The value of redistribution: Natural resources and the formation of human capital under weak institutions☆

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Abstract: We exploit time and spatial variation generated by the commodities boom to measure the effect of natural resources on human capital formation in Peru, a country with low governance indicators. Combining test scores from over two million students and district-level administrative data of mining taxes redistributed to local governments, we find sizable effects on student learning from the redistribution. However, and consistent with recent political economy models, the relationship is non-monotonic. Based on these models, we identify improvements in school expenditure and infrastructure, together with increases in health outcomes of adults and children, as key mechanisms explaining the effect we find for redistribution. Policy implications for the avoidance of the natural resource curse are discussed.

Keywords: Natural resource booms
Academic achievement
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1. Introduction

A long-standing question in the economics literature explores whether natural resource abundance is a curse or a blessing. The recent commodities boom has brought back this discussion. While the impact of such a boom on aggregate economic growth has been explored elsewhere,1 the study of the linkages between the abundance of natural resources and human capital formation still requires deeper analysis. For instance, cross-country correlations indicate a negative relationship, suggesting that natural capital crowds out human capital (Gylfason, 2001; Birdsall et al., 2001).2 As shown in Fig. 1, there is a strong negative association between a country’s reliance on natural resources and its performance on international standardized tests.

Along these lines, within-country studies using microeconomic data exploit a single-commodity boom, such as coca in Colombia (Angrist and Kugler, 2008) and oil in Brazil (Caselli and Michaels, 2013), and document some positive but modest impacts of natural resource abundance on school attendance and attainment, as well as on literacy rates. While important, much remains to be done given the increasing emphasis on learning outcomes. Indeed, the quality of education in developing countries remains below par (Hanushek and Woessmann, 2010; Kremer et al., 2015). Furthermore, differences in the quality of education appear to be more important than access to education when explaining countries’ economic performance over the past fifty years (Hanushek and Woessmann, 2012). Thus, a pending question centers on whether natural resource abundance affects human capital accumulation beyond traditional measures, towards indicators such as those test scores used in Fig. 1.3

We address this gap by analyzing the impact of natural resource abundance on students’ math and reading skills in Peru, a mineral-rich middle-income country that consistently underperforms in the World Bank’s governance measures relative to its geographical and income-level counterparts (Kaufmann et al., 2011). Specifically, we inquire about the role of the redistribution of natural resource rents on learning

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2 There is also evidence that good political institutions can ameliorate this outcome (Kronenberg, 2004; Gylfason and Zoega, 2006).

3 Recent work by Bonilla (2020) focuses on a single commodity (gold in Colombia) and finds a negative effect on learning from this natural resource.
outcomes. In this regard, our study informs an ongoing debate about whether the provision of additional resources to public schools improves students’ learning outcomes (e.g., Hanushek, 2006; Glewwe and Kremer, 2006; Glewwe and Muralidharan, 2016; Jackson, 2018).

Peru offers a unique opportunity to evaluate this question. First, Peru has near-universal school enrolment yet it shows poor results in international achievement tests (see figures above) as well as in the national standardized tests such as the Evaluación Censal de Estudiantes (ECE). Improving students achievement is a major way to address the learning crisis in developing countries (World Bank, 2018; Busso et al., 2017). We use math and reading test scores from Peru’s ECE (2007–2012) for second graders as proxies for human capital accumulation, focusing on quality measures (output) rather than access (input).

Second, mining revenues constitute around half of the taxes collected by Peru’s central government and these revenues have been partially redistributed to local governments. This transfer is the result of the Canon Minero Law (from here on Canon), introduced in 2001. The law states that 50 percent of the income tax paid by mining companies to the central government must be redistributed to the regional and local governments located in the areas where minerals are extracted. This legal framework also establishes a redistribution-rule that grants transfers to governments located in the areas where minerals are extracted. Key to our identification strategy, the redistribution rule was defined prior to our period of analysis and has not been modified since. Thus, for a given district, we study the link between test scores and the year-by-year variation in transfers received by the district’s local government. To do so, we match a unique administrative dataset collecting the redistribution to each local governments with close to 2.1 million student records obtained from the national standardized test mentioned previously.

By conditioning on district fixed effects, and in additional specifications by province-by-year fixed effects as well, our parameter of interest is identified from district-specific deviations in transfers from the district averages after controlling for shocks common to all districts in a province. Given that the amount of Canon collected depends exclusively on external factors related to global trade (through the value of mining production, a variable included in our controls) and not due to local markets, it seems reasonable to presume that Canon fluctuations are orthogonal to unobserved determinants of test scores for second graders.

Our findings reveal that Canon transfers have a positive and statistically significant effect on math test scores. For the average district receiving a positive transfer, our estimates suggest an increase in math test scores of around 0.24 standard deviations. These effects are larger than most of the interventions using randomized controlled trials considered in Kremer et al. (2013). For reading, we find smaller (and sometimes negative) effects, but they are not statistically significant. These findings remain unchanged when considering several robustness tests, including controls for the value of mining production. Furthermore, two placebo tests validate our approach: a falsification exercise where we incorrectly assign Canon transfers of one district to a randomly selected district in the country, as well as a placebo test limiting the sample to private schools. As expected, both tests show no impact on students subject records obtained from the national standardized test previously.

Following the political economy literature (e.g., Caselli, 2015; and Caselli and Cunningham, 2009), we test for the presence of non-monotonic effects of Canon transfers. Resource booms could affect

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4 The country is consistently one of the worst performing nations in the Programme for International Student Assessment (PISA) that includes OECD and developing countries. Peru is also the second from the bottom among countries in the Latin American Laboratory for Assessment of the Quality of Education, performing only better than the Dominican Republic.

