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Oil royalties and the provision of public education in Brazil

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ABSTRACT

This paper examines how resource-based windfalls to Brazilian municipalities' revenues affects their provision of education. Using within-municipality variation in per capita oil revenues transferred to municipalities, we find that receiving more oil royalties increases municipal education expenditures, which translates into more teachers, classrooms, and schools per capita. These effects are present only for municipally funded schools, implying that increased educational provision is due to better funding and not through increased demand for schooling. We also find, however, that some evidence that some types of school infrastructure and services may be affected by oil royalties, implying that this additional schooling coverage may be of lower quality. Interestingly, despite the increased provision of education student outcomes like the dropout rate worsen with higher oil royalties, although this may be due to changes in student composition.

1. Introduction

Understanding whether the blessing of natural resource abundance is beneficial to the long-term economic growth of developing countries is an important but unanswered question. Two main mechanisms hinder any potential benefits accrued from resource windfalls from translating into economic gains. First, the natural resource sector could incentivize workers to take high-paying but relatively low-skilled jobs at the expense of educational attainment. Second, weak institutions could divert revenues from resource windfalls to the hands of elites, preventing those revenues from being used for public goods provision and other types of investment.[2] More specifically, if resource windfalls do not translate into better schooling provision this could reduce the likelihood of those windfalls translating into better long-run outcomes. In this paper, we use legally mandated oil revenues passed from oil production to Brazilian municipalities to determine whether or not resource windfalls can improve the provision of education in Brazil.

In our analysis, we combine data on oil royalties provided to municipalities with detailed school census data that cover all schools in Brazil and a wide array of their characteristics. We first find that these oil royalties increase per capita municipal education expenditures.

We then find that increases to oil revenues received by municipalities increase the number of schools, staff, and classrooms per capita in those municipalities. Importantly, we show that these increases are driven purely by municipally funded schools, ruling out contemporaneous shocks to demand for schooling. We also show that the proportion of municipal schools with electricity and computer labs decreases, and that the proportion of schools offering free activities and meals also declines. We then turn to the teacher-level data and show that municipal teaching staff that are hired with oil royalties are teachers, not other education support workers.

Finally, we show that municipalities that received more oil royalties experienced lower pass rates and higher dropout rates for students in municipally funded primary schools. Taken together, the evidence in this paper suggests that extending schooling coverage through oil royalties improves schooling provision, but this increased provision may extend to a group of students that have worse outcomes due to differences in composition, although worsened provision of certain school infrastructure or services on average may also have played a contributing role. The empirical evidence in this paper does not

provide a definitive answer to why student outcomes are worsening despite better education provision, however, so the mechanism behind this result remains an important puzzle.

Our paper ties into a literature examining the effects of various economic and natural resource shocks on outcomes, and education in particular. Shah and Steinberg (2017) find that positive rainfall shocks in rural India increases the opportunity cost of schooling for older children, through raising the earnings from working in agriculture.[3] Using another type of natural resource shock, Kruger (2007) shows that increases to coffee production in Brazil induced children to exit schooling and enter the labour force; this was particularly true for poorer children. Hægeland et al. (2012) examine the effect of higher local tax revenues from hydropower plants induced by the location of waterfalls in Norway on student achievement. Like our paper, they find that the higher tax revenues led to higher school expenditures. Unlike our paper, they also report that student performance improved at age 16, in part due to more teacher hours per student.

More generally, there is work by Mideksa (2013) that shows that natural resources, as measured by the endowment of petroleum resources, increases GDP growth in Norway. There is also work examining how other types of positive economic shocks or programs affect educational provision and attainment; (Atkin, 2016), for example, uses variation in export opportunities in Mexico and finds that more jobs in export industries induce students to drop out of school due to the higher opportunity cost of education. Another example is Glewwe and Kassouf (2012), who find that conditional cash transfers tied to children's education in Brazil can improve educational attainment. In the Brazilian context, Litschig and Morrison (2013) find that exogenous increases to municipal revenues from intergovernmental transfers increased schooling provision and education. A final example is (Asher & Novosad, 2017), who look at mining booms driven by price shocks in India and show that resource rent shocks increase the hiring of criminal politicians and increase criminal behaviour by politicians. Our paper will differ from these other analyses by focusing on how one particular type of shock, oil windfalls, can impact the provision of education through potentially higher municipal revenues and the characteristics of the schools that provide this education.

More specifically, our paper ties into a very large literature examining the role of oil-related shocks in education and other outcomes. Bhavnani and Lupu (2016), similar to our work, use oil royalties given to municipalities in Brazil to explore their effect on local political outcomes. Using the energy boom in Western Canada as a natural experiment, Marchand (2012, 2015) examine the effects of natural resource-driven windfalls on local labour market outcomes such as inequality, earnings, and employment.[4] Black et al. (2005) study the coal boom and bust in 1970s US Appalachia and find that coal booms increased high school dropout rates as low-skilled wages increased, while the subsequent coal bust did the opposite.[5] Marchand and Weber (2020) examine the shale oil boom in Texas and find that oil revenues did not go towards hiring more, or better teachers, contributing to lower test scores. Finally, Maurer (2018) finds that, in early 20th-century America, oil field discoveries led to better provision of education but had no measurable improvement in attendance rates.

Relative to these papers, our work contributes to this literature by using the natural experiment from Bhavnani and Lupu (2016) to examine how natural resource shocks can improve the provision of education; in contrast to Marchand and Weber (2020), we find that both capital projects (in the form of schools and classrooms) as well as hiring of teachers (in the form of staff increases) can occur as a result of increases to municipal revenues from oil windfalls. However, similar to our paper, Marchand and Weber (2020) report that student achievement declined as a result of the revenue windfall. They attribute this to greater teacher turnover and the hiring of more inexperienced teachers. This is a mechanism that is potentially present in the Brazilian context as well because we find that the greater oil revenues lead to younger teachers being hired more. Our findings are also consistent with those of Maurer (2018), but in a very different (contemporary, non-developed country) context. In contrast to Maurer (2018) and most of the above work, we also use a Brazilian government policy that allows us to arguably better disentangle the effect of municipal revenue increases from schooling demand shocks driven by employment effects from local natural resource booms. While we are not the first to exploit this policy change,[6] we present the most comprehensive examination of the provision of education in Brazil in response to oil royalties.

The work most related to our own is that by Caselli and Michaels (2013), who examine how oil windfalls affect municipal expenditures and the provision of public goods, including education. They find evidence that oil output-driven increases in municipal revenues correlate with higher spending on public goods and services, but they also find very mixed results in terms of actual increases to the provision of public goods. In particular, when looking at purely cross-sectional specifications (Caselli & Michaels, 2013) find relatively strong evidence of municipal revenues from oil increasing teachers and classrooms per capita. However, when using pseudo-first differences specifications, they find that there is no statistically significant evidence of increases to the numbers of teachers or classrooms, which they attribute partly to corruption. One key limitation of their study is that they have only cross-sectional data on oil output.[7] In contrast, we have detailed annual data on oil revenues per municipality, allowing us to use fixed effects to control for unobservable municipality characteristics and obtain precise within-municipality estimates of the effects of oil revenues on schooling provision. Accordingly, we find that oil revenues translate to higher levels of schools, teachers, and classrooms per capita, a finding that stands in contrast to the more pessimistic results of Caselli and Michaels (2013). Our work is instead more consistent with that of Gadenne (2017) and James (2017), who show that increases to tax revenues in Brazilian municipalities and high energy prices in energy-rich US states, respectively, can improve municipal education outcomes.

The rest of the paper proceeds as follows. Section 2 describes the background and data description, Section 3 lays out the conceptual framework, Section 4 describes the empirical methodology, Section 5 presents the results, and Section 6 concludes.

2. Background and data description

In this section, we first briefly describe the context of oil royalties in Brazil. We then present a concise introduction to the Brazilian educational system. Finally, we describe the data used in the analysis.

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[3] Bjorkman-Nyqvist (2013) also leverage variation in rainfall as shocks to household income and find that enrolment in schools is negatively related to positive shocks, particularly for older girls. Another example of the use of rainfall shocks to identify resource windfalls' effect on education is Thai and Falaris (2014), who find that negative rainfall shocks worsen schooling outcomes.

