim at performing a comparison between the economic growth of eligible and non-eligible municipalities, before and after the law that entitled them to receive royalties under the new criteria.

Let y_{it} be the growth rate of the economic product per capita of district i during the period t, such that $t = 0$ means a window opened before the event (from 1996 to 2000) and $t = 1$ means a window after it (from 2001 to 2005), when localities started to be actually impacted by royalties under the new law (see Fig. 1). Diff-in-diff searches to isolate the treatment effect on the dependent variable and, since the data set is a genuine panel composed of municipalities, it is not necessary to add an excessive set of covariates to control for unobservable characteristics. The district i will belong to the treatment group ($j = T$) or to the control group ($j = C$), whether it is eligible for receiving royalties under the new law or not. If one compares the averages of growth only within eligible districts, before and after the law ($E[y_{i1}|j = T] - E[y_{i0}|j = T]$), the estimates will be biased, since local product is also affected by other factors unrelated to the policy change (Wooldridge, 2002, p. 130); on the other hand, if one compares both groups after the new legal regime ($E[y_{i1}|j = T] - E[y_{i1}|j = C]$), the bias emerges from unobservable systematic differences between them, and such differences would be wrongly attributed to the new policy.

The approach we have used is based on a non-binary treatment (e.g.: Kiel and McClain, 1995), focusing not only on the *treatment effect* per se, but also on the *treatment size*—the volume of royalties per capita transferred to each municipality. Each observation is put on a continuum of possible treatments. To show in a simple way how the diff-in-diff allows isolating the treatment effect without a wide set of control variables, one assumes that the growth rate of product per capita (y_{it}) has been estimated by the following regression:

$$y_{it} = f_i + g_t + \delta_1 \mathbf{Z}_{it} + \delta_2 x_{it} + \varepsilon_{it} \qquad (1)$$

in which δ_2 is the parameter of interest that measures the effect of royalties per capita x_{it} on the economic growth rate during period t. $\mathbf{Z}_{it}$ is the vector of all independent variables that affect the economic growth; f_i is the municipal fixed effect and g_t is the macroeconomic effects in period t.[15] ε_{it} is White Noise.

One could evaluate the impact of the treatment on the dependent variable by comparing y before ($t = 0$) and after ($t = 1$) the effect of the new law, such that by Eq. (1) and remembering that $x_{i0,\,T} = 0$

$$E[y_{i1}|j = T] = f_i + g_t + \delta_1 Z_{i1} + \delta_2 x_{i1,T}$$
$$E[y_{i0}|j = T] = f_i + g_t + \delta_1 Z_{i0}$$

Likewise, for the control group

$$E[y_{i1}|j = C] = f_i + g_t + \delta_1 Z_{i1}$$
$$E[y_{i0}|j = C] = f_i + g_t + \delta_1 Z_{i0}$$

Since the control group is the set of non-affected municipalities, $x_{it,\,C} = 0$, $t = 0, 1$. Aiming at investigating the effect of the new regulatory framework, one could find the change in the dependent variable from $t = 0$ to $t = 1$, within each group, i.e.:

$$\Delta y_{t,T} = E[y_{i1}|j = T] - E[y_{i0}|j = T] = \delta_1(Z_{i1} - Z_{i0}) + \delta_2 x_{it} \qquad (2)$$

$$\Delta y_{t,C} = E[y_{i1}|j = C] - E[y_{i0}|j = C] = \delta_1(Z_{i1} - Z_{i0}) \qquad (3)$$

[13] We have restricted the analysis to a single dimension of development, i.e., the economic product, due to the lack of available annual data about other indicators in a local basis.

[14] Angrist and Krueger (2000) and Blundell and MaCurdy (2000) both present overviews about this methodology. Some examples include Slaughter (2001), which studies the effect of trade liberalization over income convergence; and Meyer et al. (1995), which use the estimator to evaluate the impact of higher benefits on the duration of job licenses. Vicente (2009) applies diff-in-diff to study the effect of oil discoveries on perceived corruption in African countries.

