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THE IMPACT OF ROYALTIES FROM THE EXPLOITATION OF NATURAL RESOURCES ON MUNICIPAL PUBLIC FINANCES IN BRAZIL: ESTIMATES BASED ON MODIFIED BARTIK INSTRUMENTS

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ABSTRACT

The exploitation of natural resources in Brazil collects and distributes royalties to municipalities as a result of three economic activities: oil and gas exploration, mining and the use of water resources for electricity. The economic literature has mainly investigated the case of oil, neglecting the others. This paper carries out a general investigation of the simultaneous impact of these three royalties on municipal public finances, and details circumstances that suggest endogeneity mechanisms in the distribution of royalties. In this context, it proposes an instrumental variable technique that adequately deals with the problem. Econometric results indicate that royalties cause an expansion in spending on health, education and public investment - at least for some classes of royalties - and do not increase spending on personnel, but reduce the effort to collect local taxes. The investigation of heterogeneous effects suggests that high volumes of royalties per capita are behind these results.

KEYWORDS: municipal public finances; oil royalties; water royalties; mining royalties; Bartik instruments
JEL: H72, Q32, Q38

SUMMARY

1. INTRODUCTION

The 1988 Federal Constitution established the payment of royalties for the exploitation of oil and gas, minerals and water resources for electricity generation. Over the course of three decades, large sums have been shared out among the federal entities, with the municipalities, rather than the states and the Union, being the biggest beneficiaries.

The literature has mainly investigated the case of oil royalties, given some attention to mining royalties, but almost none to water royalties. In most cases, royalties of one type were dealt with, ignoring the others. Farias (2011) described them together, but did not generate an econometric treatment. Using econometric techniques, this paper makes four contributions to the subject, the main one being the general, integrated and simultaneous analysis of all royalties. As far as we know, this is the first paper to use this approach. Several municipalities receive combinations of these three royalties and the literature neglects the possible cross-effects.

The second contribution to the literature is to explain the possible endogeneity of royalties on municipal public finances. Generally, the literature treats them as exogenous transfers to municipalities or, at best, assumes possible endogeneity as a logical possibility. The third contribution is a proposal for an instrument that adequately deals with the problem of endogeneity, based on the literature on instrumental variables of the Bartik type (1991). The fourth contribution is the econometric investigation of the impacts of royalties on municipal public finances, with special emphasis on heterogeneous effects along the royalty distribution curve.

This paper is divided as follows: in addition to this introduction, Chapter 2 presents the descriptive statistics of royalties in Brazilian municipalities; Chapter 3 discusses endogeneity in royalties and the econometric strategy to deal with this issue; Chapter 4 presents the data sources and the econometric protocol; Chapter 5 presents the results of the estimations and puts them in the light of the findings of the literature; Chapter 6 concludes the paper.

2. THE ECONOMY OF ROYALTIES IN THE CONTEXT OF MUNICIPALITIES

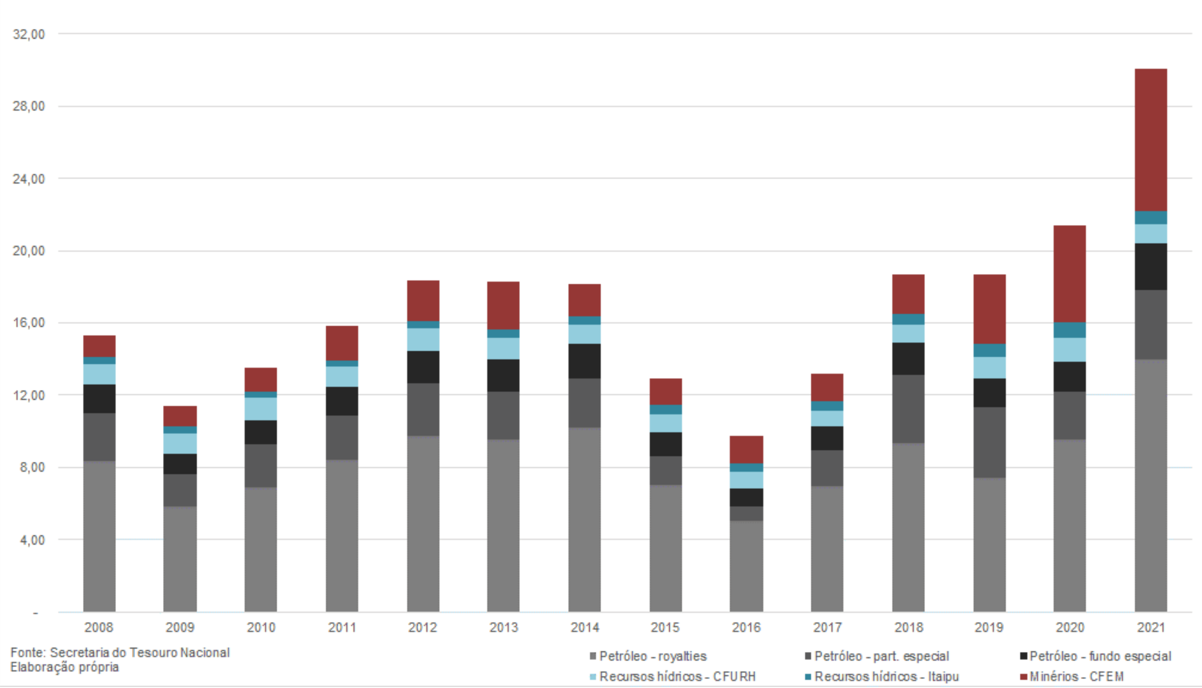
According to data from the National Treasury Secretariat (STN), R$27.76 billion in royalties were distributed to Brazilian municipalities in 2021 - just under a quarter of the Municipal Participation Fund (FPM). Although this amount is significant, its importance for municipal public finances presupposes a larger set of information, namely the number of beneficiary municipalities, the size of their populations and, above all, the relevance for local public finances.

2.1 Volume of resources, frequency of receipt and municipalities benefited

Between 2008 and 2021, royalties transferred measured at constant prices jumped from R$15.29 billion to R$30.10 billion (Graph 1) and oil royalties[1] have always been the most abundant; royalties from water resources surpassed those from minerals until 2011, but since 2012 (with the sole exception of 2015), mining royalties have taken second place in terms of the volume of resources distributed.

Although oil royalties represent the most significant share (80.3% in 2008 and 64.8% in 2021) and have grown at an average rate of 3.8% per year (in real terms), it is mining royalties that have grown the most (15.8% per year on average). These resources have multiplied almost sevenfold in fourteen years and their share of the total royalties distributed to municipalities has risen from 8.5% in 2008 to 28.6% in 2021. Royalties from water resources, on the other hand, grew at an average annual rate of just 1.3%, and their share of the total distributed fell from 11.2% in 2008 to 6.6% in 2021. In 2021, oil royalties transferred to municipalities amounted to R$17.82 billion, while those from mining and water resources for energy purposes amounted to R$7.88 and R$1.82 billion, respectively.

Gráfico 1 - Royalties pelo uso de recursos naturais - transferências aos municípios
Deflacionados pelo IPCA (base: out/2022 = 100)
R$ bilhões



Royalties were distributed to an increasing number of municipalities over the period

1 The special oil fund - one of the rents collected from oil exploration - is distributed to all Brazilian municipalities according to the same rules as the Municipal Participation Fund (FPM). It does not function like the other "oil royalties", and is therefore not analyzed as such.

analyzed (Table 1). In 2008, 50.7% of municipalities received some kind of royalty; in 2021, 65.5%. This reality has been altered by the growing number of municipalities with mining activity. While the number of towns benefiting from water royalties jumped from 649 to 739, and the number benefiting from oil royalties from 912 to 933, the number benefiting from mining royalties went from 1,947 to 3,064. Municipalities may well receive more than one type of royalty, and these intersections can be seen in Table 1.

Tabela 1 - Contagem de municípios que recebem algum tipo de royalty por exploração de recursos naturais
De 2008 a 2021

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Não recebe royalties	2.747	2.735	2.636	2.529	2.418	2.351	2.314	2.273	2.296	2.267	2.272	2.171	1.944	1.921
Apenas minério*	1.332	1.313	1.428	1.500	1.605	1.618	1.681	1.721	1.687	1.696	1.693	1.777	1.992	2.062
Apenas petróleo**	526	531	515	466	455	434	424	421	432	426	433	397	366	347
Apenas hídrico***	318	329	311	299	292	275	275	269	277	272	263	252	224	218
Minério e petróleo	316	331	313	374	381	450	433	436	429	455	446	489	530	501
Minério e hídrico	261	260	305	329	346	362	367	375	374	376	384	405	432	436
Petróleo e hídrico	32	34	31	31	32	30	26	23	29	31	29	20	21	20
Minério, petróleo e hídrico	38	37	31	42	41	50	50	52	46	47	50	59	61	65

Fonte: Secretaria do Tesouro Nacional
Elaboração própria
* Inclui municípios afetados; ** Fundo Especial do Petróleo não é contabilizado; *** Inclui os royalties de Itaipu

Counting the beneficiary municipalities and the intersections raises another relevant question: the permanence of royalty receipts. Water and oil royalties have a more stable flow over time than mining royalties. Between 2008 and 2021, 93.7% of the beneficiaries of water resource royalties received royalties for at least eleven years, 87.5% of those who received oil royalties, and only 50.1% of those who received mining royalties.