[4] Other examples include Basso (2017), who uses US data to examine the labour market and educational implications of oil booms and busts, Kumar (2017), who studies the effect of oil booms and busts on US oil regions' economic outcomes and educational attainment, and Smith and Wills (2018), who look at oil booms and show, using satellite night light data, that urban–rural inequality increases because oil booms benefit only urban areas.

[5] A paper by Cascio and Narayan (2020) examines a similar question using fracking activity as the shock.

[6] Nishijima et al. (2020) also leverage this policy to examine its effects mainly on nutrition and human capital attainment; we instead focus mainly on the provision of public education using rich educational data. Our findings also stand in contrast to their findings, which suggest an improvement in human capital with little to no change in the few educational provision indicators they use.

[7] The first differences specification they construct presumes that oil revenue in the first period is zero because the legislation mandating the sharing of oil revenues with municipalities had not yet become law.

2.1. Background on oil in Brazil

In Brazil, oil production is overseen by the federal regulating body, the National Agency of Petroleum, Natural Gas and Biofuels (ANP). Following the liberalization of the oil sector in 1997, new offshore fields were discovered, which led to a substantial increase in oil production. Beginning in 1997, Brazilian federal law has dictated that, overseen by the ANP, the main oil corporation in Brazil (Petrobras) must transfer 10% of its oil revenues to various levels of government, of which approximately 30% went to municipalities. In practical terms, because Petrobras controls almost all oil production in Brazil, this amounts to a large regular transfer of funds to municipal governments coming from overall oil production in Brazil. The royalties law was enacted as part of a series of policy reforms designed to weaken the power of Petrobras, to increase regulation and oversight in Brazil with the establishment of the ANP, and to increase the level of competition in the country's oil sector. These royalties can be considerable for a given municipality—during the time frame and for the sample of municipalities in our study, royalties accounted for slightly above 5% of total municipal budget on average. Moreover, royalties accounted for more than 20% of total municipal budget for more than 10% of all of our municipalities.

The manner in which municipalities received these royalties was determined using a series of criteria. Municipalities can be awarded royalties if oil production facilities, such as storage facilities or onshore oil wells, are located within that municipality. Population estimates published by the Brazilian statistical agency (IBGE) are also factored into the allocation of royalties. Possibly most importantly, however, is that geographical factors determined how much of an offshore oil field's revenues went to different municipalities. Specifically, ANP allocated these offshore revenues based on whether a municipality faced an offshore oilfield and how much it faced that oilfield. This was done by ANP extending the boundaries of each municipality towards the sea and then calculating the proportion of each oil field that fell into each extended municipality's borders.

The procedure to establish the set of "facing" municipalities associated with a particular oil field involves drawing out each municipality's borders onto the Brazilian continental shelf. Each municipality is allocated royalties from the fraction of the oil field that lies within these drawn-out borders, also known as the municipality's maritime boundaries. This task is undertaken by the Brazilian Geographical Institute (BGE). The BGE develops two sets of borders, both of which are incorporated in the formula that determines the amount of oil royalties a "facing" municipality is going to receive (Caselli & Michaels, 2013). The first set of borders is based on perpendicular lines. This begins by "linearizing" the Brazilian coast, and then drawing out perpendicular lines from the points where the municipal borders reach the coastline until they meet the boundaries of Brazil's territorial water. The second set of boundaries are constructed using parallel lines. Under this method, municipal maritime boundaries are identified by using the parallel line that passes by the point at which municipal boundaries coincide with the coastline. Following this, the variable quota of oil royalties is allocated among facing municipalities based on the average of each municipality's share of the total oil field area from both the perpendicular and parallel set of borders. The formula multiplies this simple average for a given municipality with respect to a particular oil field—with the value of the oil output from that field to determine the royalties accruing to that particular municipality (Bhavnani & Lupu, 2016).

The resulting allocation of royalties was in accordance with these calculated proportions. As a result, municipalities in Brazil receive oil revenue based on a predetermined formula over which local government officials have no control, as demonstrated by Bhavnani and Lupu (2016). The as-if random assignment of oil royalties to municipalities leads to a plausibly exogenous variation in municipality revenues, allowing us to identify their effect on education outcomes. Because these calculations and determinations are formula-based and a function of international oil prices,[8] we treat the allocation of oil royalties, conditional on ever receiving oil royalties, to be plausibly exogenous.

2.2. Background on Brazilian educational system

Education has been a primary focus for different federal governments in Brazil since 1995, culminating in reforms such as FUNDEF (to equalize funding across states and municipalities), implementation of common national standards (Prova Brasil), and provision of financial aid to students from poor families (initially through Bolsa Escola, which was later consolidated with Bolsa Familia). Educational attainment in Brazil has improved since the 1990s, as evidenced by the steady increase in average years of education and proportion of adults who have completed secondary education. However, there are still multiple challenges confronting the sector in the form of effectiveness of public expenditures, high variability of enrolment rates and completion rates across regions, the quality of teaching services, and inadequate schooling infrastructure. In this section, we first describe how the public education system in Brazil is organized. We then discuss each of the current limitations of the existing system in order to understand how oil royalties may affect municipal education provision.

Brazil's educational system can be broken down broadly into three sequential stages: preschool, elementary school, and high school. These stages are relatively similar to the equivalent stages in many other countries in the world, but we will briefly describe them below. Preschool, or educação infantil, is designed for children under the age of six. Elementary school, or ensino fundamental, is the next level of education after preschool, for children from the ages of 6 to 14. The curriculum is in part determined by the federal government, although there is also variation across regions in Brazil. The core curriculum consists of standard subjects such as Portuguese, science, and math. Preschool and elementary school is mandatory. Finally, high school, or ensino médio, is an additional three years of schooling.

The responsibility for the provision of primary and secondary education is shared by both the state and municipal governments. In practice, most state governments manage secondary schools, while municipal governments are responsible for basic (primary) education, which is equivalent to elementary and middle school in the US. Enrolment in primary schools managed by the municipal government doubled from 1990 to 2009 (Bruns et al., 2011), and approximately 85% of all first to fourth grade primary schools are managed by municipal governments (Bursztyn & Coffman, 2012). Due to the highly decentralized nature of the provision of public education, municipal governments have significant authority and ability to influence the quality of primary schooling provision for the local residents. When it comes to schools run by the municipal government, the municipal governments are responsible for construction of school buildings, provision of infrastructure (e.g., computers, laboratories, libraries), and the training and compensation of teachers.

During the timeframe of our study, Brazil spent more than 4.1% of its GDP on public education per year. There are still important questions about the allocation and effectiveness of public funds across different levels of education. Brazil spends almost six times in tertiary education as it does at the primary level, while the equivalent ratio for OECD countries is twice as much. This lack of prioritization for primary schools is reflected by the persistently high repetition rates at the primary schooling level in Brazil. Moreover, a number of government audits and papers have documented the prevalence of malfeasance and mismanagement of education funds, motivating our investigation into the heterogeneous effects of oil royalties based on prevailing levels of corruption at the municipality level.

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[8] For a thorough explanation of these calculations, see Bhavnani and Lupu (2016) and the online appendix of Caselli and Michaels (2013) for more information on the legislation and allocation rules and criteria.

Historically, spending per student in Brazil has been characterized by high variability across regions. For example, spending per primary student in municipal schools was more than 15 times higher in the Southeast regions relative to the Northeast during the 1990s. While the FUNDEF initiative closed the gap to a large extent, primary enrolment still varies a lot across regions. According to the 2011 Brazilian National Household Survey, 98.4% of children in aged 7 to 14 are enrolled in primary school, while 76.8% of students in Brazil are enrolled in public schools. However, this number masks the variability of enrolment across regions and is also inflated because of the high level of repetition rates in Brazilian primary schools. From the Brazilian census of 2010, we see that net primary school enrolment at the level of individual municipalities varies from anywhere between 51.77% to almost 100%. In our sample of municipalities receiving oil royalties, the enrolment ratio at the primary level varies from 79.69% to 99.55%, as reported in the national census of 2010. A second impact of the FUNDEF initiative was to shift the burden of primary school enrolment from state to municipal schools.