[15] This component allows controlling for mandatory changes in the national policy that affected uniformly each city in Brazil, with the assumption that these national changes or macroeconomic factors have homogeneous impact on localities. Of course, it is possible that national changes affect municipalities in a heterogeneous way, but the measure of such effects would require much more advanced econometric techniques, which are beyond the purpose of this paper. See, for example, Athey and Imbens (2006).

Table 1
Descriptive statistics.

Variable	# Observations	Average	Standard deviation	Minimum	Maximum
Municipal product growth[a] (1996–2000)	4266	0.4437	0.4307	−2.566	4.138
Municipal product growth (2001–2005)	4266	0.1063	0.3241	−1.766	2.292
Difference (2001–2005) to (2000–1996)	4266	−0.3373	0.5982	−4.567	2.575
Royalties 1999 (per capita)	734	11.09102	53.9956	0.000711	1027.42
Royalties 2000 (per capita)	681	19.5637	87.0992	0.000656	1586.18
Royalties 2001 (per capita)	726	18.94602	86.8969	0.000711	1667.654
Royalties 2002 (per capita)	726	25.08461	113.1131	0.000656	1936.839
Royalties 2003 (per capita)	725	31.3708	129.2604	0.000984	2077.912
Royalties 2004 (per capita)	726	30.10263	122.0067	0.000875	1878.126
Royalties 2005 (per capita)	743	32.28913	130.8401	0.000601	1938.211

Source: elaborated by the author, based on IBGE, IPEA, and ANP data. 2006 values, in US dollars. municipalities measured in the MCA.
[a] The growth rate was calculated as the difference of log of the municipal products.

However, the estimation of Eq. (2) would lead to a potential bias, as the presence of the term $\delta_1(Z_{i1}-Z_{i0})$ reveals, since the economic growth is also affected by other factors unrelated to the policy change.[16] In order to investigate the genuine treatment effect, the diff-in-diff allows eliminating such unobserved variables through the difference:

$$\Delta y_{t,T} - \Delta y_{t,C} = \delta_2 x_{it}$$

That is

$$\delta_2 = \frac{d(\Delta y_{t,T} - \Delta y_{t,C})}{dx_{it}} \tag{4}$$

The diff-in-diff estimator can be implemented through the following regression model:

$$y_{it} = \alpha_0 + \alpha_1 d_t + \alpha_2 d^j + \beta d_t^j x_i, + \varepsilon_{it} \tag{5}$$

in which y_{it} is the growth rate of the economic product per capita of municipality i in t. d_t is a time dummy variable, if the district is observed after the treatment ($t=1$); d^j is a dummy for eligible municipalities (equals one if $J=T$ and zero if $J=C$). d_t^j is a dummy variable for $t=1$ *and* $J=T$. The identifying assumption requires that the approval of the new law is exogenous. The effect of royalties on the eligible districts is measured by β. Taking the first difference in Eq. (5), we have the functional model to be tested:

$$\Delta y_{it} = y_{i1} - y_{i0} = \alpha_1 + d_t^j \beta x_{i,} + \varepsilon_{it}$$

Equivalently, remembering that $d_t^j = 1$, if and only if $x_i > 0$

$$\Delta y_{it} = \alpha_1 + \beta x_{i,} + \varepsilon_{it} \tag{6}$$

The constant α_1 tests possible changes in the pattern of municipal economic growth as a whole between $t=0$ and $t=1$. The parameter of interest is β searches to measure whether the volume of royalties has a significant impact on local development. Regarding other determinants of local economic growth, the population of 1996 (the initial year) was included in the regression to take into account possible heterogeneity in the pattern of growth according to the municipalities' sizes. Moreover, following Bravo-Ortega and Gregorio (2005), a proxy for municipal human capital was included, measured by the share of adults over 25 years old with more than 11 years of schooling in 2000. This variable aims at evaluating how the quality of the local labor force potentially impacts on economic growth.[17]

[16] Wooldridge (2002, p. 130).

[17] Although there are other proxies for human capital in the economic literature, like enrolment rate, life expectancy and health indicators, the years of schooling of adult population is the only one resembling human capital that is available for the minimum comparable area level.