The rules for collecting and distributing the three types of royalties explain this phenomenon. In the case of water resources, for example, the right to receive royalties is linked to the hydroelectric generation of the plant that caused the flooding in the municipality. Hydroelectric plants are designed to run for decades and, once they start operating, interruptions are rare. The case of oil is less extreme, but similar. Oil and gas wells have a lifespan determined by the estimated volume of hydrocarbons and their prices on the international market. Once extraction begins, there is an acceleration or deceleration of activities, but there are rarely interruptions and reactivations, so oil and gas production usually generates regular flows of royalties over time.

The case of mining is different. According to the Interactive Brazilian Mineral Yearbook of the National Mining Agency (ANM)[2], in 2021 Brazil had 10,428 mines in operation, of which 5,565 are classified as micro-sized and 231 as large, and the size of the enterprise is greatly influenced by the numerous types of minerals exploited. This multiplicity of substances creates

2 Link to access the Yearbook, https://app.powerbi.com/view?r=eyJrIjoiZTRkNjI3MWEtMGI3My00ZTgzLWIyN2YtMzNjNDhjNTViM2Q2IiwidCI6ImEzMDgzZTIxLTc0OWItNDUzNC05YWZhLTU0Y2MzMTg4OTdiOCJ9&pageName=ReportSection8ade98fc00b628f1766f (acessado em 16/10/2023). (accessed on 16/10/2023).

several possible situations: multiple scales of operation; multiple minerals extracted in the same municipality; multiple depletion horizons for deposits; mines operated by multinationals and family businesses, etc. These situations lead to irregularities in the flow of mining royalties.

2.2 The macro and microeconomics of royalties

Royalties have low relevance from a macroeconomic point of view. In 2008, the sum of the three royalties represented 1.9% of the total revenue of all Brazilian municipalities, and in 2021 this figure reached 2.5%; the average for the period was 1.7%. In the face of the large revenue streams that reach municipalities, such as the FPM and the distribution of ICMS, royalties do not stand out. However, royalties are important for all the municipalities that receive them, even though the distribution of resources is very uneven. Tables 2, 3 and 4 present the microeconomic perspective in three ways, respectively: absolute level, as a proportion of total revenue and in per capita terms.

Tabela 2 - Os 20 maiores recebedores de royalties em números absolutos em 2021 por recurso natural
Em milhões de Reais, deflacionados pelo IPCA (base: out/2022 = 100)

Petróleo*			Minérios**			Hídrico***		
Município	UF	Valor	Município	UF	Valor	Município	UF	Valor
Marica	RJ	2.882,54	Parauapebas	PA	1.628,86	Santa Helena	PR	161,00
Niteroi	RJ	2.071,24	Canaa Dos Carajas	PA	1.221,79	Foz Do Iguacu	PR	123,21
Macae	RJ	1.070,85	Conceicao Do Mato Dentro	MG	425,84	Porto Velho	RO	112,16
Saquarema	RJ	910,38	Congonhas	MG	365,20	Itaipulandia	PR	109,71
Campos Dos Goytacazes	RJ	644,49	Itabirito	MG	344,36	Sao Miguel Do Iguacu	PR	55,49
Ilhabela	SP	576,13	Mariana	MG	257,78	Guaira	PR	53,00
Rio De Janeiro	RJ	536,58	Itabira	MG	248,64	Altamira	PA	46,90
Cabo Frio	RJ	341,17	Nova Lima	MG	217,98	Vitoria Do Xingu	PA	45,36
Presidente Kennedy	ES	299,21	Sao Goncalo Do Rio Abaixo	MG	214,38	Novo Repartimento	PA	37,52
Marataizes	ES	270,97	Maraba	PA	173,17	Marechal Candido Rondon	PR	31,83
Armacao Dos Buzios	RJ	259,28	Belo Vale	MG	154,21	Pato Bragado	PR	28,73
Quissama	RJ	251,75	Itatiaiucu	MG	153,46	Santa Terezinha De Itaipu	PR	25,58
Itapemirim	ES	246,73	Sao Luis	MA	125,34	Missal	PR	24,46
Rio Das Ostras	RJ	208,79	Brumadinho	MG	110,87	Paranaita	MT	24,24
Angra Dos Reis	RJ	206,45	Mazagao	AP	66,65	Tucurui	PA	20,14
Sao Joao Da Barra	RJ	194,85	Acailandia	MA	65,71	Entre Rios Do Oeste	PR	20,08
Arraial Do Cabo	RJ	167,25	Paracatu	MG	56,68	Niquelandia	GO	18,89
Paraty	RJ	156,08	Alto Alegre Do Pindare	MA	48,86	Goianesia Do Para	PA	14,22
Araruama	RJ	150,80	Curionopolis	PA	45,56	Caninde De Sao Francisco	SE	12,01
Sao Sebastiao	SP	148,06	Itaituba	PA	43,40	Mercedes	PR	11,79
Soma de todos municípios		17.822,70	Soma de todos municípios		7.877,99	Soma de todos municípios		1.820,19
Quantidade de municípios		933	Quantidade de municípios		3.064	Quantidade de municípios		739
Participação dos 20 primeiros		65,0%	Participação dos 20 primeiros		75,8%	Participação dos 20 primeiros		53,6%

Fonte: Secretaria do Tesouro Nacional
Elaboração própria
* Fundo Especial do Petróleo não é contabilizado; ** Inclui municípios afetados; *** Inclui os royalties de Itaipu

Table 2 shows the twenty largest recipients of each type of royalty in 2021, in absolute terms; they account for a disproportionate share of the resources distributed: 65% of all oil royalties, 75.8% of all mineral royalties and 53.6% of water royalties. The statistical distribution of these resources is quite asymmetrical, with the majority of municipalities receiving insignificant amounts.

Table 3 shows the twenty municipalities whose royalties occupy the highest shares of total municipal revenue. The distribution of this relative variable is also asymmetrical, with a large number of municipalities whose royalties received represent very little of the total revenue: in half of those receiving oil royalties, these resources amount to a maximum of 0.33% of the total revenue; this share is 0.2% in the case of mining royalties and 0.83% in the case of water resources.

Tabela 3 - Os 20 maiores recebedores de royalties em proporção da receita total em 2021 por recurso natural

Petróleo*			Minérios**			Hídrico***		
Município	UF	Valor	Município	UF	Valor	Município	UF	Valor
Ilhabela	SP	67,66%	Conceicao Do Mato Dentro	MG	71,02%	Itaipulandia	PR	63,30%
Presidente Kennedy	ES	67,55%	Belo Vale	MG	70,37%	Santa Helena	PR	53,75%
Marica	RJ	64,02%	Canaa Dos Carajas	PA	68,08%	Pato Bragado	PR	44,45%
Marataizes	ES	63,88%	Itatiaiucu	MG	57,29%	Entre Rios Do Oeste	PR	34,09%
Saquarema	RJ	62,13%	Crixas	GO	53,99%	Sao Miguel Do Iguacu	PR	30,53%
Quissama	RJ	52,82%	Parauapebas	PA	52,22%	Missal	PR	28,30%
Itapemirim	ES	48,62%	Mazagao	AP	48,78%	Guaira	PR	28,26%
Arraial Do Cabo	RJ	45,69%	Itabirito	MG	45,71%	Paranaita	MT	26,50%
Armacao Dos Buzios	RJ	44,93%	Sao Goncalo Do Rio Abaixo	MG	45,34%	Mercedes	PR	23,53%
Carapebus	RJ	42,96%	Congonhas	MG	42,58%	Santa Terezinha De Itaipu	PR	21,17%
Guararema	SP	42,75%	Mariana	MG	41,99%	Vitoria Do Xingu	PA	21,12%
Niteroi	RJ	41,19%	Sao Pedro Da Agua Branca	MA	40,04%	Tres Ranchos	GO	18,83%
Rio Das Flores	RJ	41,18%	Catas Altas	MG	35,47%	Campinacu	GO	18,44%
Alto Do Rodrigues	RN	40,95%	Cidelandia	MA	35,14%	Grupiara	MG	17,85%
Tibau	RN	40,78%	Vila Nova Dos Martirios	MA	29,08%	Porto Grande	AP	17,74%
Paraty	RJ	36,90%	Alto Alegre Do Pindare	MA	28,74%	Gloria	BA	16,65%
Iguaba Grande	RJ	36,67%	Bom Jesus Do Tocantins	PA	27,77%	Novo Repartimento	PA	15,32%
Queluzito	MG	33,83%	Alto Horizonte	GO	27,36%	Diamante D'Oeste	PR	14,92%
General Maynard	SE	33,62%	Itabira	MG	26,02%	Cascalho Rico	MG	14,63%
Ilha Comprida	SP	33,22%	Bacabeira	MA	25,50%	Douradoquara	MG	13,37%
Quantidade de municípios****		919	Quantidade de municípios****		3.035	Quantidade de municípios****		730
Valor médio		5,09%	Valor médio		0,84%	Valor médio		2,38%
Valor mediano		0,33%	Valor mediano		0,02%	Valor mediano		0,83%
9º decil		16,69%	9º decil		0,86%	9º decil		5,59%

Fonte: Secretaria do Tesouro Nacional
Elaboração própria
* Fundo Especial do Petróleo não é contabilizado; ** Inclui municípios afetados; *** Inclui os royalties de Itaipu

Table 4 shows the twenty largest royalty recipients, by type of natural resource, in per capita terms, and their distribution is similarly asymmetrical. Of the 933 oil royalty recipients, half received less than R$15.17 in 2021; of the 3,064 mining royalty recipients, half received pennies per inhabitant: up to R$0.78; and of the 739 water resource royalty recipients, half received less than R$46.98.