5 During the period of our analysis (2007–2012) the country exported over 127.9 billion US dollars in minerals. The sector accounts for nearly two-thirds of the value of the country’s exports. However, the country does not rely on just one mineral. Peru is one of the world top producers of silver, tin, zinc, copper and gold. Oil and gas are of little relevance (USGS, 2015). As a result, there is time and spatial variation in the value of mining production over a wide set of minerals (see Figure A1 and A2 in Appendix). Importantly as well, Peru’s mining sector is traditionally export oriented, since Colonial times (Dell, 2010), with most of its production being shipped directly overseas (Osinergmin, 2017).

6 During the period of analysis, the sum of Canon transfers was 8.9 billion US$. In 2012 alone, the central government transferred US$1.9 billion as Canon; six times the budget allocated to the country’s antipoverty conditional cash transfer program (Juntos) and 1.8 times the entire budget of the Ministry of Social Development, which is in charge of all welfare programs. Canon transfers also differ significantly even among the top recipients over our period of analysis. See Appendix Figure A2 for an example of this variation.
the behavior of the local incumbent in a non-monotonic fashion (Maldonado, 2020). Political competition rises as natural resource rents increase and this competition could work as a discipline device, creating incentives for investments in public goods provision such as human capital. At low rents levels, the outside option for potential politicians is higher than the rents they could extract while in office, so challenging the incumbent is less attractive and deters the entrance of a political competitor. In this scenario, incumbents can use Canon transfers to provide public goods (such as investing in human capital) because the lack of challengers disincentivize buying-off citizens’ electoral support or coercing political competition. This behavior continues even as more resources become available, as long as these rents are lower than the opportunity costs outside political office, so higher Canon rents still translate into more public goods investments. However, when natural resource rents are too high, the value of holding office increases so much that it dominates the opportunity cost of staying out of politics. This motivates potential politicians to challenge the incumbent. In this scenario, incumbents would prefer to reduce the investment in public goods and instead influence electoral outcomes by buying-off citizens’ electoral support and coercing political competition. This model would predict an inverted-U relationship between natural resource windfalls and public spending (e.g., public spending in education). This would be the key mechanism behind a non-monotonic relationship between natural resource rents and children educational outcomes. Only with large natural resource windfalls have detrimental effects on human capital—creating a natural resource curse.

We find evidence in favor of these predictions and document a non-monotonic effect on learning outcomes. We show that a quadratic model fits the data best compared to linear, cubic and quartic specifications. We use additional administrative data to explore some of the mechanisms behind our findings. For instance, we show that year-to-year variation in Canon transfers is associated with higher expenditure on education at the level of the local government, a result consistent with the aforementioned mechanism. We complement this with an analysis at the school level, where we find that Canon transfers lead to positive investments in public-school infrastructure (e.g., electricity and sanitation). We do not observe changes in school enrollment, ruling out the possibility that the impact of Canon transfers on test scores is driven by population effects (i.e., areas with larger windfalls attracting or repelling families with children). We use household surveys to explore additional mechanisms and find strong evidence that health outcomes of adults and children are also potential mechanisms for the impact we find for redistribution.

Our findings contribute to the recent literature exploring the effects of resource windfalls on the behavior of the local government. Caselli and Michaels (2013) show that oil-rich municipalities in Brazil increase their spending on public goods, but they find mixed results on welfare-relevant outcomes such as household income. Rather, the authors argue that public spending (e.g., public spending in education). This would be the key mechanism behind a non-monotonic relationship between natural resource rents and children educational outcomes. Only with large natural resource windfalls have detrimental effects on human capital—creating a natural resource curse.

The work by Bonilla (2020) points to that direction. He shows that in the context of illegal and small-size gold mining in Colombia, windfalls lead to more revenue, but it does not translate into more education spending. Our findings show in contrast, that a natural resource boom can lead to an increase of human capital accumulation when adequate institutional mechanisms for the distribution of natural resource windfalls are in place.

The rest of the paper proceeds as follows. In Section 2 we briefly describe the institutional setting of the Peruvian Canon law. In sections 3 and 4, respectively, we present the data sources and the identification strategy. In Section 5 we present our results, including our robustness checks. In Section 6 we summarize our findings.

2. Local transfers in Peru: the case of the canon minero

Several countries have implemented mechanisms that share the taxes and royalties paid by extractive companies with subnational governments. This has been associated with an important expansion of fiscal resources in natural resource-rich countries, creating opportunities to improve the living conditions of citizens (Brosio and Jimenez, 2012). In Peru, the Law 27506 or Ley del Canon (Canon Law), approved in 2001, mandates that part of the income tax paid by mining companies should be allocated to the regional and local governments located in the areas where minerals are extracted.

The Canon Law was not related to the commodity boom—increases in mineral prices would take place later in the decade—but rather was implemented as part of the country’s decentralization process during the final days of the transitional government. After several amendments to the original law, it was established in 2004 that the Canon should be 50% of the income tax and that it should be distributed depending on whether districts are producers of a mineral or not. To help guide our description, please note that Peru is divided into regions, which in turn are divided into provinces, which are divided into districts (municipalities). The law established that 10% of the Canon goes directly to the producing district, that is, the municipality where the resources are obtained. The law also establishes that if the mineral is extracted in more than one district, the Canon is distributed among these producing districts proportionally to the corresponding sales specified by mining companies. Non-producing districts located in a producing province get 25%. Local governments located in non-producing provinces get 40% and the regional government where the mineral is extracted receives 20%. The remaining 5% goes to public universities of the region.