Data

Municipalities are commonly split in Brazil to create new ones. Since the number of districts varies across the years, we used a device called *minimum comparable area* (MCA), calculated by IPEA, the Applied Economics Research Institute. The MCAs are groups of cities that allow for time-consistent comparisons of municipal data, considering municipalities created over time. Therefore, instead of the current 5560 municipalities in Brazil, the data set has 4266 MCAs, according to 1990s criteria.[18] From now on, 'municipalities' and 'MCA' are treated as synonymous.

The economic products of the Brazilian municipalities (municipal GDPs) were estimated by IBGE (Brazilian Institute of Geography and Statistics) from 1999 to 2005, while in 1996, they were estimated by IPEA.[19] Municipal population data were estimated by IBGE.[20] The data on royalty transfers to municipalities were supplied by the ANP, the National Petroleum Agency in Brazil. Among the current 5560 municipalities in Brazil, about 800 receive royalties in very different amounts, either for sheltering productive units or for being producer localities, according to the criteria described above.[21]

All estimates were performed in the Brazilian currency, in constant values of 2000. Table 1 summarizes the royalty data, in US dollar terms. It is easy to notice the enormous variability in royalty revenues among municipalities.

The largest portion is transferred to districts located in Rio de Janeiro, since the major oil basins – Campos Basin and Santos Basin – are located in this state. Table 2 exhibits the top ten municipalities in cumulative volume of royalties from 1999 to 2005. Table 3 presents the top ten in per capita terms.[22]

The Petroleum Law was approved in August 1997, but its effects were felt gradually only after 1999, when the volume of royalties increased substantially. By 1999–2000, the international

[18] *Source*: IPEA.

[19] The diff-and-diff allows controlling for such global changes in the methodology, since their effects vanishes as we take the difference between the control group and the treatment group. Moreover, another global change in methodology was introduced in 2002 (see www.ibge.gov.br for details), but the estimator is not affected as well for the same reason.

[20] For 1991, 1996 and 2000: population census; for the other years: IBGE estimates.

[21] The distribution criteria are described by Serra (2003) and Leal and Serra (2002). The amount of royalties depends directly on the oil production within the projection of the municipal circumscription over the sea, but the set of municipalities that receive royalties has increased over time, since the number of wells operating (and producing oil and gas) increased from 1999 to 2005. As new wells start to operate, new municipalities are added to the set of eligible localities.

[22] We added the value of royalties per capita each year, from 1999 to 2005.

Table 2
The top 10 municipalities benefitting from royalties in Brazil from 1999 to 2005.

State	Municipality	Royalties ($)	%
RJ	Campos dos Goytacazes	1,186,643,267.00	15.6
RJ	Macaé	959,870,040.00	12.6
RJ	Rio das Ostras	470,299,998.00	6.2
RJ	Cabo Frio	348,151,235.00	4.6
RJ	Quissamã	236,007,466.00	3.1
SP	São Sebastião	179,143,331.00	2.4
AM	Coari	170,173,358.00	2.2
RJ	Armação dos Búzios	157,754,072.00	2.1
RJ	Casimiro de Abreu	143,261,747.00	1.9
RJ	São João da Barra	130,524,673.00	1.7
Sum		3,981,829,187.00	52.5
Others		3,608,143,253.00	47.5
Total		7,589,972,440.00	100.0

Source: ANP—elaborated by the author.

Table 3
The top 10 municipalities benefitting from royalties in Brazil from 1999 to 2005, $ US per capita.

State	Municipality	Royalties per capita ($)
RJ	Quissamã	16991.66
RJ	Carapebus	12303.90
RJ	Rio das Ostras	11604.96
RN	Guamaré	9724.36
RJ	Armação dos Búzios	7958.72
RJ	Macaé	6825.83
RJ	Casimiro de Abreu	6095.07
BA	Madre de Deus	6039.83
SE	Pirambu	5603.35
RJ	São João da Barra	4771.73

Source: ANP and IBGE—elaborated by the author.

oil price has a major increase, resulting in a large rise in royalty revenues in the hands of municipalities after 2000. So, year 2000 was defined as the watershed. In order to implement the diff-in-diff, the dependent variable Δy_{it} was calculated as the difference between the growth rate of the municipal product per capita in four years before 2000 (from 1996 to 2000, equivalent to $t = 0$) and the same growth rate four years after the event (from 2001 to 2005, equivalent to $t = 1$). Variable x_i is the cumulative royalties per capita transferred to district i from 1999 to 2005.