An interesting aspect is the high level of correlation between the relative forms in Tables 3 and 4 compared to the absolute resource levels in Table 2. In 2021, the correlation between the distribution of royalties per capita and royalties as a proportion of total municipal revenue was 80% in the case of oil, 78% in the case of minerals and 92% in the case of water resources.

These correlations are much higher than the correlations of these distributions with the distribution at absolute levels.

The municipalities that tend to have the highest per capita values also tend to have the highest proportions of total revenue. Foz do Iguaçu - PR, for example: it is the second largest recipient of royalties from water resources in 2021, but it doesn't even appear in the top twenty of Tables 3 and 4; the same happens with Cabo Frio-RJ: 8th largest recipient of oil royalties, it doesn't appear in Tables 3 and 4.

Despite this high correlation, the proportion of total revenue and per capita revenue are not identical and it would be misleading to interchange them in the analysis. The Rio de Janeiro municipalities of Macaé and Casimiro de Abreu received very different absolute amounts in 2021: R$1 billion against R$122 million; in both cases, oil royalties represented 32% of the municipalities' total revenue, but amounted to R$4,000 per capita in Macaé and R$2,600 in Casimiro de Abreu. Examples of this type abound in all the years of the series analyzed, for all royalties.

Tabela 4 - Os 20 maiores recebedores de royalties per capita em 2021 por recurso natural
Em Reais, deflacionados pelo IPCA (base: out/2022 = 100)

Petróleo*			Minérios**			Hídrico***		
Município	UF	Valor	Município	UF	Valor	Município	UF	Valor
Presidente Kennedy	ES	25.484,26	Canaa Dos Carajas	PA	31.245,52	Itaipulandia	PR	9.467,50
Marica	RJ	17.191,94	Conceicao Do Mato Dentro	MG	24.420,37	Santa Helena	PR	5.955,11
Ilhabela	SP	15.917,93	Belo Vale	MG	19.967,53	Pato Bragado	PR	4.992,54
Saquarema	RJ	9.902,07	Sao Goncalo Do Rio Abaixo	MG	19.288,76	Entre Rios Do Oeste	PR	4.317,90
Quissama	RJ	9.858,89	Itatiaiucu	MG	13.515,81	Grupiara	MG	3.304,86
Armacao Dos Buzios	RJ	7.395,23	Parauapebas	PA	7.444,96	Vitoria Do Xingu	PA	2.941,36
Itapemirim	ES	7.058,08	Congonhas	MG	6.540,63	Missal	PR	2.284,63
Marataizes	ES	6.901,99	Itabirito	MG	6.497,78	Paranaita	MT	2.147,00
Rio Das Flores	RJ	5.542,88	Alto Horizonte	GO	5.640,50	Mercedes	PR	2.099,55
Arraial Do Cabo	RJ	5.425,43	Catas Altas	MG	5.467,11	Sao Miguel Do Iguacu	PR	2.003,63
Sao Joao Da Barra	RJ	5.304,69	Mariana	MG	4.169,14	Tres Ranchos	GO	1.828,74
Queluzito	MG	5.106,30	Mazagao	AP	2.966,50	Guaira	PR	1.582,30
Carapebus	RJ	4.736,82	Passa Vinte	MG	2.880,62	Campinacu	GO	1.558,92
Tibau	RN	4.685,47	Brumadinho	MG	2.690,46	Douradoquara	MG	1.548,36
Guararema	SP	4.378,74	Curionopolis	PA	2.564,77	Cascalho Rico	MG	1.511,44
Macae	RJ	4.023,69	Nova Lima	MG	2.238,54	Santa Terezinha De Itaipu	PR	1.068,93
Niteroi	RJ	4.006,41	Sao Pedro Da Agua Branca	MA	2.175,30	Ferreira Gomes	AP	1.014,04
Galinhos	RN	3.688,40	Itabira	MG	2.042,78	Abdon Batista	SC	1.009,83
Paraty	RJ	3.533,20	Antonio Dias	MG	1.974,07	Pinhal Da Serra	RS	980,03
Ilha Comprida	SP	3.413,81	Cidelandia	MA	1.868,72	Jacareacanga	PA	926,50
Quantidade de municípios		933	Quantidade de municípios		3.064	Quantidade de municípios		739
Valor médio		394,13	Valor médio		84,76	Valor médio		175,77
Valor mediano		15,17	Valor mediano		0,78	Valor mediano		46,98
9º decil		982,18	9º decil		38,95	9º decil		360,96

Fonte: Secretaria do Tesouro Nacional e IBGE
Elaboração própria
* Fundo Especial do Petróleo não é contabilizado; ** Inclui municípios afetados; *** Inclui os royalties de Itaipu

The per capita view of the royalties of the beneficiary municipalities gives the real dimension of their importance, as it incorporates the discrepancy between the levels of poverty/ relative wealth between the municipalities. To complete the analysis of the per capita figures, it is necessary to compare them with the per capita values of total municipal revenue, to find out whether the R$2.6 thousand in royalties that Casimiro de Abreu-RJ received in 2021 is too much or too little. In that year, the average per capita total revenue of all Brazilian municipalities was R$5,252.11; after royalties, this figure drops to R$5,162.57. In aggregate, royalties represent little - they add a mere R$ 89.64 reais to the national per capita average.

It is undeniable, however, that royalties greatly alter the economic potential of hundreds of Brazilian municipalities. In 2021, fourteen municipalities more than doubled their total revenue per capita due to royalties and 139 municipalities increased their total revenue per capita by between 20% and 100%. When stratifying the distribution of total revenue per capita, with and without royalties, into quartiles, the receipt of royalties allowed 183 municipalities to move up to the upper quartiles of the distribution, of which 63 were below the national average and, with royalties, were above the national average.

3. THE IMPACT OF ROYALTIES ON THE DECISIONS OF SUB-NATIONAL GOVERNMENTS: THE ENDOGENEITY PROBLEM AND THE ECONOMETRIC IDENTIFICATION STRATEGY

The impact of royalties on the economy of municipalities is a natural question to ask, since they are actually distributed to the municipalities' coffers. This possible impact therefore depends on the mayor's political allocation choices. In other words, the question "How do municipalities spend the resources from royalties?" - a question of municipal public finance - logically precedes the question "What is the impact of royalties on municipalities?". This matters because there is a literature on subnational governments and their decisions to use federal transfers - which emphasizes the so-called *flypaper effect*. Together with institutional/legal details that influence the distribution of royalties, this literature suggests clear mechanisms for the endogeneity of royalties.

3.1 Flypaper effect

Mayors' decisions can be seen as particular cases of the "general economic policy problem" (PERSSON and TABELLINI, 2002). In this model, individuals act as consumers and voters (SAMUELSON, 1954). In the first role, they choose optimally based on their preferences for private and public consumer goods (the supply of which is decided by politicians). As voters, they vote according to their preferences about the supply of public goods and taxation. Politicians decide on the quantity of public goods offered and taxes levied, weighing up the costs of provision, their preferences and the budget constraint of the public authorities, and electoral rules determine the winners of elections (DOWNS, 1958).

Although Samuelson (1954) had in mind the decisions of the federal government, it quickly became clear (e.g. to Tiebout, 1956) that the model could also be applied to local governments. A classic finding of this literature is that exogenous and unrequited federal transfers to local governments tend to increase public spending more than equivalent increases in the income of the respective voters (COURANT, GRAMLICH and RUBINFELD; 1979) - the so-called *flypaper effect*. These transfers "stick" to local public budgets like flies to flypaper - as opposed to leading to reductions in local tax burdens, as would occur if they were perceived by local voters as increases in their respective incomes.

Royalties are classic cases of federal transfers with no counterpart. Assuming that the *flypaper effect* is valid, as advocated by the extensive literature discussed in Ferreira and Serrano (2022), it can be assumed that royalties essentially contribute to increasing municipal spending.

In this context, it should be borne in mind that the economic rationality of paying royalties has its origins in the work of Harold Hotelling (1931), who suggested that firms exploiting mineral resources maximize intertemporal profits, avoiding the accelerated depletion of deposits. This strategy is only optimal if the producer is remunerated, in the present time, for the unprofitability he would obtain if he exploited the resource in a normal competitive model (producing a quantity whose marginal cost is equal to the current market price). The difference between the price practiced in the Hotelling strategy and the price practiced in a standard competitive situation would generate a surplus income that became known as "Hotelling income"; this would be the intergenerational opportunity cost of exploiting finite resources. Hartwick (1977) suggested a long-term management rule for these rents, redirecting them towards productive reconversion investments, gradually reducing economic dependence on these activities and providing stabilization in the flow of income and well-being over time. The "Hartwick rule" depends on state action to guarantee this economic reconversion, as firms cannot be expected to do it spontaneously.