The law requires the Ministry of Finance to distribute the Canon using a poverty index in a progressive way (with higher weight to poorer districts) but only among non-producing districts. The index uses information from the Population Census, Agricultural Census, Census of Children Heights (for primary school children), District Registry and the district’s altitude above sea level. Two features of the poverty index help validate our identification strategy. First, none of these variables are based on

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7 They are also related to a vast literature evaluating the effect of school resources on student performance (e.g., Hanushek, 2006; Jackson, 2018).
8 Maldonado (2020) argues that corruption can hardly explain the lack of these effects because politicians cannot steal the whole budget without facing consequences. The lack of these effects is more likely a consequence of a failure to consider the non-monotonic effects suggested by the theoretical literature.
9 This law has as a historical antecedent: The Oil Law, which was established in 1976 during the military government through Decreto-Law 21678 after the discovery of oilfields in the Peruvian Amazon. It was later modified in 1992 to include mining activities and stated that 20 percent of the income tax should be allocated to the areas in which the profits were generated. The Canon Law explored in our paper was established by the government of President Valentín Paniagua, who came to power after Alberto Fujimori resigned from the presidency in December of 2000.
10 The original law of 2001 established that 20 percent of the transfers should be assigned to the municipalities of the province where the mineral is extracted, 60 percent to the other provinces in the region and the remaining 20 percent to the regional government. This was changed in 2003 (Law 28077) and again in 2004 (Law 28322) where the distribution applied during our period of analysis was established.
11 Peru is divided into 24 political regions, which in turn are divided into 196 provinces and into over 1867 districts or municipalities.
on test scores, and to identify some of the important mechanisms that could lie behind any significant relation. The first dataset is the Evaluación Censal de Estudiantes (or ECE for its Spanish acronym). This is a national standardized test applied yearly since 2007 to all second graders in Peru (the only grade for which this test is taken) in public and private schools.

Administered by the Ministry of Education, the ECE collects information about the students’ performance in math and reading plus a small set of students’ and schools’ characteristics (e.g., gender, mother tongue and type of school). These test scores are our main outcome variable.

Combining the tests scores from the ECE 2007 to 2012, our final sample contains over 2 million student records nationwide. Our sample includes all rural areas. We also include urban areas, except for the capital cities in each of the 24 regions. The exclusion of these largest cities reflects the different social dynamics triggered by mining in these areas compared to rural and smaller cities (Mendez et al., 2006; Arellano-Yanguas, 2008).

Our second data source, the Censo Escolar (CE), allows us to use yearly information about schools in terms of infrastructure, personnel and other administrative data. These include the share of the teacher body with long-term contracts, access to electricity, water and sanitation, among others. As explained in the next section, we use some of these variables as additional controls (e.g., length of the school day, school administration, and percentage of girls enrolled) while others allow us to explore possible mechanisms (e.g., infrastructure and school personnel).

We merge these datasets with yearly district-level data of mining production and Canon transfers. We obtain data on the value of mining production from the annual reports of the Ministry of Energy and Mining. We convert the reported volumes of copper, tin, iron, zinc, molybdenum, silver, gold, tungsten and cadmium, at the district level, into U.S. dollars using current international prices of the corresponding minerals. Canon transfers are the monetary amounts that each district receives annually from the central government. The Ministry of Finance compiles, computes, and reports these figures based on the amount of mining production in the districts themselves. This Ministry is also the source of the expenditure data by local governments on education (and culture) per year. We also convert government transfers into U.S. dollars using nominal exchange rates. We set all monetary values to 2010 prices using the U.S. consumer price index and express them in thousands of dollars per capita.

Our fifth and final dataset allows us to explore other possible mechanisms, but at the household level. We use the repeated cross-sections from 2007 to 2012 of the Encuesta Nacional de Hogares (ENAHO), a nationally representative household survey yearly conducted by the Peruvian National Bureau of Statistics (INEI, for its acronym in Spanish) aimed at measuring living standards. ENAHO allows us to estimate the effect of the mining Canon transfers on health outcomes of children and adults, their caretakers.

Table 1 presents summary statistics for inputs and outputs. To facilitate the presentation, we partition the sample into three groups: producing districts, non-producing districts located in producing provinces, and non-producing districts in non-producing provinces. This classification follows the division created by the Canon Law. The table shows that districts in producing provinces, columns 1 and 2, present higher scores in math and reading on average than other districts, as well as a higher proportion of schools with access to basic services and with better

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12 These datasets were not updated until after the end of analysis period (2017 for Population Census, 2012 for Agriculture and the Census of Heights was never updated). Also, as we describe later, we extend the model by including province-specific trends and our results are robust to that inclusion (Table A14). Note also that our period of analysis comprises 2007, thus we perform a robustness test excluding 2007 and our main results remain unchanged (Table A15).

13 The Evaluación Censal de Estudiantes is the annual standardized test that since 2007 has evaluated learning goals for students in second grade in mathematics and reading. With more than a decade of experience, the standardized evaluation has been built on international state-of-the-art knowledge, following best practices of the community of practitioners and receiving advice for international experts. All this is possible, to an important extent, thanks to the participation of Peru in OECD’s PISA. ECE takes place at the end of the school year (mid-November to early December) and has a very high coverage of schools (93%) during our period of analysis. For further details see Ministerio de Educación (2017). Finally, unlike GPA, which is determined by teachers, ECE is conducted and supervised by external provers, who do not belong to the school. Teachers are not allowed to talk or help students during the exam and are not even permitted to see the actual test.
where \( Y_{stdh} \) is the test score for the student \( i \), enrolled in school \( s \), located in district \( d \) observed in year \( t \); \( c_{dh} \) is the amount of Canon transfers to district \( d \) in year \( t \), expressed in thousands of US dollars per-capita at constant prices of 2010. Canon transfers depend on the value of taxes paid by mining companies—which in turn depend not only on the value of production (determined by international prices) and the mineral produced in the locality—but also on the rules of the transfers discussed in Section 2. Thus we exploit year-to-year variation in the amount of Canon transfers received by the same district conditional on \( D_{dt} \), a vector containing the value of mining production and two dummies for whether the district is a producer or a non-producer in a producing province. Finally, \( X \) is a vector of socio-demographic characteristics of the student including gender and mother tongue; \( S \) is a vector of schools' characteristics. These characteristics include length of the school day (full-day, half-day morning or half-day afternoon); school administration type (public/private), school type (one-teacher school/full grade) and percentage of girls enrolled in the school \( g_{td} \) and \( t \) denote district and year fixed effects respectively. \( \varepsilon_{isth} \) is an idiosyncratic error term. Standard errors are robust to unknown forms of heteroskedasticity and clustered at the district level.