Moreover, the high primary enrolment masks other forms of inequalities in educational attainment. For example, only 57% of students from the relatively poor Northeast region graduate from primary school, while the comparable figure for students in the Southeast is 76%. Furthermore, a large disparity in educational attainment in Brazil has persisted across urban and rural locations within the same municipality. Rural schools in particular have been characterized by inadequate schooling quality and low primary completion rates (only 35% of all students from rural regions graduate from primary schools, relative to 75% in urban regions). These disparities motivate our analysis of the heterogeneous impacts of oil royalties on schooling provision across rural and urban schools. The high enrolment rate could also be an artefact of high rates of repetition. National household surveys reveal that children from poor families take three additional years to complete primary school. This also explains the low levels of completion because opportunity costs of schooling keeps rising with each extra year that a student remains enrolled in primary school. Barros et al. (2010) attributed two thirds of Brazilian wage inequality to unequal access of education. While schooling access have been expanded gradually across all regions from 1993 to 2009, the Northeast region continues to lag behind other regions. For example, the average years of schooling in the Northeast in 2009 was just below 8 compared with 10.5 in the Southeast.

While the math and language performance of Brazil's high school students have undergone consistent improvements since 2005, Brazil's scores are still significantly behind OECD and East Asian countries. Moreover, Brazil still trailed behind many other countries in the Latin America and the Caribbean region on the Programme for International Student Assessment (PISA) test from 2000 to 2009, including Chile, Uruguay, Mexico, and Argentina (Bruns et al., 2011). Brazil was ahead of only three countries out of 57 in the 2006 PISA in mathematics and ahead of only seven countries in reading (Caselli & Michaels, 2013). Bruns et al. (2011) report that teachers are recruited primarily from the bottom third of high school students. Teaching at primary schools is not considered a high-status profession in Brazil. Given the concerns and limitations surrounding the quality and availability of primary school teachers, we devote a substantial portion of our empirical analysis to document how the provision of teachers responded to receipt of increased oil royalties.

2.3. Data description

2.3.1. Oil revenues

We combine data from various sources for our analysis. First, and most importantly, we obtain data on oil royalties at the municipality level from the official website of ANP, the regulator of the oil sector in Brazil.[9] These data are available from 1999 onwards, at the monthly level. We use the cumulative total royalties in December, which constitute the total royalties received by each municipality in that given year. We note that, because these oil royalty values are those reported directly by the regulator, ANP, from their calculations, these values are not subject to misreporting because of municipal-level corruption.

We also constructed estimates of offshore royalties to municipalities that are determined purely by geographic factors, for a robustness check.

2.3.2. Schooling and education

Our main schooling-level variables come from the school census in Brazil, which is conducted annually. We use data from the school censuses for each year from 2007 to 2014.[10] These data have also been used in work by Gadenne (2017) and Akhtari et al. (2017). The school-level data from the school census cover every school from preschools to high schools in Brazil in a given year, whether they are funded municipally, by state governments, or by the federal government, or are private schools. For each school, a large set of characteristics are measured. Our main schooling-level analysis focuses on the funding type (municipal, state, federal, private), the number of classrooms, and the number of staff (which includes teachers). We also make use of school characteristics such as presence of science labs, presence of computer labs, water supply, presence of libraries, and other infrastructure-related variables. To pin down some mechanisms, we also make use of information on the education level of the school (preschool, elementary school, high school) as well as its location (own building, another school, other).

We also make use of the teacher-level data from the school census. For every teacher working in Brazil, the teacher level reports a large set of demographics, teacher characteristics, and identifiers to tie each teacher to a municipality and school. More specifically, we make use of the age, race, gender, subjects taught, and municipality of their school. We use these data to present additional evidence on what types of teachers are hired using oil royalties.

2.3.3. Other data

We obtain intercensal municipality population estimates from the Brazilian statistical agency, IBGE. The Brazilian censuses are conducted every decade, with the two most recent censuses having been conducted in 2000 and 2010. Because we will be using data at an annual level, we use the official intercensal population estimates produced by IBGE at the municipality level, which are available at an annual level.[11]

We also make use of municipal-level mean student outcome data for municipally funded elementary schools. These data come from the Brazilian education ministry (INEP). We use the following three variables: the pass rate, the failure rate, and the dropout rate.

In our final sample of municipalities that receive oil royalties, we keep only those municipalities that did not undergo any change in borders from 2007 to 2015. The official municipality boundary shapefiles were downloaded for the years 2007 and 2015 from IBGE. The "Intersect" tool was used in ArcMap. After dropping intersected pieces that comprise less than 1% of any 2007 municipality, we then keep only 2007 municipalities which are only comprised of one 2015 municipality. To further ensure consistency of boundaries, we drop any 2007 municipalities where the area of the 2007 municipality and

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[9] The original royalties data were presented in PDF format. We reformatted these into a useable format and mapped them to municipality codes in Brazil, using the names and states of the municipalities originally presented in the PDFs.

[10] Comparability issues prevent us from using school censuses from earlier than 2007.

[11] Unfortunately, IBGE do not produce these estimates for subgroups of the population. This precludes us from using the number of school-age children for our analyses or from analysing whether compositional changes have occurred within our sample period for oil municipalities.
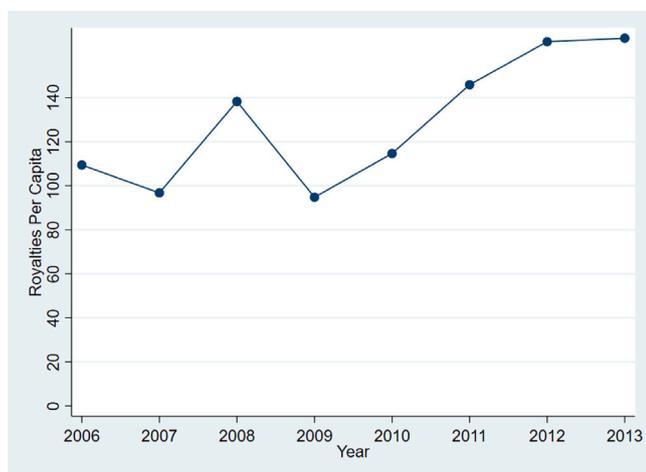
Fig. 1. Mean royalties per capita, by year.

its corresponding 2015 municipality differs by more than 1%. The remaining 2007 municipalities form our constant boundary sample.[12]

2.3.4. Summary statistics

Table 1 presents the summary statistics for our sample of oil royalty-receiving municipalities from 2007 to 2014. One key pattern that emerges is that there is substantial heterogeneity across municipalities, in terms of oil royalties per capita. Royalties per capita are reported in 2013 reals and were converted from nominal reals using the Brazilian CPI from the Federal Reserve Economic Data (FRED). The minimum amount of oil revenues per capita is zero, reflecting the fact that not all the municipalities in our sample receive revenues in every year. The mean amount of oil royalties per capita is 129.013 reals per person, but the standard deviation is 492.92, again reflecting the considerable variation across municipalities and over time.[13]

Fig. 1 shows the mean amount of royalties per capita for the municipalities in our sample at an annual level, from 2006 to 2013. Values are once again in 2013 Brazilian reals. There is a notable increase in oil royalties, increasing from a mean of just under 110 reals per capita in the beginning of the sample period to over 160 reals per capita by the end of the sample period. This is driven both by variation in oil prices and variation in oil production across various oilfields; both of these sources of variation, as well as the amount of royalties allocated to each municipality, should be plausibly exogenous to each municipality, conditional on municipality fixed effects.

Turning to the school census variables, we find that the mean number of schools per million inhabitants is 1,559.17. The majority of these are municipally funded schools, with a mean number of municipal schools of 1,231.57 per one million inhabitants. This implies that approximately 79% of schools in Brazil are municipally funded. Similar patterns emerge for staff, which includes teachers, and classrooms. In all three of the school-related variables (schools, classrooms, and staff per one million inhabitants), there is less dispersion than in the distribution of oil royalties per capita.

In the next section of Table 1, we summarize the mean of the proportion of schools that have various school characteristics or services during our sample period. Here, guided by our empirical analysis, we focus only on municipal schools in our sample municipalities. We find that a large majority of municipally funded Brazilian schools report offering meals, while a minority report having special education services or free activities for their children. By comparison, there is much more variation in infrastructure-related measures. For example, only 56.55% of schools reported having filtered water, and less than half had access to the internet. Relatively few schools have access to amenities such as science labs, computer labs, gyms, and libraries.