Brazilian legislation is conceptually based on the "Hartwick rule". Law No. 8.001/91 prohibits the use of royalties for debt payments and permanent staff (in any entity of the Federation); Law No. 12.351/2010 created the Social Fund to be financed with resources from oil royalties and stipulated areas for the mandatory use of its resources; Law No. 12.858/13 determined that portions of oil royalties must be applied to public health and education policies; and Law 13.540/17 (exclusively for mining royalties), in an exotic way, does not determine, but suggests, that at least 20% be applied to public policies for productive reconversion.

3.2 The problem of endogeneity

Brazilian municipalities therefore have to obey certain rules when spending royalties, but can they influence their revenue? Can these transfers really be classified as exogenous? Details of the legislation suggest that local economic, political and institutional conditions can condition these transfers - ruling out the possibility of exogeneity.

It is well known that the markets for these three classes of natural resources are heavily regulated by the Federal Government and that states and, above all, municipalities, have at most residual competence to legislate on these matters. In the mineral and oil sectors, companies depend on authorization from the Union to prospect for geological anomalies. In the electricity sector, even hydroelectric inventory studies to gauge river electricity potential depend on federal approval. Another important issue when discussing the exogeneity of royalties is the locational rigidity of these sectors. Unlike most economic activities, in which the location of the enterprise is part of the firm's decision-making context, this is not the case for these three sectors, for obvious reasons.

Despite this, there are important details that suggest that the receipt of royalties may be a phenomenon that is endogenous to the municipal context. In the case of offshore oil, the potential endogeneity lies in the royalty distribution rule. Chapter IV of Decree 01/91 determines distribution percentages to municipalities in accordance with the concept of geo-economic zone, which is divided into three: i) main production zone, ii) secondary production zone, and iii) border zone. The first is made up of "confronting" municipalities and those "*(...) where 3 (three) or more (...) industrial facilities for processing, treating, storing and transporting oil (...)*" and "*(...) facilities related to activities to support exploration, production and transport (...)*" are located. The second zone is made up of municipalities in which there are "*(...) compressor and pumping stations, directly linked to the flow of production (...)*".

The same Decree determines that 60% of the royalties due to the municipalities will be distributed to those in the main production zone, "*(...) ensuring that the municipality that concentrates the industrial facilities for processing, treating, storing and disposing of oil and* *natural gas will receive 1/3 (one third) of the quota (...)*” and “*(...) 10% (ten percent) to the municipalities that are part of secondary production (...)*”.

These industrial and logistical support facilities for offshore extraction are located in various municipalities, and it is unlikely that oil companies choose their locations at random. The positioning, on land, of the structures that support offshore operations certainly takes into account not only geographical aspects, but also aspects inherent to local conditions, including the possibility of deliberate action by mayors who are adept at *lobbying*. And since royalties are tied to these facilities, they are also partly tied to local conditions.

In mining royalties, there are also issues that suggest a probable endogeneity. Law No. 10.257/01, known as the Cities Statute, regulates the preparation of a Master Plan by municipalities and, in this area, it is possible that local restrictions interfere with mining activities. The Statute ensures the objective of organizing the social functioning of the city, observing the “*(...) spatial distribution of the population and economic activities of the Municipality and the territory under its area of influence (...)*”, the “*(...) protection, preservation and recovery of the environment (...)”. protection, preservation and recovery of the natural and built environment, cultural, historical, artistic, landscape and archaeological heritage (...)*” and the “*(...) hearing of the municipal government and the population concerned in the processes of implementing undertakings or activities with potentially negative effects on the natural or built environment (...)*”.

There have been many cases over the years in which municipalities and mining companies have clashed in court[3] over environmental issues in various cases[4]. Municipalities cannot legislate on mineral issues, but other municipal competencies directly interfere in the sector and, therefore, in the flow of royalties distributed to them[5].

In 2017, the law that created the ANM stated that “*The powers to inspect mining activities and collect (...) (CFEM) may be exercised through agreements with (...) municipalities (...) under conditions established by ANM act*”. This law was only regulated in 2021, by ANM Resolution No. 71/21, with the aim of expanding the Agency’s supervisory action using the bureaucratic structure of the other federal entities. With only future effects, it will certainly constitute an element of endogeneity in the volumes of mining royalties to be distributed.

3 https://gauchazh.clicrbs.com.br/noticia/2013/06/justica-proibe-extracao-de-areia-em-viamao-cj5v8yg-tk01odxbj0miwcj0mm.html (accessed on 16/10/2023).

4 https://g1.globo.com/rs/rio-grande-do-sul/noticia/2013/05/justica-proibe-tres-empresas-de-extrair-areia--do-rio-jacui-no-rs.html (accessed on 16/10/2023).

5 https://www.amig.org.br/eventos/iii-1/municipios-tem-autonomia-para-regular-atividade-mineraria-em--seu-territorio (accessed on 16/10/2023).

Finally, the endogeneity of royalty transfers to municipalities in the hydroelectric sector is due to the existence of the River Basin Committees and their influence on the sector (Water Law No. 9.433/97). These committees are made up of representatives of the public authorities, civil society and direct users of water resources - the municipalities participate in these committees (Article 39, III of the Water Law). The central task of the Committees is to approve the River Basin Water Resources Plan, which is the instrument for guiding the use of water for its various purposes. The river basins run through countless municipalities across the country and the possibilities for influencing the location of hydroelectric plants and, therefore, the flow of royalties, are obvious.

3.3 Endogeneity as an econometric problem: the identification strategy

All of these issues have practical repercussions for the empirical strategies used to investigate the effect of royalties on municipal public finances: these possible endogeneities are difficult to identify. As discussed below, the econometric strategy used in this text uses tools inspired by Bartik (1991), applied to two equations that aim to describe the fiscal conduct of Brazilian municipalities: one to measure the impact of royalties on local tax collection efforts, and the other on municipal spending (spending on staff with active ties to the municipality, spending on health and education functions, and investment). The first model, for revenue, is as follows:

$$Trib\_local_{it} = RT\_deduzida_{it} + Royalties_{it} + RPPS_{it} + PIB_{it} + POP_{it} + UF_{i} + Anos_{t} + u_{it} \quad (1)$$

$Trib\_local_{it}$ is the per capita collection of municipal taxes; $RT\_deduzida_{it}$ is the total municipal revenue per capita minus local taxes and royalties; $Royalties_{it}$ is the set of the three per capita royalties presented separately; $RPPS_{it}$ are two dummy variables for the presence of a Social Security System for civil servants[6] ; PIB_{it} is the set of three municipal GDP per capita variables: agriculture, industry and trade and services; POP_{it} is the municipality's population; UF_{i} is a set of 25 *dummies* for all states; $Anos_{t}$ is a set of *dummy* variables, one for each year of the series, with 2008 being the reference year; u_{it} is the error term; the subscripts it indicate the individual *i* in the year *t*. Equation (1) therefore shows the municipality's tax collection problem.

6 One of the dummies indicates the presence of an active personal pension scheme that is open to new borrowers, and the other indicates the presence of an active personal pension scheme that is closed to new borrowers.

The second model, for municipal spending, is as follows:

$$Y_{it} = RT\_deduzida_{it} + Trib\_local_{it} + Royalties_{it} + RPPS_{it} + POP_{it} + UF_{i} + Anos_{t} + u_{it} \quad (2)$$

Y_{it} There are four different variables on a per capita basis: i) expenditure on permanent staff; ii) health expenditure; iii) education expenditure; and iv) investment expenditure. The other variables are exactly the same. Taken together, models (1) and (2) summarize the decisions of the municipality: it gathers and manages all its revenue in a specific institutional context, in the face of a population of a certain size, and then decides on its allocation among various expenses according to the mayor's preferences.

The RPPS variables function as indicators of institutional context, since the administration of a private pension system is intrinsically complex and a potential determinant of municipal fiscal health in the long term. The population and municipal GDP variables control the size of the municipality and the local tax bases. Finally, the presence of the set of annual *dummies* only follows the guidance of the literature so that time trends are not incorrectly displaced to the other variables in the model

None of the models include variables that adequately control the possible endogeneity of royalty distribution. The econometric solution to deal with the problem of endogeneity in this case is the instrumental variable estimated by two-stage least squares (MQ2E).

3.4 Identifying the heterogeneous effects of the main beneficiaries

Chapter 2 highlighted the asymmetrical nature of the distribution of royalties between municipalities. In addition to models (1) and (2), equations were therefore estimated to investigate the heterogeneous effects caused by the discrepant volumes of royalties distributed. For this purpose, three *dummy* variables were created: elite_mining = 1, if the municipality receiving the mining royalty is above the 95th percentile of this distribution; otherwise = 0; elite_oil = 1, if the municipality receiving the oil royalty is above the 90th percentile of this distribution; otherwise = 0; elite_water = 1, if the municipality receiving the water royalty is above the 90th percentile of this distribution; otherwise = 0. The structural models (1) and (2) were then modified to incorporate these variables, as follows:

$$Trib\_local_{it} = RT\_deduzida_{it} + Royalties_{it} + Royalties_{it} * Dummies\_elite_{it} + RPPS_{it} + PIB_{it} + POP_{it} + UF_{i} + Anos_{t} \quad (1^{*})$$

$$Yit = RT\_deduzida_{it} + Trib\_local_{it} + Royalties_{it} + Royalties_{it} * Dummie\_elite_{it} + RPPS_{it} + POP_{it} + UF_{i} + Anos_{t} \quad (2^{*})$$

The differentiation of the percentiles in the construction of the *dummies* serves the purpose of mitigating the discrepancy in the number of municipalities captured by the construction of the *dummy* variables due to the high difference between the recipients of mining royalties and the other two.