4. Identification strategy

We exploit variation across districts and time in the Canon transfers. Our main specification is given by:

\[
y_{sth} = \alpha + f(c_{dh}) + \delta_1 D_{dt} + \delta_2 X_{isth} + \delta_3 S_{isth} + Y_{i}_{dth} + \theta_t + \varepsilon_{isth}
\]  

(1)

where only few districts become producers during the period of analysis. Eliminating them from our sample does not change our results (results available upon request).
were the product of circumstantial alliances between congressmen from 
mineral rich regions and not the result of pressure from regional and local 
actors or the executive power. However, these negotiations and changes 
in the law, took place in 2004, that is three years before our period of 
analysis. Moreover, these negotiations depended on time-invariant 
characteristics that are captured by our district-level fixed effects and 
thus, they provide further support to our identification approach. Hold-
ing the investment capacity of the local governments constant, by the use 
of district fixed effects, we explore whether the year-to-year variation in 
the amount of transfers and mining production helps in the formation of 
human capital measured by test scores.

Finally, unobservable factors may affect both mining production (and 
therefore fiscal redistribution) as well as the educational outcomes if for 
instance local demand and labor market conditions are correlated with 
the mining production. However, by controlling for the value of mining 
production we address this concern insofar as observed production is the 
result of a market equilibrium. On top of this, we perform robustness tests 
later on excluding producing districts and their neighbors—whom are 
arguably subject to spillovers from producing districts—and still find 
evidence in support of our argument.

Our identification strategy differs but complements other approaches 
in the empirical literature on the effects of resource booms. For example, 
Dube and Vargas (2013), using the case of Colombia, exploits exogenous 
variation in international prices of oil to instrument endogenous value of 
production. Their strategy exploits variation for the case of producer 
districts in settings where the allocation of natural resource rents are 
granted exclusively to these type of districts.17 As discussed above, in our 
setting, producer districts are granted only the 10% of the total amount of 
Canon transfers generated, the rest being allocated to other districts in 
the province and the region (including a fraction assigned to the regional 
governments and regional universities). Hence looking at the effect of 
mining production on test scores will certainly leave aside a relevant part 
of the variation we want to understand.

5. Results

5.1. Effect of canon transfers

We start by considering the effect of the Canon transfers on test scores. 
Table 2 displays our estimates. In Panel A we focus on math and Panel B 
on reading. We start with a simple model using a linear specification for 
Canon transfers and ignoring the role of mining production but incor-
porating all the fixed effects from Equation (1). For math, panel A, we 
find a positive association in this simplest model (column 1) but it is not 
statistically different from zero. However, a quadratic functional form 
suggests a nonlinear link (column 2). This pattern is consistent with the 
non-monotonic effects of resource booms highlighted by the political 
economy literature described earlier. The effects for reading are much 
smaller and are not statistically different from zero (Panel B).18

Adding controls for the value of mining production (column 3) as well 
as student and school characteristics (column 4) does not alter our 
findings: there are positive, statistically significant (but marginally 
decreasing) effects for math, and negligible impacts for reading. 
Consistent with our previous analysis, the coefficient for mining pro-
duction is not statistically significant after controlling for Canon and its 
square. The lack of significance for mining production after controlling 
for Canon transfers suggests that the market-based channels of a resource 
boom seem to be irrelevant in our setting.

Considering column 4, where all controls are included, the test-score-
maximizing amount of Canon is about US$ 5500 per capita per year. 
Figure A3 in the Appendix reports the marginal effect for this specifi-
cation. Conditional on receiving a transfer, the 99-percentile value of Canon 
transfers is only US$ 740 per capita. Thus, for nearly all districts receiving 
Canon, our findings suggest a positive effect of the transfers on 
math test scores. Moreover, given that the average transfer during the 
period of our analysis is US$ 70 per capita for the sample of districts that 
receive strictly positive transfers, our estimates suggest an increase of 
around 24 percent of a standard deviation in math scores at this point of 
the distribution.19

To put our results in perspective, the average impact of the Canon on 
test scores is higher than 83 percent of the studies reported by Kremer 
et al. (2013) who analyze primary school interventions evaluated with 
randomized control trials. For example, based on the authors’ review, our 
effect is larger than all the studies where “business as usual” resources are 
provided (e.g., textbook, class size, flipcharts) and all but two of the 
pedagogical innovations.

5.2. Robustness checks

5.2.1. Robustness to influential observations

We explore whether our findings are driven by extreme values of 
Canon. To identify these observations, we use the standard Cook’s dis-
tance, Welsch Distance and difference in fits (DFITS) procedures. This 
comprised about 5% of observations when performing the DFITS and 
Cook’s distance procedures, and about 2% for the Welsch distance pro-
cedure. Our results are robust to removing these observations (see Ap-
pendix Table A3).20 Note that in the context of the resource curse 
literature, administrative units with extremely high values of natural 
resource rents are of particular interest. For our study, large Canon values 
are not “anomalous values” arising from problems like measurement 
error given that these come from official administrative data on transfers 
to districts. Instead, these large values are important empirically as we 
seek to test a theory predicting that we should observe a resource curse 
for large transfers.21