In the last section of Table 1, we summarize various teacher-level characteristics using the teacher-level data from the school census.[14] Motivated by our empirical analysis and consistent with the schooling characteristics summary statistics, we focus only on teachers who work in municipal schools. We find that the majority of educational staff (over 81%) are teachers. The proportion of teachers who report science, language, or arts as disciplines are relatively evenly split, at 34%, 33%, and 40%, respectively.[15] Finally, 22% of teachers are male, 58% are less than 40 years old, and 34.6% are white. This suggests that teachers in Brazil skew more towards women and away from people that are over 40 and from those who identify as white.

3. Conceptual framework

In this section, we outline a conceptual framework to help frame how increases to oil royalties, or resource windfalls more generally, can affect the provision of education and educational attainment.

The most obvious channel through which oil royalties can affect educational provision is through increased resources made available for educational spending. The exact manner in which those resources are obtained varies depending on the institutional context. In many countries, educational provision is the responsibility of local governments, and taxes generated by these localities fund public schooling. One way in which oil royalties can impact educational provision is through increased incomes of those in oil regions, which then translate into more taxes collected and better educational provision. This mechanism of course would not apply if oil windfalls do not affect local incomes or local economic conditions.

A related channel to taxation is if local governments, in response to oil shocks in their vicinity, receive more funding via transfers. The nature and magnitude of this channel, again, depends on the local context. In the Brazilian setting, however, oil royalties are explicitly collected and then transferred to municipalities via the allocation mechanism described in the previous section. This channel, therefore, is the main mechanism that we focus on in this paper through which oil shocks, as measured by oil royalties (also known as transfers to local governments), affect educational provision.

The mechanisms highlighted above indicate that the provision of education should increase, or at least not decrease, when oil shocks occur. This may not be the case, however, with educational attainment. Attainment may be affected by oil shocks in several different ways. First, if oil shocks affect those living in local areas directly via their incomes or economic opportunities, this can incentivize locals to obtain less education if education is not valued by the oil sector and locals

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[12] We note that results remain qualitatively and quantitatively almost identical when we do not drop municipalities that underwent some changes to their boundaries.

[13] Royalties divided by the municipal budget are almost always less than 1, as expected. For 21 observations, the share is over 1; in addition, these 21 observations are concentrated within five municipalities in our sample. This could occur due to discrepancies between the data sources for the oil royalties and municipal budgets. The results do not change when we drop these 21 observations.

[14] The observation counts differ from those of the school-level variables slightly. This is for two main reasons. First, there are some municipalities that appear to be missing from the teacher-level data; in particular, in 2009, slightly under 10% of municipalities do not have any teacher-level data. Second, there are some municipalities that report zero teachers but positive quantities of other staff; because teachers are the denominator in several proportions, these show up as missing values.

[15] As we mention later, having a particular discipline does not prevent a teacher from having another, so the subjects should not be seen as non-overlapping.

Table 1
Summary statistics, main sample.

	(1) Obs.	(2) Mean	(3) Std. dev.	(4) Min.	(5) Max.
Variable					
Royalties per capita, in 2013 reals	5600	129.013	492.9247	0	12158.46
Royalties as a proportion of municipal budget	3937	0.0500769	0.1341229	0	1.733332
Population	5600	95407.56	522372.4	2035	1.19e+07
School census variables, by school type					
Schools per 1 million	5600	1559.168	858.2001	290.3039	6707.122
Fed. schools per 1 million	5600	1.50474	6.170856	0	74.38262
State schools per 1 million	5600	196.6105	176.5064	0	2527.123
Mun. schools per 1 million	5600	1231.57	844.8685	64.75831	6110.564
Priv. schools per 1 million	5600	129.4828	109.0766	0	736.4674
Staff per 1 million	5600	31090.02	8773.957	12251.52	116457.70
Staff per 1 million, fed. schools	5600	144.9188	679.6719	0	15001.15
Staff per 1 million, state schools	5600	7665.608	4301.431	0	34304.32
Staff per 1 million, mun. schools	5600	20563.87	9141.39	3198.362	106931.30
Staff per 1 million, priv. schools	5600	2715.626	2640.788	0	18785.82
Classrooms per 1 million	5600	7778.898	1999.828	2606.203	33244.29
Classrooms per 1 million, fed. schools	5600	26.023	110.2848	0	1380.657
Classrooms per 1 million, state schools	5600	1616.396	1007.109	0	10768.34
Classrooms per 1 million, mun. schools	5600	5067.072	1985.301	521.2406	30770.75
Classrooms per 1 million, private schools	5600	1069.406	993.3236	0	5778.352
School characteristics, municipal schools					
Proportion of schools with:					
Filtered water	5600	56.55247	47.01146	0	100
Internet	5555	42.67355	32.95613	0	100
Broadband internet	4834	48.88888	39.01067	0	100
Science lab	5600	1.655076	4.486278	0	45.65217
Computer lab	5600	27.66183	24.52709	0	100
Library	5600	22.04114	19.5332	0	100
Electricity	5600	96.96904	10.36724	5.940594	100
Gym	2800	17.17247	17.81318	0	100
Computers	4200	53.21981	32.77557	0	100
Meals	5600	99.21899	4.308814	0	100
Free activities	4900	15.36366	21.34031	0	100
Special education activities	4200	8.818258	13.23862	0	100
Teacher characteristics, municipal schools					
Denominator is all municipal educational staff:					
Prop. staff that are teachers	5577	81.0957	30.82678	0	100
Denominator is all municipal teachers:					
Prop. science teachers	5412	33.81461	15.12684	0	91.04478
Prop. language teachers	5412	33.34967	14.82046	0	90.47619
Prop. arts teachers	5412	39.99647	16.55611	0	95.61753
Prop. male	5412	22.50389	12.88674	0	100
Prop. young (less than 40 years old)	5412	57.77947	16.76476	0	100
Prop. white	5412	34.62068	27.23265	0	100

Notes: summary statistics are calculated at the municipality–year level from 2007 to 2014, for the 1,028 Brazilian municipalities that receive oil royalties at some point during this sample period. All school characteristics variables have values that range from 0 to 100. Oil royalties per capita are measured in 2013 Brazilian reals, converted from nominal reals using the Brazilian CPI from FRED.

choose to stop their education and enter the labour market; (Mosquera, 2022) is one example of a paper that argues in favour of this mechanism, finding that oil shocks reduced college completion in the US and correspondingly increased low-skilled employment. Conversely, oil shocks can induce individuals to obtain more education if the oil sector's jobs require higher education or if more income leads to better investment in human capital for children of oil workers. The latter mechanism is backed by a substantial literature linking higher family income to educational attainment of their children, such as Acemoglu and Pischke (2001).

In addition to any direct effects on the choices that individuals and families make about education, oil shocks can also affect educational attainment via their impacts on the provision of education. These effects can also be positive or negative. On the one hand, ceteris paribus, better provision of education should improve access to schooling and educational outcomes because additional resources such as more classrooms, staff, and teachers should, all else being equal, improve the quality of education. In addition to being fairly intuitive, this mechanism is well supported by the literature; one example of a paper that links school resources to student achievement is Hægeland et al. (2012).

On the other hand, an expansion of education provision may not operate on the same set of students that are already in schools, before the oil shock. For example, if extra schools and classrooms induce marginal students with lower chances of success and graduate to attend school, pass rates and other student outcomes could actually be worsened while improving access to schooling. In order to illustrate this mechanism, we highlight one possible difference in students: their socio-economic status. A large quantity of research has studied whether families' socio-economic status affects educational attainment for children. If the expansion of schooling provision disproportionately benefits students from less privileged backgrounds, the change in student composition might mechanically induce a decrease in means for student outcomes even if individual students are each better off.

In our setting of Brazil, direct mechanisms should not come into play because oil royalties are based on the allocation of oil money from specifically defined formulae, and not local economic conditions. This still leaves the effects of provision itself, however. Because there are two countervailing effects and it is not clear which of the two dominate, this question is an empirical issue that we will be able to address with the student outcome data later in our paper.