3.5 Bartik-type instrumental variable, or shift-share instrument

The technical literature is clear on the appropriate use of instrumental variables to deal with endogeneity problems. In the presence of a variable suspected of endogeneity, another variable can function as a suitable instrument (say, *z*) if it meets two conditions: i) *z* it needs to be correlated with the variable suspected of endogeneity, i.e. $Cov(z,x) \neq 0$; and ii) z it cannot be correlated with unobserved factors affecting the variable yi.e. $Cov(z,u) = 0$ - this is called the "exclusion condition" (ANGRIEST and PISCHKE, 2009).

The first condition can be tested by estimating the first stage and checking the level of correlation and its statistical significance. The second condition, however, cannot be verified, as the error term *u* term is unobservable, which always requires a conceptual and theoretical defense of compliance with the exclusion condition. Once the theoretical and conditional defense of the instrument has been made, the exclusion condition, in practice, means that the instrument - variable *z* - only has an influence on the variable *y* conditional on the other covariates, by means of first-stage estimation (ANGRIEST and PISCHKE, 2009).

However, finding instrumental variables is a non-trivial challenge. In 1991, economist Timothy J. Bartik suggested that the traditional *shift-share* method could provide an instrument for labor demand in various locations in the US. He used the proportions of each economic sector in the total employment of each locality (*shares*) interacted with the national growth rates of the level of employment of each of these economic sectors (*shifts*) as an instrument for the level of local employment to measure its impact on the demand for labor. More recently, a number of articles have looked into how this technique works, pointing out its limitations, describing its possible working mechanisms and possible auxiliary tests to corroborate its use (GOLDSMITH-PINKHAM et al, 2019; BORUSYAK et al, 2020; MONTANÍA et al, 2020; BREUER, 2021; FERRI, 2022).

Messias (2017) suggested an instrumental variable for the isolated case of mining royalties in Brazil. In 2005, the author fixed the proportions of each municipality in the national total of royalties transferred and interacted them with a price index she constructed. As the author points out, this instrument suffers from not taking into account variations in physical production over the years and, by leaving the *share* component fixed in 2005, it does not incorporate municipalities that later entered this economic activity. The author argues that the international prices of mineral commodities are exogenous to the municipal context - this reasoning is directly applicable to the case of oil and gas prices and hydroelectric generation tariffs. Functioning as a *shift* element, however, prices suffer from non-variability *across sections* and therefore depend on interaction with the *share* to have their effect.

Brown *et al* (2019) use an instrument inspired by Bartik to measure the impact of oil royalties on the income of American counties. The instrument consists of lagged royalties for each locality as the *share* element and an exogenous shock measure as the *shift* element - the lag served to attenuate the endogenous character of the contemporaneous variable. This shock would be the first difference in the physical volume of production in each county between one period and the next. Aware that local production is possibly endogenous, the authors replaced the first difference of local production with a measure of the first difference of the production of all the counties deducted from the production of each locality, thus removing any local specificity in the *shift* element attributed to it.

The use of this relocation strategy was compiled by Ferri (2022) and pointed out as the strongest and most distinctive aspect of the technique's exogeneity. Several authors have used this strategy, including Bartik himself, so that the relocation could be geographical - eliminating the individual component of the *shift* formulation - or temporal - creating significant time lags in the *share* formulation.

3.6 A Bartik-inspired instrument for royalties in Brazil

This work suggests an instrument inspired by the literature started by Bartik. It should first be noted that the *share element* of an instrument inspired by Bartik for the case of royalties would be suspect of endogeneity, since it would be nothing more than a proportional rescheduling of the original value of production. On the other hand, fixing the *share element* in a temporal relocation strategy, along the lines practiced by Messias (2017), would incur the same limitations pointed out by the author. Finally, the likely *shift element* - prices and tariffs - does not have *cross-sectional* variability, and therefore does not serve as an instrument. Therefore, for oil and mineral royalties, the simple average of the relocated national production per capita of each municipality (i.e. a relocated *shift*) is suggested as an instrument, as follows: Be

$$\theta_{it} = \frac{P_t C_t Q_{it}}{Pop_{it}}, \quad i = 1, ..., n, \ t = 1, ..., T \ (3)$$

the municipality's per capita production i over time t. Therefore, the instrument of the *ith* municipality is given by

$$VI_{it} = \frac{1}{n-1}\left(\theta_{1t} + \ ... \ + \theta_{i-1,t} + \theta_{i+1,t} ... + \theta_{nt}\right) = \frac{1}{n-1}\sum_{j:j\neq i} \theta_{jt} \ (4)$$

VI_{it} is the instrument assigned to the municipality i in the period t; P_t is the international price of the commodity in the period t; C_t is the average exchange rate in the period t; Q_{it} is the municipality's production i in the period t; Pop_{it} is the population of the municipality i in the period t; n are the oil or iron ore producing municipalities; i is the relocated oil or iron ore producing municipality to which the instrument will be assigned. The numerator of the formula for the instrument assigned to the municipality i indicates the sum of the per capita production of all the producing municipalities, minus the per capita production of the municipality itself i.

The instrumental variable formula for hydropower royalties is identical, but it has a more radical element of relocation by excluding all the plants that affect a given municipality. Let

$$\theta^k_{it} = \frac{P_t Q^k_{it}}{Pop_{it}}, \quad i = 1, ..., n, \ t = 1, ..., T, \ k = 1, ..., K \ (5)$$

the municipality's per capita production i over time t from the plant k where Q^k_{it} is the quantity produced in the respective municipality at the time t associated with the plant k. Let $U \epsilon \{1,\ldots,K\}$ be the set of power plants whose reservoirs do not cover the municipality i, e $N_U \epsilon \{1,\ldots,n\}$ the set of municipalities associated with U. Then the hydro instrument of the *i-th* municipality is given by

$$VI_{it} = \frac{1}{m_t} \sum_{k:k\in U,\ j:j\in N_U} \theta^k_{jt} \ (6)$$

In which

$$m_t = \sum_{k:k\in U,\ j:j\in N_U} 1$$

is the total number of entries associated with the sets U e N_U in time t.

The economic output of the three sectors depends on local and non-local factors. Local issues are idiosyncratic, some random, some not, distributed among the various producing municipalities and likely sources of endogeneity. What formulas (4) and (6) do, therefore, is construct a proxy for the production of each locality *i* based on the average behavior of national production, excluding *i*. This *proxy* eliminates any idiosyncratic element due to geographical relocation, and works as an instrument because it meets the two requirements mentioned: i) it is correlated with the local royalty, as it is a *proxy* for its generating event, i.e., $Cov(VI_{it}, Royalties_{it}) \neq 0$ and ii) it is not correlated with unobserved factors that affect local variables, since y variables, since relocation removes the idiosyncratic element, i.e, $Cov(VI_{it}, u_{it}) = 0$.

The conceptual validity of the proposed instrument, therefore, derives from the understanding that all producing localities are strongly linked to the average behavior of all of them, all of which are strongly influenced by unified vectors originating from market contexts that are beyond the local domain.

4. DATA SOURCES AND ECONOMETRIC PROTOCOL

4.1 Sources of data and information

The data used comes from various sources, as follows: from the Brazilian Institute of Geography and Statistics (IBGE) comes population estimates and municipal GDP information, segmented by sector; from the STN comes revenue data (including royalties) and municipal expenditure; from the ANM, gross and beneficiated mineral production for all Brazilian municipalities; from the National Petroleum Agency (ANP), data on onshore and offshore oil and gas production, and the coefficients for apportioning royalties to neighboring municipalities; from the National Electricity Agency (ANEEL) came data on electricity generation by hydroelectric plant and the distribution coefficients resulting from flooding in the affected municipalities. The prices and deflators used came from the World Bank, ANEEL and IBGE.

4.2 The econometric protocol

The estimations were carried out combining the instrumental variable technique (MQ2E) with fixed effects (EF) for panel data, with a Log-Log functional form. The F-test (GREENE, 2012, p. 403) and Hausman test (GREENE, 2012, p. 419) were carried out to choose between fixed, random and *pooled effects* - fixed effects estimation was indicated in both tests. In accordance with the technical literature, diagnostic tests were carried out to identify possible violations in the estimation by FE: the Durbin-Watson (GREENE, 2012, p. 963) and Breusch-Godfrey/Wooldridge (GREENE, 2012, p. 964) tests indicated autocorrelation. 964) indicated autocorrelation; the Breusch-Pagan test (GREENE, 2012, p. 316) indicated heteroscedasticity; and the Breusch-Pagan LM (BREUSCH and PAGAN, 1980) and Pesaran CD tests (PESARAN, 2004; PESARAN, 2014) indicated *cross-section* dependence. For longitudinal models that simultaneously suffer from all three problems, the literature recommends that the standard errors of the estimators be calculated using robust techniques; the option used was the Driscoll-Kraay technique (DRISCOLL and KRAAY, 1998; HOECHLE, 2007).

Finally, three diagnostic tests were carried out for the presence of weak instrumental variables and verification of the exogeneity/endogeneity of the variables of interest. These tests indicate the quality of the instrumental variable and whether or not the estimates produced by MQ2E are preferable to the traditional MQO method. The Wu-Hausman test (GREENE, 2012, p. 274), to test the hypothesis of exogeneity of the variables of interest, and the Cragg-Donald F (CRAGG and DONALD, 1993) and Wald (ANDREWS et al, 2007) tests to detect weak instruments.