5.2.2. Lagged model

Our main specification does not include Canon lags. Indeed, there is 

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17 This was certainly the case for Colombia before 2011, before the royalty 
system was modified. See Gallego et al. (2020) for a discussion about the 
Colombian royalty system and the effects of the reform.
18 We are not the first to find impacts on math scores but no effects on reading 
scores. The existence of effects on one subject but not in the other has been 
documented for interventions such as school vouchers (Shakeel et al., 2016), 
school feeding programs (Lawson, 2012) and other educational interventions 
(Evans and Popova, 2016). Even the effects of climate change on learning show 
a differential impact between math (negative) and reading (no effect) as sug-
gested by Graff Zivin et al. (2018). The lack of effects on reading scores has been 
interpreted as evidence of household complementarities in learning, especially 
for primary schools because parents and older siblings can support students’ 
learning process due to the lack of complexity of the subject (Shah, 2017). This 
does not occur in the case of math given that it requires more specialized 
knowledge. This has led to the development of innovations designed to help 
parents to engage in their children math learning (Berkowitz et al., 2015).
19 Our results are robust to an additional standardization of test scores in 
the form of a z-score using the mean and standard deviations from 2007. Table A1 in 
the Appendix shows these results and Table A16 reports them for the heterog-
enous case.
20 Figure A5 in the Appendix plots the partial regression lines associated with 
the first- and second-order effects of the value of Canon on math test scores. 
Consistent with our main findings, the first-order effect is positive, and the 
second-order effect is negative, with tight 95 percent confidence bands. The 
panels of the figure illustrate that the result is robust to different specifications 
of the residuals.
21 We also consider whether our results are affected by transforming the Canon 
transfers using natural log (plus one), box-cox and inverse hyperbolic sine. 
However, as shown in Appendix Figure A4, these transformations do not change 
the shape of the empirical distribution because there are many districts whose 
local governments do not receive canon transfers while a relatively small frac-
tion of them receiving large levels of transfers. Therefore, regressions using this 
transformation do not alter our main finding (available upon request).
evidence suggesting that mayors react immediately to the transfers because not doing so could lead to higher political competition and higher likelihood that the central government will reduce transfers due to low budget execution (e.g., Maldonado, 2020; Maldonado and Ardanaz, 2020). Furthermore, in the case of mining production, previous studies have shown that the effect on market outcomes is contemporaneous (Jacobsen and Parker, 2014).22

Also, we argue that it is quite common to find contemporaneous effects of educational interventions on test scores. McEwan (2015) reviews 77 randomized controlled experiments focusing on primary school interventions in developing countries. He finds that in all but seven studies, the evaluation was conducted at the end of the academic year when the intervention started. This review is very important for our study because it focuses on children in primary school while our analysis centers on second graders. Thus, our findings of contemporaneous effects among second graders in Peru, are in line with the vast literature evaluating school learning in developing countries.

Nonetheless, in this sub-section we expand the model to test whether lagged values of the Canon matter. In our setting, we only have test score data for second graders, so we control for Canon transfers when students were in first grade.23 Grade repetition is not an issue here because, by law, children cannot repeat first grade in Peru. In Table 2, column 5, we present the results of including \( t - 1 \) in the Canon transfers (and its square). Such addition does not change our previous findings and shows that lagged values play no role on test scores. This evidence reinforces the theoretical arguments we posit and therefore we conduct the rest of the analysis with Canon values at as our main specification.24

### 5.2.3. Relaxing the parametric quadratic specification

The non-monotonic effects of mining Canon on learning outcomes are consistent with the political economy arguments discussed earlier but they strongly rely on the use a quadratic parametric approximation. To evaluate whether this approach is consistent with the data, we extend the

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22 On top of this, recent theoretical scholarship has shown that lag identification requires stronger and implausible identification assumptions. For instance, Bellemare et al. (2017) have shown that using lags would require strong assumptions regarding the dynamics of unobservables. Even more concerning are results obtained from Monte Carlo simulations that provide evidence that lags could worsen identification and the quality of inference in such a way that it is often better just to ignore lags altogether (see Bellemare et al., 2017, for details).

23 Lags beyond \( t - 1 \) would make little sense when considering second graders. For example, \( t - 2 \) implies evaluating the effects on transfers to schools before children entered first grade. Therefore, we limit our analysis to \( t - 1 \).

24 We also consider the lagged model when we explore heterogenous effects and continue to find only a contemporaneous effect. See Appendix Table A5.
empirical model to include other polynomials and check whether they offer a better fit.

Table A3-A in the Appendix presents the results of the analysis. Columns 1 to 3 replicate the results for the basic specification while we add cubic and quartic terms for mining Canon in columns 4 and 5. As a benchmark, we first test whether the coefficients for the quadratic approximation are both equal to zero. We confidently reject the null hypothesis that both coefficients are equal to zero (F-statistic of 3.08 with a p-value of 0.05) for the case of math scores. For the case of the cubic and quadratic approximations, we implement a test for nested models in which the null hypothesis assumes that the quadratic approximation offers a better fit compared to alternative specifications. In both cases, we fail to reject the null: F-statistic of 0.32 with a p-value of 0.56 against the cubic specification and F-statistic of 0.19 with a p-value of 0.83 against the quartic model. Therefore, the evidence suggests that the quadratic approximation offers the best fit to the data. Similar results are obtained for reading (Panel B).

One related concern is that this estimated non-monotonic relationship is driven by a particular type of student, for example those that overperform or underperform in the standardized test. Therefore, it is possible that our main results are not robust to this issue. To address this concern, we implement the fixed effects quantile regression model proposed by Machado and Santos Silva (2019). As it is well known, although it weights the errors in a different way, quantile regression is robust to a potential problem with outliers in the conditional distribution of the outcome (Koenker, 2005).

Table A3-B in the Appendix presents results from the proposed approach. The results for the median (quantile = 0.5) are, incidentally, close to the mean effects estimated in Table 2. Remarkably, all the estimates for the quantiles 0.1 to 0.9 show robust evidence in favor of the non-monotonic relationship highlighted by our conceptual framework.

5.2.4. Alternative samples of districts according to mining production

One possible concern is that endogenous production responses may play a role even after controlling by mining production in the econometric specifications. To address this issue, we take advantage of the fact that the mining Canon Law establishes that non-producer districts located in a producing province also receive a fraction of the rent generated by mining exploitation. This allows us to test the impact of the redistribution of natural resource rents in settings where production externalities and endogenous responses to mining production are not expected to play a role.

For this purpose, we limit the sample to non-producing districts located in producing provinces. Table A4.1 in the Appendix presents the results. The coefficients are statistically significant and larger than those reported in Table 2 for the basic specification on math test scores (Panel A, columns 2 and 3). This result is robust to controlling for student and school characteristics (column 4). In Table A4.2, we exclude districts that share a boundary with producing districts. We still find the same effect: a non-linear relationship between Canon transfers and test scores. As before, there is no effect for the case of reading scores (Panel B of Table A4.1 and A4.2).