Similarly, even if higher oil royalties increase expenditures in education and increase the number of teachers hired, the effect on the composition of teachers is not clear. There is very little known about how oil and natural resource shocks affect the composition of teachers. The most relevant paper in this area is Marchand and Weber (2020), who find that shale booms in the US led to worsened teacher quality as teachers left their jobs for higher paying jobs in the private sector; this then led to worsened student outcomes. Without this direct effect on local labour markets, however, oil booms' effects on teacher composition become even less obvious. On the one hand, if better funding in education leads to more attractive employment prospects in education, teachers with better education, who teach more difficult subjects like math, and men (who are underrepresented in teaching in Brazil) might be induced to enter the profession. On the other hand, as in the case with students, additional funding may induce only marginal candidates to become teachers; in this story, the additional funding from oil royalties would reduce the overall quality and selectivity of teachers. The overall effect of oil royalties on teacher composition is, therefore, ambiguous theoretically.

We evaluate these competing mechanisms and channels through which oil royalties affect education provision and attainment using our econometric analysis.

4. Empirical methodology

Using our data, we estimate regressions of the following form:

$$y_{mt} = \beta_0 + \beta_1 \text{oil royalties p.c.}_{m,t-1} + \gamma_m + \alpha_t + \epsilon_{mt}. \quad (1)$$

Here, y_{mt} represents an outcome of interest for municipality m and year t, such as schools per one million people, staff per one million people, and classrooms per one million people.[16] The coefficient of interest is β_1, the coefficient for the oil royalties per capita variable, oil royalties p.c.$_{m,t-1}$. More specifically, oil royalties per capita is defined as

$$oil royalties p.c._{m,t-1} = \frac{oil royalties_{m,t-1}}{population_{m,t}}.$$

We regress the outcome variables against a lagged (by one year) oil royalties variable, to allow for the adjustment in municipal revenues to translate into changes in outcomes in educational provision. We then normalize the oil royalties by population to facilitate comparisons across municipalities of varying sizes, and to help account for the fact that population is factored into oil royalties allocation by ANP.[17] We also include municipality fixed effects γ_m and year fixed effects α_t, focusing on within-municipality variation. In some robustness checks we further include state–year fixed effects.[18] We cluster standard errors at the municipality level.

As previously mentioned, we have only population estimates at the municipal level and not any other demographic characteristics because our sample period includes only one wave of the decennial Brazilian census. We use population instead of pupils or students for three main reasons. First, if municipal student enrolment is endogenously responding to the oil royalties shocks, then we may confound responses in both the numerator and denominator of our schooling provision measures. In addition, if schooling provision is actually increasing, this should mechanically also cover more students in municipalities as the number of schools, classrooms, and teachers increases. In this case, a

Fig. 2. Brazilian municipalities that receive some oil royalties from 2007 to 2014.

null finding could simply be that the ratio of schools to students has not changed, but the provision of education overall has increased. Finally, we aim to facilitate comparisons of our results with those of Caselli and Michaels (2013), who also use population based per capita measures.

Our main specifications use data on municipalities at an annual level from 2007 to 2014. In our main sample, we focus only on municipalities that received oil revenues at some point from 2006 to 2013, keeping in mind the one-year lag for the oil royalties we impose. This allows us to avoid selection issues in comparing municipalities that receive oil revenues to those that do not, and is also a necessity given our within-municipality specifications. As stated earlier, we also focus only on municipalities that have constant boundaries. We have a total of 700 municipalities in Brazil that receive oil revenues during our sample period and have constant boundaries, giving us a balanced panel of 5600 observations in our main sample.[19]

By focusing on a within-municipality specification, one might be concerned that we are removing all meaningful variation in oil royalties allocated to municipalities. We note that even though the proportions with which certain municipalities receive royalties from different oilfields, variation across time and oilfields can give different municipalities varying amounts of royalties during our sample period. For example, if the royalties for a particular municipality are derived from the production in one oilfield and that oilfield shuts down production, that municipality would experience a reduction (to zero) of its royalties. Conversely, if an additional oilfield begins or increases production close to a municipality, that municipality would receive increased royalties relative to other municipalities which do not receive royalties from this other oilfield.

Fig. 2 displays the municipalities in our sample. These are the municipalities that at some point between 2007 and 2014 received oil royalties as mandated by legislation. The map shows that the majority of oil municipalities are those close to the coast. This reinforces the importance of our within-municipality specifications because it is unlikely that non-oil municipalities would serve as a reasonable control group for oil municipalities.

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[16] We will refer to these per-one-million-people variables interchangeably as per capita variables, for ease of exposition.

[17] Annual municipal population estimates published by the Brazilian statistical agency (IBGE) do not respond to changes in municipal oil royalties during period under study in this paper.

[18] In Brazil, municipalities are equivalent to US counties. Multiple municipalities form a state. Brazil has over 5500 municipalities, divided over 26 states and a federal district that includes the national capital, Brasilia.
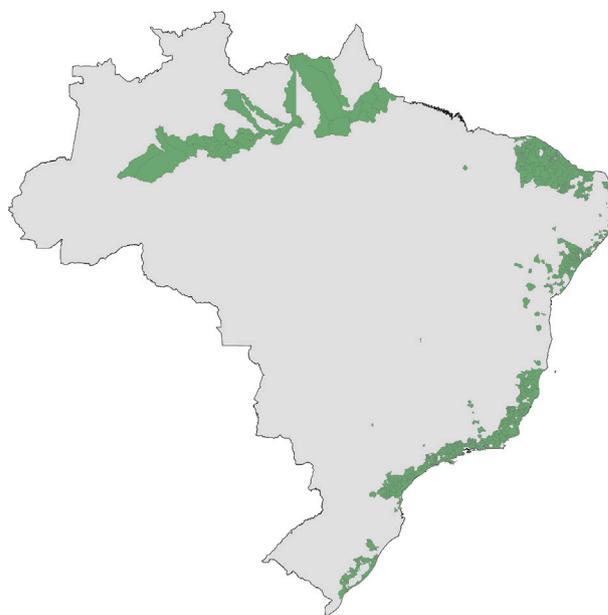
[19] In some specifications, the sample size is slightly smaller due to missing data for some schools. One example of this occurs in the infrastructure results.

Table 2

Oil royalties and education expenditures.

Dependent variable:	(1) Education expenditures per capita	(2) Education expenditure share
Royalties per capita	0.276***	−0.00102
	(0.0870)	(0.000814)
Observations	3937	3937
R^2	0.914	0.845

Notes: *** denotes 1% significance, ** denotes 5% significance, * denotes 10% significance. Standard errors are clustered at the municipality level. Royalties per capita are in 2013 Brazilian reals, converted from nominal reals using the Brazilian CPI from FRED, while the dependent variables are the total municipal education expenditures per capita, in 2013 Brazilian reals, while in column (2) it is the share of total municipal expenditures made up by education. All regressions include municipality and year fixed effects.

5. Results

5.1. Main analysis

5.1.1. Municipal schooling expenditures

In our analysis, the mechanism through which oil royalties affect schooling provision is through increased resources for expenditures on education. To verify this mechanism, in Table 2, we first present regression results where the dependent variables are the per capita education municipal expenditures and the educational expenditure share. We have data on municipal expenditures only up to 2012, and the data do not cover 100% of municipalities in our sample, but we still find very informative results. The coefficient on the oil royalties variable in column (1) shows that, as expected, an increase to royalties per capita is associated with higher levels of educational expenditures per capita. This confirms that municipalities do spend more on education when receiving oil royalties. In column (2), we instead look at the share of total expenditures made up by education. Interestingly, this is not affected by oil royalties, suggesting that oil windfalls can benefit potentially other public goods provision other than education. We focus on education for a variety of reasons: better measurement, high-quality data, and the importance of education.

5.1.2. Main educational provision results

We next present the results of our analysis on the relationship between schools per million inhabitants and royalties per capita, using the specification from the prior section. The regression results are summarized in Panel A of Table 3. Each column of Panel A shows the results for a different regression on a different sample of schools; column (1) shows the results for all schools, while columns (2) to (5) show the results for federally funded, stated-funded, municipally funded, and private schools, respectively.

The results from column (1) in Panel A of Table 3 show that higher levels of oil royalties per capita is associated with higher levels of schools per one million inhabitants; more specifically, one additional real per capita in royalties is associated with 0.0267 more schools per one million inhabitants. Using the summary statistics from Table 1, this implies that a one standard deviation increase in royalties per capita is associated with an approximately 13.16 more schools per million inhabitants. In the rest of the columns, we then analyse the association between oil royalties and schools by school type. We show that oil royalties are significantly positively associated with more schools for municipally funded schools. The coefficients on the other school types (federal, state, private) are all small in magnitude, statistically insignificant, and relatively precisely estimated. In contrast, column (4), which uses only municipally funded schools, shows a similar magnitude, sign, and level of significance to the overall schools effect from column (1).