4.3 The construction of instrumental variables

The construction of the instrumental variable for the case of mineral exploration followed the following script: i) the beneficiated production of municipal iron ore in tons was multiplied by the annual price of iron ore, generating an estimate of the value of beneficiated iron ore production; ii) this value was converted into Reais at the official exchange rate and deflated by the IPCA (October 2022); iii) the result was submitted to formula (4).

In the case of oil, the route was identical: i) the physical volume in m³ of Brazilian oil production was allocated to the producing municipalities: i.a) in the onshore case, the ANP website provides the monthly production of onshore producing wells for calculating royalties, with identification of the municipality in which production occurs; i.b) in the offshore case, the apportionment coefficients were rebalanced so that each state's physical oil production was distributed only among the municipalities in the main and secondary production zones (the municipalities considered "producers", as explained above); iii) these production volumes were multiplied by the price of oil, generating an estimate of the value of oil production; iv) this value was converted into Reais at the official exchange rate and then deflated by the IPCA; iii) the result was submitted to formula (4).

Finally, the construction of the instrument for hydroelectric power generation: i) all hydroelectricity generation in MWh from the plants that owe royalties was distributed to the Brazilian municipalities according to each municipality's respective percentage share of the total flooded area; ii) power generation was multiplied by the Annual Reference Tariff (TAR) and deflated by the IPCA; iii) the result was submitted to formula (6).

Before looking at the results, a few clarifications should be made about the instruments used. Iron ore[7] accounted for 74.2% of mining royalties in the period analyzed, and the value of gross production (2010 to 2021) was R$6.6 billion, while beneficiated production was R$983.9 billion, 149 times higher. Of the 92 municipalities that collected royalties from iron ore extraction between 2008 and 2021, only 58 collected royalties from beneficiated production. This group of municipalities received 74.4% of the mining royalties distributed to municipalities between 2008 and 2021. In 2021, 16 of these 58 were among the top 20 per capita recipients of mining royalties in Brazil. It is important to note that mineral processing plants are a potential and additional element of endogeneity in the case of mining royalties, since the location of processing plants can generate local royalties resulting from extractive processes in other regions, through the sale of minerals by companies that own mines without processing units.

Between 2008 and 2021, the number of onshore oil-producing municipalities in Brazil was 98; following the definition of primary and secondary production zones, the number of offshore municipalities would be 84; in total, 165, as some have both types of production. This group accounted for 84% of all the oil royalties distributed to municipalities in the period analyzed and, in 2021, 16 of these municipalities were on the list of the 20 largest recipients of oil royalties.

5. ECONOMETRIC RESULTS

5.1 Econometric results of EF and MQ2E

Table 5 shows the econometric results of models (1) and (2). The MQ2E diagnostics re-

7 Interactive Brazilian Mineral Yearbook, available at https://app.powerbi.com/view?r=eyJrIjoiZTRkNjI3MWEtMGI3My00ZTgzLWIyN2YtMzNjNDhjNTViM2Q2IiwidCI6ImEzMDgzZTIxLTc0OWItNDUzNC05YWZhLTU0Y2MzMTg4OTdiOCJ9&pageName=ReportSection8ade98fc00b628f1766f.

ject the hypothesis of weak instruments, suggesting first-stage estimations with good statistical significance; the Wu-Hausman test suggested the presence of endogeneity only in model 1; in model 2, the suggestion of endogeneity is rejected for the personnel, health and education expenditure models, leaving the investment equation in an undefined situation.

The estimates of the revenue effort model showed that the effects of royalties on revenue are different: in the case of water resources, the model shows that local revenue falls by 0.08% for every 1% of royalties transferred to municipalities; in the case of oil and mining, the transfer of royalties suggests an increase in local revenue of 0.06% and 0.11%, respectively (Table 5, column 1).

Queiroz and Postali (2010) observed a drop in IPTU collection in municipalities that receive oil royalties. A study by Brasil (2015) on mining royalties found a reduction in the collection of IPTU, but when looking at the collection of all local taxes, his results suggest that royalties induce a greater collection effort - in line with the findings of this study. Postali (2015) and Carnicelli and Postali (2014) found evidence of a reduction in tax collection effort in municipalities that receive oil royalties.

Tabela 5 - Resultados econométricos para estimação dos modelos (1) e (2) pelas técnicas de EF / MQ2E e EF / MQO, com erros-padrão robustos do tipo Driscoll-Kraay