5.2.5. Permutation tests

To further validate our empirical strategy, we consider falsification tests by incorrectly assigning the time series of Canon transfers and mining production, \([c_a, m_u]\), that belong to district d to a randomly chosen district \(j\) from the set of all districts in the country. If unobserved characteristics, beyond the ones controlled with the district and year fixed-effects, are behind our findings for the Canon transfers, we should expect this permutation exercise to produce non-zero impacts.\(^{25}\) In Fig. 2, we show the distributions for the linear and quadratic coefficients from 10,000 permutations, after controlling for mining production. This is the same specification used in Table 2, column (3), whose benchmark parameter is reproduced here as the vertical dashed lines to ease the comparison. As expected, in Panels A (linear) and B (quadratic) we clearly observe that the incorrect assignment of Canon transfers produces estimates centered around zero (no effect). The original estimates are far away from these non-zero effects and they are unlikely to be generated by this (incorrect) random assignment given the shape of the density function. These results provide further evidence of the validity of the identifying assumptions for our empirical strategy.\(^{26}\)

5.3. Heterogeneous effects

In Table 3 we report regressions exploring heterogeneous effects regarding the public-private and urban-rural divides. In column (1) we reproduce the results for the entire sample to ease comparisons. The quadratic relationship in mathematics is present in all subsamples except for private schools (column 4). This result is consistent with the fact that mining production has very limited impact on local economic conditions, otherwise the effects would be noticed on children attending private schools too. These findings provide additional support to the hypothesis that the main driving factor is political since Peruvián mayors seem to use mining Canon funds to improve learning conditions in public schools only. We will provide additional evidence on this regard in the next section. Also, in columns (6) and (7) we show that effects are the same when dividing the sample by gender: in both cases we continue to find non-linear effects of the Canon for math and no impact for reading.\(^{27}\)

5.4. Mechanisms

We now explore several mechanisms that could explain how the Canon transfers increase academic performance, as measured by test scores. We do this by using the same identification strategy as before but replacing the test scores in Equation (1) with new outcomes at the district, school and household level, depending on the dataset.

We start by testing whether transfers increase local government’s expenditures on education and cultural items. Based on the theoretical models of political economy discussed earlier, we expect this expenditure to increase with transfers to local governments but to exhibit diminishing marginal returns, because at higher rent levels incumbents would invest less on public goods. In Table 4, column 1, using data at the district level, we find evidence in support of such models. These results expand the findings from Caselli and Michals (2013), who show that oil windfalls in Brazil increase local-government education expenditure. Also, in Brazil, but in the late 1980s, Litschig and Morrison (2013) find a positive effect on local expenditure on education from intergovernmental transfers. These papers, however, did not explore, non-linear specifications making our findings an important contribution.

We expand our set of outcomes to explore whether Canon transfers created improvements in school infrastructure and the quality of teachers for the subset of public schools. Specifically, we use data from the Censo Escolar and test if variation in Canon transfers relates to the hiring of

\(^{26}\) Note that the nature of the Canon transfers makes it impossible to obtain valid inference if this incorrect random assignment is done when \(j\) is obtained from the region or province where \(d\) is located. As described in Section 2, districts in the same province or region of a producing district will receive a transfer that is correlated with the one received by district \(d\). Thus, transfers to \(d\) and its neighboring districts are not spurious as is the case when \(j\) is drawn from any district in the country. In the Appendix, Figure A6, we show that when such permutations are done, the distribution of the incorrect permutations is not centered around zero. However, our point estimates are still located in low-probability regions for these distributions.

\(^{27}\) These results are robust to the exclusion of influential observations (Tables A6-A to A6-C in the Appendix).

\(^{25}\) The use of permutation tests as a robustness check is not rare in the empirical literature. See, for instance, Abadie and Demirli (2008) for an application in a similar spirit of the one used in our paper.
teachers with long-term contracts (columns 4), percentage of teachers with college degrees in education (columns 5) and basic infrastructure services in the school: electricity (column 6), water (column 7) and sanitation (column 8).

We find that the Canon is non-linearly and statistically significantly associated with improvements in the access to electricity and sanitation.28 As further shown in the Appendix, Tables A7 and A8, these effects are indeed concentrated on public schools and schools in rural areas. These findings also speak to the large literature about the role of resources on education outcomes (e.g., Hanushek, 2006; Glewwe and Kremer, 2006; Glewwe and Muralidharan, 2016; Jackson, 2018). In this sense, we also complement the work by Ferraz et al. (2012), who find that corruption has a negative effect on students’ academic performance in Brazil as politicians deviate resources away from education.

In columns (2) and (3) of Table 4 we rule out the possibility that population effects drive improvements in test scores. We find no effect on school enrollment from Canon transfers, suggesting that larger windfalls did not seem to attract families with children. This is consistent with the work of Aragón and Rud (2013) who focused on Yanacocha, a large gold mine in Northern Peru. The authors also find no changes in the composition of the labor force—measured by education, gender and portfolio of crops—using a difference-in-difference approach.

Yet, Loayza and Rigolini (2016), using the 2007 Peruvian population census, find that areas with mining booms attracted skilled migrants. Our results showing no effect on school enrollment could still be consistent with the Loayza and Rigolini’s findings, if migrants are not coming with their families. Such migration pattern would be consistent with a household division of labor aimed at maximizing earnings from work opportunities (e.g., Chant, 1991; Hugo, 2003, 2006). Also, Loayza and Rigolini’s analysis uses only data for 2007, which is the starting of our period of analysis. Thus, if skilled migration were temporary, circular, or concentrated at the beginning of the boom, our results would also be consistent with theirs. Furthermore, they base their empirical design on a cross-sectional variation that does not necessarily allow them to account for unobserved factors related to both, migration and mining production or Canon transfers. We base our design, in contrast, on a method that

28 According to the current legal framework, local governments’ responsibilities can be classified in exclusive and shared with other government levels. The shared functions include participation in management of school services, public health, culture, sports and recreation, citizen security, transport, housing, and social programs and waste management. Although local governments do not hold the full responsibility of managing schools, they do participate in supporting schools under their jurisdiction.
whether changes in health outcomes as additional potential mechanisms.

cussed by Litschig and Morrison (2013), investigating the impact of
improves health conditions of adults and children (aged 6–10). As discussed by Litschig and Morrison (2013), investigating the impact of

Table 3
Heterogeneous effects of Canon on academic achievement.