Our mechanism through which schooling provision is affected by oil revenues is through the additional municipal funding provided by the legislatively mandated royalty sharing from Petrobras. The fact that municipally funded schools seem to be driving our main results is reassuring for our identification strategy. If higher levels of oil royalties

Table 3

Effect of oil royalties on education provision.

School type:	(1) All	(2) Federal	(3) State	(4) Municipal	(5) Private
Panel A: Schools per million					
Royalties per capita	0.0267**	1.11e−05	−0.00554	0.0328**	−0.000592
	(0.0126)	(0.000474)	(0.00650)	(0.0163)	(0.00170)
Observations	5600	5600	5600	5600	5600
R^2	0.936	0.752	0.906	0.939	0.898
Panel B: Staff per million					
Royalties per capita	1.633***	−0.00282	0.0191	1.559***	0.0570
	(0.444)	(0.0249)	(0.132)	(0.524)	(0.0895)
Observations	5600	5600	5600	5600	5600
R^2	0.848	0.745	0.921	0.887	0.941
Panel C: Classrooms per million					
Royalties per capita	0.172***	−0.00193	−0.0212	0.220***	−0.0248
	(0.0487)	(0.00571)	(0.0276)	(0.0675)	(0.0192)
Observations	5600	5600	5600	5600	5600
R^2	0.866	0.822	0.919	0.901	0.947
Panel D: Students per million					
Royalties per capita	4.355*	−0.0212	−1.709	6.679***	−0.593
	(2.428)	(0.153)	(1.869)	(2.457)	(0.414)
Observations	5600	5600	5600	5600	5600
R^2	0.841	0.856	0.929	0.921	0.953

Notes: *** denotes 1% significance, ** denotes 5% significance, * denotes 10% significance. Standard errors are clustered at the municipality level. Royalties per capita are in 2013 Brazilian reals, converted from nominal reals using the Brazilian CPI from FRED, while the dependent variables are the schooling outcome variables per one million people. All regressions include municipality and year fixed effects.

per capita within municipalities were also occurring contemporaneously with higher local demand for schooling, for example, we would expect that other types of schools, particularly private schools, would also have a positive association with oil royalties. Because we do not find that this is the case, and in fact find that only municipally funded schools are driving our main results, we are, therefore, more confident that additional municipal revenues derived from higher oil royalties translate into more schools per million inhabitants for oil municipalities.[20] The fact that federal or state-funded schools per million do not decline in a statistically or economically significant manner suggest that there is no corresponding offsetting decrease in federal or state-level education funding in response to this increased municipal spending.

We use the same main specification and sample and analyse the relationship between oil royalties and staff per capita. This variable,

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[20] This also helps us rule out the potential that changes in the denominator, population, could be driving our results. If this were the case, then the coefficients across all three school types would be significant because all three use the same denominator. Given that this is not the case, it must be that changes to schooling provision are driving our results instead. In a later robustness check, we also include a control for population and show that our main results remain robust to its inclusion, further ruling out this possibility.

reported in the school census, captures both teachers and other school staff. Consistent with the results from the prior table, we also find that oil royalties per capita is positively associated with more staff per million inhabitants (Panel B of Table 3). A 1 real increase in oil royalties per capita is associated with a 1.633 increase in staff per million inhabitants; this is equivalent to a one standard deviation increase in oil royalties per capita being associated with an approximately 804.93 increase in staff per million inhabitants. As in the school results, we find here that the staff increases are driven principally by staff in municipally funded schools; only the municipal staff respond statistically significantly to oil royalties per capita.

We next examine whether classrooms per capita responds to increases in oil royalties. These estimates are presented in Panel C of Table 3. We again find that higher oil royalties per capita are associated with more classrooms per million inhabitants. From column (1), a 1 real increase in oil royalties per capita is associated with a 0.172 increase in classrooms per million inhabitants. This is equivalent to a one standard deviation increase in royalties per capita being associated with 84.78 more classrooms per million inhabitants. As with schools and staff, this is driven by classrooms in municipally funded schools (column (4)); there is no statistically significant association with classrooms in federal, state, or private schools.

We next present the analysis on the relationship between students per million inhabitants and royalties per capita, using the same specification from the prior sections. We construct variables related to total annual municipal student enrolment by school type by using the student-level data from the school census. The regression results are summarized in Panel D of Table 3. We show that the same pattern of results observed in the last three sections holds for student enrolment as well. Oil royalties are significantly positively associated with more students enrolled in schools. This increase is driven by higher enrolment in municipally funded schools, but not in schools funded by the state or federal governments (whose coefficients are negative, small in magnitude, and statistically insignificant). Column (4) shows that a 1 real increase in oil royalties per capita is associated with a 6.68 students per million inhabitants increase for municipal schools; this is equivalent to a one standard deviation increase in oil royalties per capita being associated with approximately 3293 more students per million inhabitants. We also see some evidence of potential substitution between private and municipal schools in column (5); though the magnitude by which student enrolment is dropping in private schools is one twelfth of the magnitude of increase observed for municipal schools.

The main analyses here with the four outcome variables serve to help jointly demonstrate that, in contrast to Caselli and Michaels (2013), oil royalties provided to Brazilian municipalities do not necessarily fail to translate to better provision of schooling. They also provide supportive evidence for the main mechanism highlighted in the conceptual framework, where government transfers (oil royalties) increase resources available for education provision.

5.1.3. Results by type of school

In Table 4, we focus on municipal schools, motivated by our findings in Table 3. The school census data allow us to divide schools into three levels: preschool, elementary school, and high school. These schooling levels are described briefly in the prior section. In our sample, the mean proportion of schools within oil municipalities during our sample period that offer preschool is 69%, the mean proportion of schools that offer elementary school is 80%, and the mean proportion of schools that offer high school is less than 1%.[21] In Table 4, we then break down the municipal schools results from column (4) in Table 3 into the

Table 4
Effect of oil royalties on education provision, by school level.

School level:	(1) Preschool	(2) Elementary school	(3) High school
Panel A: Schools per million			
Royalties per capita	0.0262***	0.0247*	0.000598
	(0.00850)	(0.0140)	(0.00108)
Observations	5600	5600	5600
R^2	0.907	0.943	0.523
Panel B: Staff per million			
Royalties per capita	1.088***	1.221***	0.0782
	(0.360)	(0.460)	(0.0652)
Observations	5600	5600	5600
R^2	0.856	0.899	0.616
Panel C: Classrooms per million			
Royalties per capita	0.148***	0.146**	0.00887
	(0.0442)	(0.0708)	(0.0112)
Observations	5600	5600	5600
R^2	0.867	0.907	0.591
School type:	Municipal	Municipal	Municipal

Notes: *** denotes 1% significance, ** denotes 5% significance, * denotes 10% significance. Standard errors are clustered at the municipality level. Royalties per capita are in 2013 Brazilian reals, converted from nominal reals using the Brazilian CPI from FRED, while the dependent variables are the schooling outcome variables per one million people. All regressions include municipality and year fixed effects.

three school types. We find that our results are driven by preschools and elementary schools, but not high schools. The magnitudes of the coefficient on oil royalties per capita for all three outcome variables are similar for preschools and elementary schools, but are much smaller and statistically insignificant for high schools.

The fact that our results are concentrated amongst preschools and elementary schools is important in the context of Brazil because evidence suggests that Brazil's basic education seriously lags behind comparable nations. The Council on Foreign Relations, in a blog post,[22] argues that a key contributor to Brazil's poor performance in PISA standardized testing is overspending at the postsecondary level and resulting underspending at the basic levels of education. The results in Table 4, therefore, suggest that oil royalties may help narrow the gap faced between Brazil and other countries in basic education and alleviate the distorted spending patterns seen in the Brazilian educational system.