	Modelo 1		Modelo 2		Modelo 2		Modelo 2		Modelo 2	
	Y = Log_Trib_local_pc		Y = Log_Gasto_Pessoal_Ativo_pc		Y = Log_Gasto_Saúde_pc		Y = Log_Gasto_Educação_pc		Y = Log_Investimento_pc	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Covariadas	EF / MQ2E	EF / MQO	EF / MQ2E	EF / MQO	EF / MQ2E	EF / MQO	EF / MQ2E	EF / MQO	EF / MQ2E	EF / MQO
Log_RT_deduzida_pc	0.4993***(0.0564)	0.5006***(0.0565)	0.1363**(0.0402)	0.1359**(0.0406)	0.2437***(0.0572)	0.2437***(0.0569)	0.2375***(0.0497)	0.2375***(0.0493)	0.6148**(0.1775)	0.6162**(0.1780)
Log_Trib_local_pc	---	---	0.1281***(0.0301)	0.1280***(0.0298)	0.0773***(0.0122)	0.0776***(0.0122)	0.0818***(0.0116)	0.0818***(0.0117)	0.1178***(0.0166)	0.1191***(0.0169)
RPPS_ativo	-0.0728***(0.0160)	-0.0798***(0.0162)	0.0259(0.0350)	0.0250(0.0365)	0.0055(0.0171)	0.0039(0.0178)	-0.0021(0.0199)	-0.0039(0.0200)	-0.0100(0.0432)	-0.0091(0.0433)
RPPS_inativo	-0.1121**(0.0284)	-0.1163**(0.0297)	-0.0140(0.0212)	-0.0153(0.0207)	0.0322(0.0227)	0.0305(0.0230)	0.0324(0.0214)	0.0305(0.0221)	-0.0134(0.0223)	-0.0115(0.0221)
Log_PIB_agro_pc	0.0379(0.0249)	0.0377(0.0262)	---	---	---	---	---	---		---
Log_PIB_serv_pc	0.1740***(0.0272)	0.1852***(0.0262)	---	---	---	---	---	---		---
Log_PIB_ind_pc	0.0227(0.0181)	0.0372+(0.0183)	---	---	---	---	---	---		---
Log_Pop	-0.0138(0.1231)	-0.0056(0.1284)	-0.4460***(0.0824)	-0.4414***(0.0814)	-0.3874***(0.0679)	-0.3843***(0.0695)	-0.2340**(0.0592)	-0.2301**(0.0594)	-0.4405*(0.1699)	-0.4512*(0.1693)
Ano_2009	0.0325***(0.0027)	0.0283***(0.0021)	0.0867***(0.0035)	0.0855***(0.0018)	0.0344***(0.0017)	0.0328***(0.0017)	0.0264***(0.0021)	0.0246***(0.0018)	-0.3920***(0.0064)	-0.3899***(0.0055)
Ano_2010	0.0865***(0.0075)	0.0847***(0.0078)	0.1131***(0.0038)	0.1119***(0.0035)	0.0600***(0.0045)	0.0592***(0.0041)	0.0812***(0.0041)	0.0800***(0.0038)	-0.0086(0.0142)	-0.0053(0.0142)
Ano_2011	0.0987***(0.0093)	0.1013***(0.0099)	0.1948***(0.0071)	0.1936***(0.0058)	0.0932***(0.0087)	0.0935***(0.0087)	0.1319***(0.0082)	0.1317***(0.0079)	-0.0887**(0.0287)	-0.0841*(0.0283)
Ano_2012	0.1056***(0.0123)	0.1114***(0.0129)	0.2624***(0.0097)	0.2612***(0.0077)	0.1598***(0.0119)	0.1606***(0.0123)	0.1980***(0.0117)	0.1981***(0.0116)	0.0430(0.0399)	0.0488(0.0393)
Ano_2013	0.1024***(0.0117)	0.1119***(0.0123)	0.3000***(0.0120)	0.2990***(0.0079)	0.1130***(0.0110)	0.1147***(0.0108)	0.1073***(0.0120)	0.1083***(0.0101)	-0.3699***(0.0357)	-0.3637***(0.0347)
Ano_2014	-0.2081***(0.0154)	-0.1969***(0.0161)	0.3553***(0.0164)	0.3544***(0.0104)	0.3149***(0.0134)	0.3173***(0.0139)	0.2707***(0.0129)	0.2722***(0.0119)	-0.0068(0.0449)	0.0006(0.0438)
Ano_2015	-0.2560***(0.0142)	-0.2481***(0.0149)	0.3311***(0.0163)	0.3294***(0.0111)	0.2533***(0.0118)	0.2546***(0.0120)	0.2434***(0.0114)	0.2434***(0.0104)	-0.3816***(0.0360)	-0.3733***(0.0350)
Ano_2016	-0.4372***(0.0147)	-0.4334***(0.0154)	0.3268***(0.0189)	0.3247***(0.0157)	0.2588***(0.0140)	0.2588***(0.0140)	0.2303***(0.0121)	0.2292***(0.0118)	-0.4897***(0.0389)	-0.4813***(0.0385)
Ano_2017	-0.2713***(0.0150)	-0.2645***(0.0156)	0.3959***(0.0159)	0.3944***(0.0112)	0.2673***(0.0118)	0.2685***(0.0119)	0.2258***(0.0111)	0.2259***(0.0099)	-0.8179***(0.0342)	-0.8101***(0.0334)
Ano_2018	0.1016***(0.0176)	0.1074***(0.0179)	0.3723***(0.0129)	0.3715***(0.0103)	0.3394***(0.0149)	0.3409***(0.0150)	0.2322***(0.0149)	0.2330***(0.0136)	-0.4207***(0.0470)	-0.4152***(0.0466)
Ano_2019	0.1865***(0.0194)	0.2021***(0.0205)	0.1797***(0.0180)	0.1773***(0.0130)	0.3330***(0.0179)	0.3345***(0.0173)	0.2378***(0.0187)	0.2378***(0.0159)	-0.4966***(0.0548)	-0.4852***(0.0536)
Ano_2020	0.2248***(0.0206)	0.2553***(0.0229)	0.4184***(0.0260)	0.4148***(0.0159)	0.4816***(0.0235)	0.4844***(0.0222)	0.1356***(0.0253)	0.1360***(0.0204)	-0.1495+(0.0722)	-0.1316+(0.0696)
Ano_2021	---	---	0.4142***(0.0284)	0.4119***(0.0185)	0.4626***(0.0262)	0.4669***(0.0254)	0.1990***(0.0279)	0.2011***(0.0234)	-0.3724***(0.0822)	-0.3567***(0.0800)
Variáveis de interesse										
Log_Royalties_minério_pc	---	0.0131(0.0158)	---	-0.0074(0.0046)	---	0.0024(0.0036)	---	0.0049(0.0028)	---	0.0290+(0.0135)
Log_Royalties_petróleo_pc	---	0.0081(0.0129)	---	-0.0002(0.0044)	---	0.0105+(0.0051)	---	0.0082+(0.0038)	---	0.0436**(0.0114)
Log_Royalties_hídrico_pc	---	-0.0815***(0.0104)	---	0.0295(0.0230)	---	0.0145(0.0107)	---	0.0134(0.0078)	---	0.0427***(0.0099)
Instrumentos das variáveis de interesse										
Log_Royalties_minério_pc_VI	0.1152***(0.0264)	---	-0.0171(0.0523)	---	0.0095(0.0296)	---	0.0046(0.0352)	---	0.0785(0.0455)	---
Log_Royalties_petróleo_pc_VI	0.0602*(0.0246)	---	0.0190(0.0433)	---	0.0363+(0.0195)	---	0.0380+(0.0178)	---	0.0142(0.0228)	---
Log_Royalties_hídrico_pc_VI	-0.0885***(0.0139)	---	0.0288(0.0245)	---	0.0067(0.0099)	---	0.0126(0.0108)	---	0.0224*(0.0099)	---
Observações	70645	70645	76167	76167	76167	76167	76167	76167	76167	76167
R^2 ajustado	0.79	0.79	0.26	0.26	0.26	0.26	0.36	0.36	0.49	0.49
AIC	106597.62	105776.61	184465.29	184454.09	184465.29	184454.09	107613.32	107561.05	164967.66	164830.35
RMSE	0.48	0.47	0.75	0.75	0.75	0.75	0.46	0.46	0.66	0.66
Teste Wu-Hausman (estatística / p-valor)	4.109 / (0.006)	---	0.136 / (0.939)	---	1.062 / (0.364)	---	0.774 / (0.508)	---	2.493 / (0.058)	---
Teste Cragg-Donald F_minério (estatística / p-valor)	247.793 / (0.000)	---	344.075 / (0.000)	---	344.075 / (0.000)	---	344.075 / (0.000)	---	344.075 / (0.000)	---
Teste Cragg-Donald F_petróleo (estatística / p-valor)	1155.522 / (0.000)	---	1096.974 / (0.000)	---	1096.974 / (0.000)	---	1096.974 / (0.000)	---	1096.974 / (0.000)	---
Teste Cragg-Donald F_hídrico (estatística / p-valor)	33023.266 / (0.000)	---	35892.368 / (0.000)	---	35892.368 / (0.000)	---	35892.368 / (0.000)	---	35892.368 / (0.000)	---
Teste Wald_minério (estatística / p-valor)	19.119 / (0.000)	---	18.341 / (0.000)	---	18.341 / (0.000)	---	18.341 / (0.000)	---	18.341 / (0.000)	---
Teste Wald_petróleo (estatística / p-valor)	69.087 / (0.000)	---	80.639 / (0.000)	---	80.639 / (0.000)	---	80.639 / (0.000)	---	80.639 / (0.000)	---
Teste Wald_hídrico (estatística / p-valor)	1138.609 / (0.000)	---	2001.271 / (0.000)	---	2001.271 / (0.000)	---	2001.271 / (0.000)	---	2001.271 / (0.000)	---

*** p-valor < 0,001; ** p-valor < 0,01; * p-valor < 0,05; + p-valor < 0,1

Elaboração própria

In relation to spending on health and education policies, there is an indication that only oil royalties have a positive effect, but with relatively low statistical significance (p-value < 0.1), and with very modest elasticities; for every 1% increase in this royalty, spending on health increases by 0.01%, and on education by 0.008%.

In this regard, Barros (2015) found evidence of an increase in health expenditure in municipalities receiving oil royalties, although this did not correspond to an improvement in health indicators. Caselli and Michaels (2013) show that oil royalties lead to an increase in municipal public spending in various areas, including education and health. Monteiro (2015) found that oil royalties led to significantly higher spending compared to neighboring municipalities that did not receive royalties, while Givisiez and Oliveira (2011) found no evidence of improvements in education indicators associated with oil royalties. Messias (2017), studying the case of mining royalties, observed a positive impact on health and education spending.

With regard to investment, the estimates indicate that all royalties have a positive impact (Table 5, column 10), with mining royalties having the lowest statistical significance (p-value < 0.1); the estimates indicate that a 1% increase in mining royalties would lead to a 0.03% increase in investment; a 1% increase in oil and water royalties would each increase investment by 0.04%. The MQ2E estimation (Table 5, column 9) suggests that only the water resources royalty leads to an increase in investment. In this case (Table 5, column 9) only water resource royalties have an impact on municipal investment: a 1% increase in these royalties would increase investment by 0.02%.

The studies by Leal and Santana (2002), Bregman (2007) and Reis and Santana (2015), investigating the case of oil-producing municipalities, found evidence of an expansion in municipal public investment as a result of the flow of royalties. Messias (2017) showed that mining royalties are associated with increases in investment.

Beyond the focus on public finances, the literature has some other findings on the impact of royalties on the economic life of the municipalities investigated. Postali (2012) suggests that receiving oil royalties causes administrative inefficiencies in the municipal public sector. Postali and Nishijima (2011, 2013) analyzed the evolution of social indicators in municipalities receiving oil royalties and found a mixture of positive and negative results. In 2011, they found negative impacts of royalties on employment and formal income in the recipients, and zero impact on education and health indicators. In 2013, they found a positive association between receiving oil royalties and positive results in indicators of access to electricity, piped water and illiteracy rates, compared to municipalities that do not receive oil royalties.

Postali (2009) found a small but significant reduction in the GDP growth rate in municipalities that receive oil royalties compared to municipalities that do not. Tavares *et al* (2021) again investigated the effect of royalties on the economy of recipient municipalities - this time, GDP per capita, rather than the growth rate. Using spatial econometric models, they found evidence that royalties have a negative impact on the level of per capita income of the municipalities that receive them and their neighbors.

5.2 Heterogeneous effects of royalty distribution

According to the diagnostic tests of the original structural models, only model (1) has a strong suspicion of endogeneity; in model (2) the Wu-Hausman test is incisive in indicating exogeneity for all expenses, but not so much for investment - even so, at a 5% significance level, it also suggests exogeneity. The investigation of the heterogeneous effects of the distribution of royalties will only use the EF/MQO technique (Table 6).