Results

Table 4 reports t-test results for comparison of means on the dependent variable (Δy_{it} in Eq. (6)) between both groups of municipalities (eligible and non-eligible ones). The null hypothesis that both means are equal is rejected, showing that royalty receivers have grown less than municipalities that did not receive such resources after 2000.

Table 5 shows the estimated coefficients of Eq. (6), considering different specifications and estimators (OLS and GMM). We also have included state dummies with the purpose of incorporating local characteristics, controlling for fixed effects of each federative unit. These dummies allow controlling for possible heterogeneity in the evolution of economic product, due to local specificities. Among the 4266 MCAs, 743 were eligible as royalty beneficiaries in 2005, according to the legal criteria introduced by the new law. The GMM estimates[23] use the human capital of each municipality

[23] In this case, we performed a two-stage least squares (TSLS) with White's robust covariance matrix which is equivalent to a GMM with a single instrument.

Table 4
Mean comparison test, assuming unequal variances.

Group	Observations	Average	Standard deviation	t-statistic
Treatment	742	−0.44815	0.762948	4.543**
Control	3524	−0.31401	0.554749	

** 1%—significant; Satterthwaite's degree of freedom.

in 1991 (share of population over 11 years of schooling) as an instrument for the human capital in 2000, since years of schooling is possibly endogenous to the economic growth.

The coefficient that measures the marginal effect of royalties on growth (β) is negative and significant: the growth rate of product slows down as the royalty revenue per capita increases. Moreover, the GMM estimates are not significantly different from the OLS ones: on average, an increase of one monetary unit in royalties per capita reduces the growth of economic product in 0.002 percentile points. Despite the small magnitude, the effect is statistically significant. The effects of population and human capital on growth are positive, as expected, since populous cities with highly skilled labor forces tend to exhibit more dynamic agglomeration economies that favor economic growth.

Royalties are shared unequally among the Brazilian localities, with a huge concentration in few federative units, mainly in Rio de Janeiro's municipalities. An interesting exercise is to investigate whether such effects also exist within each state. Table 6 shows the estimated coefficients of Eq. (6) for the restricted sample containing only municipalities within the six largest oil producer states—and consequently, the major beneficiaries of royalties: Rio de Janeiro, Rio Grande do Norte, Espírito Santo, Bahia, Sergipe and Amazonas. The results show a pattern of growth analogous to the whole country, since there is a negative relationship between royalties per capita and the municipal growth.[24]

Summing up, results suggest the existence of a phenomenon that resembles the so-called resource curse, in the extent that high resource-dependence seems to impact negatively on local economic growth. Higher royalty revenues tend to reduce the economic growth of municipalities entitled to receive them compared to the control group.[25] This result is analogous within the major producer states.

Concluding remarks

The international literature about growth and economic development has tried to solve an interesting puzzle: why resource-rich countries exhibited low GDP growth rates? When such evidence seemed to be robust, several explanations were provided: Dutch disease, investment crowding out, capital and consumption overshooting, dynamics of nonrenewable resource, institutional weaknesses, corruption and rent-seeking. However, another set of researchers have expressed skepticism about the resource curse hypothesis, arguing that measures of resource-dependence are far from free of controversy. By using wider data sets and other econometric techniques, more recent contributions demonstrate that previous conclusions about the negative effect of resource on economic growth were misleading. Thinking about the economic nature of the resource curse was also the object of revision, with interesting contributions that explain the

[24] However, differently from the national case, the human capital is not significant.

[25] It is important to highlight that the product per capita of eligible cities did not decrease after 2000, but grew less than the municipalities of the control group (non-eligible districts).

Table 5
The impact of royalties on municipal growth: estimates for the full sample.