The richness of our data allows us to further disentangle which types of municipal schools are driving our main results. Specifically, we have data on the location of the school, such as whether they are located in their own school building, another school, in a business, in the teacher's house, and so on. We do this to tackle concerns that Brazilian municipalities could simply be spending the money from oil royalties by adding potentially lower-quality additions to existing schools or even other buildings instead of building new schools. To ease interpretation, we categorize the possible locations into three categories: their own school building, another school, and other. We report these results in Table 5. The analysis shows that, across schools, staff, and classrooms per million, the main results in Table 3 are clearly driven by schools within their own school building. Specifically, the coefficients for schools in their own building are of similar magnitude to the main results and are statistically significant; in contrast, the coefficients for the other location types are very small in magnitude and statistically insignificant. One feature of the data to keep in mind is that, in our sample, approximately 81.67% of municipal schools are located in their own building. Nonetheless, these results imply that the oil revenues are being spent on improving schooling coverage in a

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[21] It is important to note that these levels do not necessarily have to be separated by school: in our data, we observe a significant degree of overlap, i.e., schools that house multiple levels of schooling.

[22] See "Public Education in Brazil", available at www.cfr.org/blog/public-education-brazil.

Table 5
Effect of oil royalties on education provision, by school location.

School location:	(1) Own building	(2) Other school	(3) Other
Panel A: Schools per million			
Royalties per capita	0.0306**	−0.00284	0.00199
	(0.0145)	(0.00705)	(0.00583)
Observations	5600	5600	5600
R^2	0.931	0.731	0.741
Panel B: Staff per million			
Royalties per capita	1.532***	−0.275	0.0487
	(0.435)	(0.266)	(0.159)
Observations	5600	5600	5600
R^2	0.870	0.727	0.457
Panel C: Classrooms per million			
Royalties per capita	0.227***	−0.0346	−0.00568
	(0.0600)	(0.0452)	(0.0259)
Observations	5600	5600	5600
R^2	0.890	0.696	0.465
School type:	Municipal	Municipal	Municipal

Notes: *** denotes 1% significance, ** denotes 5% significance, * denotes 10% significance. Standard errors are clustered at the municipality level. Royalties per capita are in 2013 Brazilian reals, converted from nominal reals using the Brazilian CPI from FRED, while the dependent variables are the schooling outcome variables per one million people. All regressions include municipality and year fixed effects.

longer term sense, and not simply converting sheds and teachers' homes into extra classrooms.

5.1.4. Student inputs

It is clear that schools, staff, classrooms, and students are highly correlated. In other words, more students, by necessity, will require more schools, and more staff will involve the availability of extra classrooms in existing schools for students in affected municipalities. We, therefore, combine our student enrolment data from the student-level school census with the school-level and teacher-level data to construct the following educational inputs related to class size and school capacity: (i) student–teacher ratio, (ii) student–classroom ratio, and (iii) student–school ratio. This will help determine whether the per-student educational resources are increasing.

Table 6 presents the results of our analysis on the relationship between input per students and royalties per capita, using the same specification from the prior sections. The coefficient on student–teacher ratio is positive, suggesting that student enrolment grows at a higher rate than teachers, but the estimate is statistically insignificant. The coefficients on student–classroom ratio and student–school ratio are all small and imprecisely estimated. Therefore, we do not find strong statistically significant evidence that oil royalties have an effect on any of the three different input measures considered. These results are a potential explanation for our findings on slightly worsening student outcomes as captured by the pass rate, the failure rate, and the dropout rate. The implications are discussed further in Sections 5.4 and 5.5.

5.1.5. School infrastructure and activities

We also examine whether mean levels of municipal school amenities and services are affected by oil royalties. While schooling infrastructure in the form of inadequate libraries, science labs, and computer facilities remains a challenge in Brazil, the consensus is that this predominantly applies to secondary schools (which are run almost exclusively by state governments). A total of 40% of all Brazilian secondary schools are considered "dropout factories" because a majority of students enrolled in these schools fail to graduate. However, given that municipal governments are chiefly in charge of primary schools, we do not expect to see a large response in primary schooling infrastructure indicators to increases in oil royalty revenues.

We regress our oil royalties measure against the proportion of municipally funded schools in each municipality that have the following infrastructure-related features: libraries, science labs, computer labs, gyms, internet access, broadband internet access, filtered water, and electricity. The results presented in Table 7 provide some evidence, albeit weak, that schooling infrastructure is affected by oil royalties. Although higher oil royalties increase the proportion of schools with access to filtered water and libraries, it statistically significantly decreases the proportion of schools with computer labs and electricity. There is no statistically significant relationship between oil royalties and the presence of science labs, gyms, broadband or regular internet access in municipal schools within affected municipalities. The presence of positive and negative coefficients, combined with the relatively small magnitudes and marginal statistical significance of the significant coefficients, suggest that there is no clear overall positive or negative effect of oil royalties on school infrastructure. In Table 8, we turn to analysing the proportion of municipal schools who provide the following services: meals, special education services, and free activities. We find that schools in municipalities with higher oil royalties per capita are statistically less likely to offer free activities or meals, although again the magnitudes are relatively small and the coefficient for meals is significant only at the 10% level.

The results in this subsection provide some evidence that, although the provision of schooling is increasing overall, some of this expansion could be impacting the quality of this provision. Specifically, schools may be less likely to have electricity and are less likely to have free activities and have meals provided. An important caveat to these results, however, is that the infrastructure results are mixed in both sign and statistical significance. These findings nonetheless imply that the additional marginal coverage provided could potentially be of lower quality than pre-existing education provided without oil royalties.

5.2. Teacher results

To determine whether oil royalties could be driving changes to teachers' composition, we use data at the teacher level. We briefly discuss our findings here, and relegate more in-depth discussion of these results to the online Appendix.

In short, we find that the staff results in the main analysis is driven by hiring of teachers, and not other types of support staff (Table A9). In contrast, we do not find that there is significant heterogeneity in terms of the types of subjects taught by teachers (Table A10) or by teachers' demographics (Table A11). We therefore conclude that, on balance, all types of teachers are being hired due to oil royalties, with little evidence that teacher composition is changing in a meaningful way.

5.3. Student outcomes

One natural question to ask is whether this improvement in schooling provision has an effect on student outcomes. The direction of the effects is ex ante ambiguous. It is possible that expanded access to schooling may be associated with declines in student outcomes in the short to medium run. Such findings have been documented in Brazil by Bruns et al. (2011). They report that the rapid expansion of primary schools in Brazil in the second half of the 1990s also coincided with a decline in average learning levels during the same time—a trend that began to reverse from 2005. They attribute these results to selection effects—access to schooling also led to increased enrolment of academically unprepared students.

We make use of Brazilian education ministry (INEP) data, which provide mean outcomes for a variety of student-level outcomes for each municipality–year. We focus on data from municipally funded schools, as we do in our main analysis, as well as students in elementary

Table 6

Effect of oil royalties on inputs per student.

	(1) Student–teacher ratio	(2) Student–classroom ratio	(3) Student–school ratio
Royalties per capita	0.0189	−0.000361	0.000293
	(0.0189)	(0.000474)	(0.00152)
Observations	5412	5600	5600
R^2	0.2367	0.8480	0.9368

Notes: *** denotes 1% significance, ** denotes 5% significance, * denotes 10% significance. Standard errors are clustered at the municipality level. Royalties per capita are in 2013 Brazilian reals, converted from nominal reals using the Brazilian CPI from FRED. All regressions include municipality and year fixed effects.

Table 7

School infrastructure.

Proportion of schools with:	(1) Library	(2) Science lab	(3) Computer lab	(4) Gym
Royalties per capita	0.00158***	7.83e−05	−0.00145*	−7.55e−05
	(0.000509)	(0.000234)	(0.000810)	(0.000792)
Observations	5600	5600	5600	2800
R^2	0.767	0.831	0.756	0.947

Proportion of schools with:	(5) Internet	(6) Broadband internet	(7) Filtered water	(8) Electricity
Royalties per capita	0.00169	−0.00179	0.000741*	−0.000315***
	(0.00160)	(0.00136)	(0.000433)	(0.000116)
Observations	5555	4834	5600	5600
R^2	0.729	0.789	0.937	0.864

Notes: *** denotes 1% significance, ** denotes 5% significance, * denotes 10% significance. Standard errors are clustered at the municipality level. Royalties per capita are in 2013 Brazilian reals, converted from nominal reals using the Brazilian CPI from FRED, while the dependent variables are the schooling outcome variables per one million people. All regressions include municipality and year fixed effects.

Table 8

School-provided services.