In the estimation of models (1*) and (2*), the *dummy* variables identifying the group of large royalty recipients proved to be significant, especially in expenditure. In model (1*) there is no indication that high volumes of royalty receipts interfere with local revenue in any way different to the general average (Table 6, column 1). In model (1), the Wu-Hausman test indicated the presence of endogeneity and therefore the variables

Tabela 6 - Resultados econométricos para estimação dos modelos (1) e (2) pelas técnicas de EF / MQO com interação com dummies, , com erros-padrão robustos do tipo Driscoll-Kraay

Covariadas	Modelo 1* Y = Log_Trib_local_pc (1) EF / MQO	Modelo 2* Y = Log_Gasto_Pessoal_Ativo_pc (2) EF / MQO	Modelo 2* Y = Log_Gasto_Saúde_pc (3) EF / MQO	Modelo 2* Y = Log_Gasto_Educação_pc (4) EF / MQO	Modelo 2* Y = Log_Investimento_pc (5) EF / MQO
Log_RT_deduzida_pc	0.5003***(0.0565)	0.1357**(0.0407)	0.2430***(0.0567)	0.2369***(0.0491)	0.6139**(0.1773)
Log_Trib_local_pc	- - -	0.1280***(0.0298)	0.0774***(0.0123)	0.0816***(0.0117)	0.1183***(0.0169)
RPPS_ativo	-0.0796***(0.0162)	0.0252(0.0364)	0.0043(0.0178)	-0.0036(0.0199)	-0.0078(0.0435)
RPPS_inativo	-0.1162**(0.0295)	-0.0154(0.0207)	0.0296(0.0233)	0.0298(0.0224)	-0.0150(0.0211)
Log_PIB_agro_pc	0.0377(0.0262)	- - -	- - -	- - -	- - -
Log_PIB_serv_pc	0.1849***(0.0262)	- - -	- - -	- - -	- - -
Log_PIB_ind_pc	0.0369+(0.0182)	- - -	- - -	- - -	- - -
Log_Pop	-0.0029(0.1296)	-0.4410***(0.0812)	-0.3782***(0.0700)	-0.2260**(0.0605)	-0.4348*(0.1691)
Ano_2009	0.0282***(0.0021)	0.0855***(0.0018)	0.0323***(0.0017)	0.0243***(0.0018)	-0.3915***(0.0055)
Ano_2010	0.0848***(0.0078)	0.1122***(0.0035)	0.0592***(0.0041)	0.0802***(0.0037)	-0.0049(0.0142)
Ano_2011	0.1015***(0.0099)	0.1942***(0.0059)	0.0938***(0.0087)	0.1321***(0.0078)	-0.0827*(0.0283)
Ano_2012	0.1116***(0.0129)	0.2619***(0.0079)	0.1609***(0.0123)	0.1986***(0.0115)	0.0507(0.0393)
Ano_2013	0.1120***(0.0124)	0.2998***(0.0081)	0.1149***(0.0108)	0.1088***(0.0100)	-0.3618***(0.0348)
Ano_2014	-0.1968***(0.0161)	0.3553***(0.0107)	0.3177***(0.0140)	0.2729***(0.0120)	0.0033(0.0439)
Ano_2015	-0.2481***(0.0150)	0.3302***(0.0113)	0.2545***(0.0121)	0.2438***(0.0104)	-0.3721***(0.0350)
Ano_2016	-0.4335***(0.0154)	0.3252***(0.0159)	0.2584***(0.0141)	0.2292***(0.0119)	-0.4815***(0.0384)
Ano_2017	-0.2646***(0.0157)	0.3951***(0.0114)	0.2683***(0.0119)	0.2261***(0.0100)	-0.8095***(0.0334)
Ano_2018	0.1074***(0.0180)	0.3720***(0.0105)	0.3410***(0.0150)	0.2333***(0.0136)	-0.4141***(0.0465)
Ano_2019	0.2021***(0.0207)	0.1783***(0.0132)	0.3346***(0.0173)	0.2384***(0.0158)	-0.4834***(0.0536)
Ano_2020	0.2553***(0.0230)	0.4166***(0.0163)	0.4848***(0.0222)	0.1371***(0.0203)	-0.1279+(0.0698)
Ano_2021	- - -	0.4135***(0.0187)	0.4677***(0.0255)	0.2024***(0.0233)	-0.3520***(0.0802)
Variáveis de interesse					
Log_Royalties_minério_pc	0.0143(0.0166)	-0.0140*(0.0055)	0.0013(0.0050)	0.0007(0.0040)	0.0153(0.0115)
Log_Royalties_petróleo_pc	0.0068(0.0136)	-0.0008(0.0034)	0.0020(0.0054)	0.0022(0.0036)	0.0141(0.0120)
Log_Royalties_hídrico_pc	-0.0857***(0.0098)	0.0294(0.0237)	0.0100(0.0105)	0.0106(0.0079)	0.0362**(0.0089)
Variáveis de interesse - interação dummies					
Log_Royalties_minério_pc * elite_minério	-0.0027(0.0045)	0.0133(0.0092)	0.0021(0.0058)	0.0083(0.0056)	0.0271**(0.0069)
Log_Royalties_petróleo_pc * elite_petróleo	0.0035(0.0031)	0.0018(0.0063)	0.0236***(0.0051)	0.0165**(0.0041)	0.0817***(0.0066)
Log_Royalties_hídrico_pc * elite_hídrico	0.0153(0.0090)	0.0005(0.0079)	0.0149+(0.0077)	0.0094(0.0079)	0.0205**(0.0066)
Observações	70645	76167	76167	76167	76167
R^2 ajustado	0.79	0.26	0.42	0.36	0.49
AIC	105775.05	184456.86	123236.19	107544.25	164623.16
RMSE	0.47	0.75	0.50	0.46	0.66

*** p-valor < 0,001; ** p-valor < 0,01; * p-valor < 0,05; + p-valor < 0,1

Elaboração própria

were better suited to capturing the effect of royalties on the tax collection effort. The results of model (1*) should therefore be viewed with caution in light of the results of model (1). The receipt of royalties from water resources reduces revenue in a non-heterogeneous way. The estimate shows that a 1% increase in the receipt of these royalties reduces local tax collection by 0.08%.

In model (2*), municipalities receiving mining royalties show a reduction in personnel expenditure (Table 6, column 2). The introduction of *dummy* variables controlling for large volumes of royalties altered the estimate of the average conditional effect for mining royalties: every 1% increase in the receipt of these resources reduces personnel expenditure by 0.01%.

Model (2*) suggests that only large amounts of oil and water royalties increase municipal spending on health. For every 1% increase in royalties for large recipients, health spending increases by 0.02% and 0.01% respectively. In comparison with the results of model (2), presented in column (6) of Table 5, it can be suggested that the overall average effect detected for oil royalties is influenced by the municipalities that receive large volumes per capita.

The case of spending on education is identical: model (2*) suggests that only large volumes of oil royalties cause increases in spending on education: for every 1% increase in this range of high volumes, spending on education increases by 0.01% (Table 6, column 3). Compared to model (2) - Table 5, column (8), it is possible to hypothesize that the overall average result detected there is actually an influence of this segment of municipalities

Finally, in the case of investments (Table 6, column 5), the (2*) model suggests heterogeneous effects for royalties from water resources: the average impact of these resources on investment is 0.03% for every 1% increase; if the municipality is in the high volumes received group, this 0.03% impact is added to 0.02%, totaling 0.05%. In the case of mining and oil, the effect of royalties only seems to occur in the group of high volumes received: the impacts for 1% increases in each of the royalties are 0.02% and 0.08% respectively. In comparison with model (2) - Table 5, column (10) - there is a suggestion that these results are influenced by the average result of the stratum of beneficiaries of large volumes of mining and oil royalties, unlike what happens with water resource royalties, which seem to have an impact in general, but with additional effects due to high volumes received.

The issue of heterogeneous effects is little explored in the literature. Reis *et al* (2018) stratified the municipalities into four groups, according to criteria of dependence on royalties designed by the authors. In their estimates, spending on education and culture differed significantly between the groups, so that "(...) municipalities that are more dependent on royalties, on average, reduce the weight of spending on education and culture (...)".

Nishijima *et al* (2020) found positive effects of oil royalties on some health indicators (infant vaccination coverage and dengue cases per inhabitant) and education (number of elementary school enrolments and basic education for young people and adults). Their results, estimated by differences-in-differences, found no statistically significant differences when excluding the 19 largest oil recipients in the period analyzed.

6. CONCLUSION

This work deals with the impacts of royalties of various kinds on municipal public finances in an integrated way. It also presents an innovative and technically appropriate tool for dealing with the issue of endogeneity in econometric regressions with royalty receipts as an explanatory variable.

Contrary to more pessimistic views (*e.g.* CASELLI and MICHAELS, 2013; RODRIGUES and RODRIGUES, 2019; NISHIJIMA *et al*, 2020), the findings of this study are in line with those of authors who believe that the impacts of receiving royalties are multiple and potentially benign (*e.g.* POSTALI and NISHIJIMA, 2013). With the exception of the findings that suggest a reduction in municipalities' collection efforts in the case of water resources (a potentially negative result), there is evidence that oil royalties expand spending on health, education (MONTEIRO, 2015) and investments (REIS and SANTANA, 2015), as well as indications that mining and water resource royalties expand investments (BREGMAN, 2007). The results also suggest that royalties do not increase spending on personnel by municipalities (CARNICELLI and POSTALI, 2014).

Other results, which investigated possible heterogeneities based on the large volumes of royalties received (NISHIJIMA *et al*, 2020), suggest that the positive impacts found are linked to the group of large recipients. Only in the case of water resources did investment expand in general. When controlling for large recipients, mining royalties are associated with a reduction in personnel expenses, which reinforces the presence of important nuances advocated in this work and corroborated by selected results from the literature.

Naturally, the impact on public finances is only a subset - albeit a relevant one - of the total impact of royalties on municipal public management. Although the criticism is valid, the analysis of the impact of receiving royalties, for example, on the results of public education (among other "policy/management" variables) provided by municipalities can be better analyzed in stages (MONTEIRO, 2015). First, the impact of royalties on municipal spending is analyzed, followed by the impact of this spending on outcome indicators. The view that "on the input side", at least, royalties do not harm municipal public management seems defensible. It is therefore hoped that the approach and tools proposed in this work will be useful in further studies "on the output side".

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