Estimated coefficients (Eq. (6))	OLS	OLS	OLS	GMM	GMM
Constant (α_1)	−0.491**(0.022)	−1.564** (0.154)	−1.169** (0.254)	−1.574** (0.154)	−1.495** (0.338)
Royalties per capita (00–05) (β_2)	−0.0021** (0.0005)	−0.0021** (0.0005)	−0.0020** (0.0005)	−0.0021** (0.0005)	−0.0020** (0.0005)
Log of population (1996)	–	0.104** (0.016)	0.094** (0.017)	0.106** (0.016)	0.083** (0.019)
Proxy for municipal human capital	–	0.085** (0.017)	0.221** (0.032)	0.075** (0.020)	0.263** (0.046)
Federative unit dummies	No	No	Yes	No	Yes
R^2	0.3351	0.3462	0.4097	0.3461	0.4094
Significance F (k, M–k)	15.15**	31.03**	34.85**	–	–
Significance *Wald* $c^2(k)$	–	–	–	77.98**	971.94**
# Total observations (MCA's)	4267	4266	4265	4266	4265
# Observations control group	3524	3523	3522	3523	3522
# Observations treatment group	743	743	743	743	743

White's robust standard deviations in parenthesis.
*Significant at 5%.
** Significant at 1%.

Table 6
The impact of royalties on municipal growth: estimates for the restricted sample.

Estimated coefficients (Eq. (6))	OLS	OLS	GMM
Constant (α_1)	−0.604** (0.083)	−2.762** (0.757)	−2.733** (0.807)
Royalties per capita (00–05) (β_2	−0.0022** (0.0005)	−0.0022** (0.0005)	−0.0022** (0.0005)
Log of population (1996)	–	0.221** (0.074)	0.218** (0.079)
Proxy for municipal human capital	–	0.078 (0.067)	0.085 (0.091)
R^2	0.5291	0.5389	0.5389
Significance F (k, M–k)	15.28**	8.81**	–
Significance *Wald* $\chi^2(k)$	–	–	27.08**
# Total observations (MCA's)	837	836	836
# Observations control group	346	345	345
# Observations treatment group	491	491	491

White's robust standard deviations in parenthesis.
*Significant at 5%.
** Significant at 1%.

phenomenon on a political basis. The controversy goes on, as researchers aim to decipher the actual nature of the phenomenon.

In this context, although Brazil is not considered a major oil producer, deposits are located unevenly inside the territory. Producer and affected municipalities enjoy mineral rents by receiving part of the royalty revenues to offset them for possible damages due to oil and gas production.

In 1997, Brazil enacted a new law (#9478/97) that changed substantially the regulatory paradigm of the oil and gas industry. The new criteria for the calculation and for the distribution of royalties are among the most important novelties, which resulted in substantial increase in the availability of such revenues for municipalities. The legal change affected about 800 municipalities (among the national total of 5500), entitling them to receive royalty revenues.

The paper aimed at exploring the change in the law to evaluate whether royalty revenues have impacted positively or negatively on the economic growth of municipalities. Diff-in-diff estimator was used to do so, assuming that the policy change is an exogenous event.

Results confirm a phenomenon analogous to the resource curse in the local economic growth, since municipalities that received royalties grew less than the non-eligible ones after 2000, when the new law started to be effective. Moreover, the marginal effect of royalty on municipal growth is negative. It is important to warn that this conclusion of "resource curse" refers only to a single dimension of development, i.e., the growth of local economic product. It is very possible that other indicators of human development have exhibited improvement as a consequence of royalties, but due to the lack of data in municipal basis (the Brazilian Census is conducted each ten years and the next one is scheduled to 2010), this subject is still open.

Although these results deserve a deeper investigation to evaluate whether each municipality allocates such resources according to the new law, the explanation related to the Dutch disease is not satisfactory, since, in this case, it cannot be linked to foreign trade. On the other hand, blaming local institutions or opportunistic behavior for inefficiencies in the use of those revenues can be tempting, but premature explanation.

This study offers fewer answers than questions and some shortages still need to be overcome, suggesting further possible developments. A detailed investigation is needed to enlighten the phenomenon, but a natural question emerging from this study is whether royalties are being invested on a suitable basis. Moreover, endogeneity issues were not fully addressed and other indicators of regional development still need to be evaluated. Nonetheless, given the lack of studies in a national basis in Brazil, the present study opens the debate regarding the consequences of the Petroleum Law one decade after its approval, mainly when the Brazilian society is amid an intense discussion about the sharing of petroleum rents, following the just announced pre-salt discoveries.

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