<table>
<thead>
<tr>
<th></th>
<th>All</th>
<th>Urban</th>
<th>Rural</th>
<th>Private</th>
<th>Public</th>
<th>Female</th>
<th>Male</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
<td>(6)</td>
<td>(7)</td>
<td></td>
</tr>
<tr>
<td><strong>Canon</strong></td>
<td><strong>25.1328</strong>*</td>
<td><strong>26.2588</strong></td>
<td><strong>21.7433</strong></td>
<td><strong>–4.9008</strong></td>
<td><strong>27.0129</strong>*</td>
<td><strong>28.5620</strong>*</td>
<td><strong>21.8927</strong></td>
</tr>
<tr>
<td><strong>Canon squared</strong></td>
<td><strong>–2.2729</strong>*</td>
<td><strong>–2.3552</strong></td>
<td><strong>–2.1770</strong></td>
<td><strong>–0.1002</strong></td>
<td><strong>–2.4098</strong>*</td>
<td><strong>–2.5609</strong>*</td>
<td><strong>–1.9968</strong></td>
</tr>
<tr>
<td></td>
<td>(0.8257)</td>
<td>(0.9809)</td>
<td>(0.8555)</td>
<td>(1.2529)</td>
<td>(0.8626)</td>
<td>(0.9171)</td>
<td>(0.7864)</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.1604</td>
<td>0.1472</td>
<td>0.1278</td>
<td>0.0986</td>
<td>0.1519</td>
<td>0.1582</td>
<td>0.1646</td>
</tr>
<tr>
<td>Number of students</td>
<td>2,012,798</td>
<td>1,353,896</td>
<td>653,410</td>
<td>299,441</td>
<td>1,713,357</td>
<td>987,444</td>
<td>1,025,354</td>
</tr>
</tbody>
</table>

Panel B. Reading scores

<table>
<thead>
<tr>
<th></th>
<th>All</th>
<th>Urban</th>
<th>Rural</th>
<th>Private</th>
<th>Public</th>
<th>Female</th>
<th>Male</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
<td>(6)</td>
<td>(7)</td>
<td></td>
</tr>
<tr>
<td><strong>Canon</strong></td>
<td><strong>–2.4656</strong></td>
<td><strong>0.6823</strong></td>
<td><strong>0.9681</strong></td>
<td><strong>–24.7742</strong></td>
<td><strong>1.7615</strong></td>
<td><strong>–2.0640</strong></td>
<td><strong>–2.8719</strong></td>
</tr>
<tr>
<td><strong>Canon squared</strong></td>
<td><strong>0.2535</strong></td>
<td><strong>–0.0805</strong></td>
<td><strong>–0.0391</strong></td>
<td><strong>2.0427</strong>*</td>
<td><strong>–0.2218</strong></td>
<td><strong>0.0516</strong></td>
<td><strong>0.4126</strong></td>
</tr>
<tr>
<td></td>
<td>(0.3835)</td>
<td>(0.3959)</td>
<td>(0.6528)</td>
<td>(0.7328)</td>
<td>(0.4063)</td>
<td>(0.3903)</td>
<td>(0.4129)</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.2895</td>
<td>0.2303</td>
<td>0.1693</td>
<td>0.1505</td>
<td>0.2483</td>
<td>0.3054</td>
<td>0.2751</td>
</tr>
<tr>
<td>Number of students</td>
<td>2,008,941</td>
<td>1,351,621</td>
<td>651,838</td>
<td>299,302</td>
<td>1,709,639</td>
<td>985,751</td>
<td>1023190</td>
</tr>
</tbody>
</table>

Note: Robust standard errors clustered at the district level in parentheses. * Significant at ten percent; ** significant at five percent; *** significant at one percent. Canon corresponds to the value of Canon per-capita, in thousands of USD at constant prices of 2010. All regressions include the value of mining production (constant USD, 2010 = 100), dummies for type of province (i.e., producer and non-producer in producing district), and fixed effects at the district level and by year. We also control for school and student characteristics. School characteristics include school day (full-day, half-day morning or half-day afternoon); school administration type (public/private), and school type (one-teacher school/full grade). Student characteristics include gender and mother language (Spanish/other) of the children.

Source: Authors’ calculations based on data from Peru’s Ministries of Education, of Finance, of Energy and Mines, and INEI.

Table 4
Mechanisms: Local government expenditure and school-level characteristics.

<table>
<thead>
<tr>
<th>Dependent Variables</th>
<th>All</th>
<th>Public schools only</th>
<th>Percentage of teachers with a tertiary education degree in a school teaching program</th>
<th>School has access to water</th>
<th>School has access to sanitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
<td>(6)</td>
</tr>
<tr>
<td><strong>Canon</strong></td>
<td><strong>0.0755</strong>*</td>
<td><strong>0.0116</strong></td>
<td><strong>0.0020</strong></td>
<td><strong>0.0123</strong>*</td>
<td><strong>0.0533</strong>*</td>
</tr>
<tr>
<td></td>
<td>(0.0272)</td>
<td>(0.0084)</td>
<td>(0.0061)</td>
<td>(0.0388)</td>
<td>(0.0309)</td>
</tr>
<tr>
<td><strong>Canon squared</strong></td>
<td><strong>–0.0093</strong></td>
<td><strong>–0.0011</strong></td>
<td><strong>0.0001</strong></td>
<td><strong>–0.0086</strong>*</td>
<td><strong>–0.0032</strong></td>
</tr>
<tr>
<td></td>
<td>(0.0044)</td>
<td>(0.0008)</td>
<td>(0.0022)</td>
<td>(0.0033)</td>
<td>(0.0025)</td>
</tr>
<tr>
<td>R-squared</td>
<td><strong>0.4607</strong></td>
<td><strong>0.1560</strong></td>
<td><strong>0.1242</strong></td>
<td><strong>0.3481</strong></td>
<td><strong>0.3319</strong></td>
</tr>
<tr>
<td>Number of districts</td>
<td><strong>9947</strong></td>
<td><strong>82.449</strong></td>
<td><strong>82.449</strong></td>
<td><strong>92.463</strong></td>
<td><strong>92.459</strong></td>
</tr>
</tbody>
</table>