Proportion of schools with:	(1) Meals	(2) Special ed. programs	(3) Free activities
Royalties per capita	−0.000403*	0.000181	−0.00209**
	(0.000227)	(0.000687)	(0.000821)
Observations	5600	4200	4900
R^2	0.244	0.732	0.651

Notes: *** denotes 1% significance, ** denotes 5% significance, * denotes 10% significance. Standard errors are clustered at the municipality level. Royalties per capita are in 2013 Brazilian reals, converted from nominal reals using the Brazilian CPI from FRED, while the dependent variables are the schooling outcome variables per one million people. All regressions include municipality and year fixed effects.

Table 9

Student outcomes.

Outcome:	(1) Pass rate	(2) Fail rate	(3) Dropout rate
Royalties per capita	−0.000861***	0.000660***	0.000201*
	(0.000224)	(0.000219)	(0.000116)
Observations	5598	5598	5598
R^2	0.854	0.813	0.818

Notes: *** denotes 1% significance, ** denotes 5% significance, * denotes 10% significance. Standard errors are clustered at the municipality level. Royalties per capita are in 2013 Brazilian reals, converted from nominal reals using the Brazilian CPI from FRED. All regressions include municipality and year fixed effects. All student outcome variables are for only students in municipal elementary schools.

schools.[23] We specifically examine whether oil royalties have an effect on the following three variables: the pass rate, the failure rate, and the dropout rate.

In Table 9, we show that increases in per capita oil royalties actually seem to worsen student outcomes. This can be seen by the statistically significant negative effect on the pass rate (column (1)) as well as the statistically significant positive effect on the fail rate (column (2)) and dropout rate (column (3)). One explanation is that oil royalties improve the coverage and provision of schooling, but that as coverage increases, the composition of students changes and changes the mean outcomes of students in affected municipalities, as discussed in Bruns et al. (2011) and in our conceptual framework section.

Moreover, as documented previously, we do not find any evidence that oil royalties have a statistically significant effect on any of the three different student input measures that the literature on education

considers important determinants of student performance. Our findings are also consistent with earlier work by Haddad et al. (2017), who show that educational spending in Brazil is only weakly correlated with student test scores. Finally, in earlier results (Tables 7 and 8), we found that some aspects of schooling infrastructure and school services like electricity or free activities were less likely to be present in schools whose municipalities received more oil royalties; this decline in the proportion of schools that have these characteristics may also have contributed to the worsened student outcomes. Nonetheless, we do not have strong evidence of mechanisms behind the worsened student outcomes against the backdrop of improving educational provision, and the worsened student outcomes remains a puzzle for future research.

5.4. Heterogeneity by school location

In this subsection, we very briefly discuss the supplementary analyses conducted with respect to heterogeneous effects by school location. For the tables and a more thorough discussion of results, see the online Appendix.

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[23] This is because the high school variables have many more missing observations. Preschools do not report any student outcome data.

First, in Table A14, we examine our main results but split municipalities by rural versus urban; we find some weak evidence that new schools may be driven by oil royalties in rural areas, although the precision of the estimates makes a definitive conclusion along these lines infeasible. We also explore whether increases to schooling provision are different in old versus new schools in Table A15; we find that classrooms, staff, teachers, and students all increase in existing schools while new schools do not seem to have a change to classrooms, staff, or students per million. This table therefore suggests that while new schools are an important way in which educational provision is increased, the expansion of older schools is also a channel through which oil royalties affects schooling provision.

5.5. Robustness checks and additional results

In this subsection, we briefly outline a series of robustness checks. For a fuller discussion of these checks as well as the tables themselves, we refer readers to the online appendix. First, Table A1 of the online appendix shows that oil royalties have no statistically significant relationship with federal and state transfers or total municipal taxes (column (2)), but Column (3) shows that every additional real of oil royalties is associated with a statistically significant increase in total reported municipal expenditures by 1.19 reals (not statistically different from 1), which shows that oil royalties have a direct effect on municipal expenditures. Turning to the robustness of our main analysis, we find that our main results are robust to the inclusion of state–year fixed effects (Table A16 of the online appendix), the inclusion of logged population as a control variable (Table A17), dropping individual years one at a time from our sample (Table A18), adding all other coastal municipalities that do not receive oil royalties but have constant boundaries (Table A19), two-way clustering standard errors by municipality and year (Table A20), and clustering errors by microregion (Table A21). In Table A3, we construct family of outcome measures for education provision (by school type) as well as school infrastructure and school activities for municipal schools.[24] Table A3 reports the results of regressions where each of these family of outcome measures are the dependent variable. These results corroborate our findings in the main tables. In Table A22, we limit our sample to only those municipalities that receive offshore oil royalties as in Caselli and Michaels (2013) and construct a similar offshore oil output measure to them for use as an instrumental variable. We find that, despite the lack of statistically significant coefficients due to a lack of precision, using only variation in offshore oil output as in Caselli and Michaels (2013) produces results consistent with our main analysis. We also take our subsample of offshore output municipalities from Table A23 of the online appendix and estimate whether these municipalities have a differential effect of oil royalties on education and do not find a meaningfully large or significant differential impact of oil royalties in offshore municipalities, suggesting that our main results are not subject to major issues owing to the source of variation for our oil royalties measure. For student outcomes, we check whether outcomes are affected differentially by gender in Table A2, finding no difference. For our schooling infrastructure and services results, we show that restricting the school level to elementary and preschool only does not affect our main findings, suggesting that our infrastructure and services results are not driven by a compositional change in schooling levels. Finally, in Tables A12 and A13, we use two different measures of

corruption[25] and do not find meaningful evidence that corruption could be mitigating the effects that we find in the main analysis.

6. Conclusion

In this paper, we analysed the relationship between oil royalties transferred to Brazilian municipalities and those municipalities' provision of education. Our results showed that there is a statistically significant, but economically modest increase in the provision of education in terms of schools, school staff, and classrooms per million inhabitants. These increases are also moderated somewhat by the fact that student outcomes, on average, worsen and some schooling infrastructure and services are less likely to be provided. The worsened student outcomes suggest that one fruitful avenue for further research is to explore why student outcomes are worsening when expansions to educational provision occur. In particular, if the mechanism at play is one not specific to the Brazilian context, then this implies that investments to educational provision may generate unintended consequences in student achievement.

Our work is more optimistic that oil revenues can benefit public goods provision, relative to Caselli and Michaels (2013) and Ferraz et al. (2012). Like these two sets of authors, however, the relatively modest magnitudes suggest that corruption and misappropriation of public funds towards education could be playing a role in limiting the extent to which the public is benefitting from allocated funds for education and other municipal services. We do conduct some secondary analyses and do not find evidence that there are heterogeneous effects by municipal-level corruption, but we nonetheless cannot rule out the fact that corruption could be present and explaining some of the magnitude of our results.

The fact that our results are concentrated amongst municipal preschools and elementary schools shows that oil royalties' impact on education is concentrated in the more basic levels of education. Given Brazil's below-average performance in basic education indicators such as performance in PISA testing and its overspending on its tertiary education, our paper, therefore, provides one mechanism through which this underperformance could be alleviated. If basic education provision, relative to postsecondary education, disproportionately benefits the poor then oil windfall-driven education provision improvements should also help reduce educational inequality. The additional fact that our main results are driven by schools located in their own building suggests that the oil revenues are being spent on schooling provision that is not temporary. Our paper, therefore, provides hope that oil royalties can improve education provision in Brazil and serve as a counterexample to the natural resource curse.

CRediT authorship contribution statement

Jeff Chan: Conceptualization, Validation, Formal analysis, Data curation, Investigation, Writing – original draft, Writing – review & editing. **Ridwan Karim:** Conceptualization, Validation, Formal analysis, Data curation, Investigation, Writing – original draft, Writing – review & editing.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.econedurev.2022.102351.

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[24] We construct these measures by constructing an index that standardizes all component variables and adds the components as in Kling et al. (2007). School provision indices were constructed for each of the four types of schools by using the following components: schools, staff, classrooms, and total students enrolled. For school infrastructure in municipal schools, the component variables are library, science laboratory, computer laboratory, gym, internet, broadband, filtered water, and electricity access. For school activities, the component variables are: meals, special education, and free activities.

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[25] From Bobonis et al. (2022) and Ferraz and Finan (2011).

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