Note: Robust standard errors clustered at the district level in parentheses. * Significant at ten percent; ** significant at five percent; *** significant at one percent. All regressions include the value of mining production (constant USD, 2010 = 100), dummies for type of province (i.e., producer and non-producer in producing district), and fixed effects at the district level and by year. Canon corresponds to the value of Canon per-capita, in thousands of USD at constant prices of 2010.

Source: Authors’ calculations based on data from Peru’s Ministries of Education, of Finance, of Energy and Mines, and INEI.

voids such a possibility. Thus, our different research strategy could also
explain these different findings.

We now use household-level data from ENAHO to investigate
whether changes in health outcomes as additional potential mechanisms.

Our analysis complements previous findings exploring the impacts of
production and Canon on consumption and poverty using census data
(Loayza and Rigolini, 2016), household surveys (Aragón and Rud, 2013)
or both (Zambrano et al., 2014).

For Table 5 we merge the ENAHO household surveys from 2007 to
2012 with the Canon and mining datasets. We test whether the Canon
improves health conditions of adults and children (aged 6–10). As discus-
ded by Litschig and Morrison (2013), investigating the impact of

integovernmental transfers on health outcomes is a natural step when
understanding whether such transfers could improve human capital. In
Table 5 we consider three (self-reported) indicators: having health
complications in the last four weeks, whether the individual felt sick in
the last four weeks and the number of days an individual between 15 and
64 years of age that could not work due to being sick. Our results indicate
that Canon transfers are associated with health improvements. We
observe a decline in the probability of experiencing health complications
for adults (column 1), as well as a decline in the probability of being sick
recently for both adults and children (column 3). The results are essen-
tially the same for urban and rural areas (Table A9 in Appendix),
although it seems we lack statistical power for that analysis.
We also evaluate whether Canon transfers, through the expansion of the public education budget, created a crowding-out effect on household’s education expenditures.\textsuperscript{29} We do not find evidence of crowding-out at the household level, suggesting that parents do not see their inputs as substitutes with respect to school-based inputs.\textsuperscript{30} Finally, we show that these results are robust to the exclusion of influential observations as discussed in section 5.2.1. This exercise is presented in Appendix Table A10 and A11.\textsuperscript{31}

We study whether booms of natural resources affect human capital accumulation, exploiting a natural experiment in the mining sector of Peru, a country with low governance indicators. We find non-monotonic effects of the redistribution of mining rents on math scores, but no effect for the case of reading. The former is positive and large: 0.24 standard deviations for the average municipality, implying that the mining boom in Peru has been beneficial for students in almost all recipient localities. The net effect is negative only for extremely Canon-rich municipalities (top 1% in terms of mining Canon distribution). These results are in line with recent scholarship documenting non-monotonic and perverse effects for natural resource-rich regions. This evidence is also consistent with a political economy argument where mayors invest in public goods when they expect to keep power but underinvest when they face more political competition. In fact, we find that these effects are mainly driven by public schools and by changes in school-level conditions such as infrastructure. These are ways in which incumbents can invest mining Canon transfers.

We find evidence that the redistribution fueled by the resource boom had non-monotonic effects for health outcomes too. These results can be a consequence of improvements in the quality and access to health facilities, something that has been documented in other studies (Maldonado and Ardanaz 2020; Maldonado 2020).

The evidence presented in this paper puts into question some beliefs in the literature about the role of natural resources in development. Recent studies have emphasized that natural resources can be a “blessing” only when good institutions are available. However, we have shown that a natural resource boom can lead to an increase of human capital accumulation in a context of poor institutions, but only when mechanisms of distribution of natural resource windfalls are in place.

Moreover, we find that only very Canon-rich municipalities experience negative effects of a resource boom. This may explain the anecdotal evidence of the resource curse literature, typically motivated by highlighting the economic and political distortions experienced by extreme natural wealth in the Middle East or Africa. Thus, natural resources can lead to a curse only for extremely natural resource-rich societies, and it can potentially be a blessing for some others.

Undoubtedly, the effect of natural resource booms on academic achievement deserves further research, in particular under different institutional set-ups and windfalls-redistribution schemes. Focusing on the Peruvian case, perhaps one important question that remains open for discussion is: What are the long-term effects of mining production on the social outcomes analyzed herein once the boom ends? Jacobsen and Parker (2014) find long-lived negative effects in the labor markets after the end of the 1970s gas and oil bonanza in the United States. However, we have not seen evidence documenting the long-run effects on human capital formation after the bust.

### Declaration of competing interest

None.

### Data availability

Data will be made available on request.

### Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jdeveco.2020.102581.

### References


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\textsuperscript{29} See Litschig and Morrison (2013) for a discussion of the “flypaper effect” and crowding out on own revenue and other revenue sources among local governments in the presence of intergovernmental transfers.

\textsuperscript{30} We evaluate the non-monotonic effect of Canon on household spending on education per-student living at home using data from ENAHO, finding no evidence of a statistically significant effect of Canon on the latter. These results are available upon request.

\textsuperscript{31} We also explored the robustness to the inclusion of lagged variables. See Appendix Tables A12 and A13.


