

Natural Resources, Redistribution and Human Capital Formation

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1. Motivation: Why should we care?

- Whether natural resources are good or bad for economic development is still an open question
- Less clear is whether natural resources can foster the accumulation of human capital
 - Discourage investment in human capital (Gylfason 2001) but results are sensitive to measurement issues (Stijns 2006)
 - Non-monotonic effects conditional on institutions (Cabrales and Hauk 2011)
 - Limited micro-evidence on attendance, attainment and literacy rates (Angrist et al 2008 and Litschig et al 2013), but no systematic evidence on learning outcomes
- Relevant theoretical issue (central channel to explain the “resource curse” hypothesis), but hard to address from an empirical point of view

Research Question

How do resource booms affect human capital accumulation?

- Mechanisms: ▶ Explanation for sociologists
 - **Production channel:** Impact on household economic conditions (labor market effects, entrepreneurship) and environmental externalities (pollution).
 - **Rent channel:** Impact on politicians' incentives to invest on education.

- Exploit recent boom in the mining sector in Peru to analyze its effects on human capital accumulation:
 - Local governments in Peru (1,834 districts) over the period 2007-2012.
 - Use variation in mineral resource rents due to:
 - 1 Time-series variation in mineral resource prices.
 - 2 Cross-sectional variation due to the allocation rules of mineral resource rents (Mining *Canon*).
 - Methods:
 - Difference in differences using a quadratic functional form for natural resource rents and controlling by production.
 - Robustness checks to rule out endogenous production responses and parametric model.

- Evidence of a non-monotonic patterns
 - Municipalities with average mining transfers (US\$88 per-capita) \Rightarrow 22% S.D. in math scores (Higher than 83% of studies reported in Kremer et al 2013)
 - Negative net effect for extremely rich municipalities (above US\$1,313 per-capita)
 - No effects of mining production
- Evidence of heterogeneous responses: Effects driven by public schools in urban areas
- Non-monotonic patterns in mechanisms consistent with political economy story
- Results robust to relaxing parametric approach, dropping producers from sample and to permutation tests

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2. Institutional Background

- Local politics:
 - Weak connection between national and local politics.
 - Weak local institutional capacity and overlap in terms of responsibilities among different levels of government.
- Local public finance
 - Tax revenue collection is low (13%).
 - High dependence from central government transfers (75%).
 - Mining *Canon* and mining royalties represent 72% of all canon transfers and 29% of local governments' budgets.
- Educational system and local governments:
 - Development of a local educational plan
 - Monitoring pedagogical management
 - Educational infrastructure
 - Implementation of literacy and ICT programs

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Rent allocation rules: Mining Canon

- *Mining Canon*: Participation of subnational governments in distribution of rents generated by the exploitation of mineral resources.
- Assign rents to producer and non-producer districts located in same provinces and regions as producers → key for identification.
 - The regional government (20%)
 - The municipality of the district (10%)
 - The municipalities located in the province (25%)
 - The municipalities located in the region (40%)
 - Public universities of the region (5%)

3. Data

- Annual census data on **learning outcomes and educational characteristics** at school and district level (Ministry of Education): 2007-2012.
- Annual data on **local revenues and transfers** from central to local governments (Ministry of Finance): 2007-2012.
- Annual data on **mineral production and prices** (Ministry of Energy and Mines): 2007-2012.
- Annual repeated cross-section of **household survey** (Encuesta Nacional de Hogares-ENAHO): 2007-2012.

4. Research Design

- Exploiting sub-national variation across Peruvian municipalities in mining rents and production associated to recent international mining boom.
 - 1 Increase in mineral production: from 1.35 to US\$7.05 billion.
 - 2 Increase in mining rents: from 7 to US\$827 million.
- Sources of variation:
 - 1 Time-series variation in prices of mineral resources. [▶ here](#)
 - 2 Time-series and cross-sectional variation in mineral production. [▶ here](#)
 - 3 Time-series and cross-sectional variation due to allocation rules of mining rents across municipalities.
- Significant variation in rents over time and across municipalities. [▶ here](#)

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5. Empirical Strategy: Difference in Differences

- Learning outcomes regressed on a (continuous) measure of real per-capita mining transfers and mining production:

$$y_{ijt} = \alpha_j + \lambda_t + \beta F(MR_{jt}) + \gamma Q_{jt} + X_{ijt}\delta + \epsilon_{ijt} \quad (1)$$

- Where:
 - y_{ijt} : Outcome of interest for individual i in district j in period t .
 - α_j : District fixed-effects.
 - λ_t : Time fixed-effects.
 - MR_{jt} : Measure of mineral resource rents per-capita transferred to district j in period t .
 - Q_{jt} : Real value of mineral output in district j and period t .
 - X_{ijt} : Individual/households, school and district level characteristics in period t .

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| | Producers | Non-producers in producer provinces | Non-producers in non-producer provinces |
|--------------------------------------|-----------|-------------------------------------------|-----------------------------------------------|
| 1. Learning outcomes | | | |
| Math Score | 517.66 | 531.47 | 508.98 |
| Reading Scores | 513.21 | 528.72 | 508.94 |
| 2. Mining | | | |
| Mining Production (In US millions) | 8,830,000 | 0 | 0 |
| Canon (In US millions) | 256 | 560 | 252 |
| 3. Education | | | |
| Students | 1,159.59 | 821.42 | 1,248.71 |
| Schools | 13.80 | 11.01 | 16.46 |
| % teachers with long-term contract | 25.04 | 25.75 | 21.24 |
| % teachers with a tertiary education | 97.89 | 97.41 | 95.74 |
| % schools with access to water | 78.89 | 81.41 | 72.05 |
| % schools with access to sanitation | 83.27 | 85.42 | 83.57 |
| 4. District characteristics | | | |
| Poverty rate | 56.14 | 49.71 | 56.32 |
| Income inequality (Gini index) | 0.31 | 0.28 | 0.29 |
| Distance to nearest city (km) | 659.584 | 474.884 | 927.472 |

Source: Authors' compilations

Effect of mining rents on math scores

Table 3A: Effect of Rents and Production on Test Scores

| | Dependent variable: Math scores | | | |
|-------------------|---------------------------------|-----------------------|-----------------------|------------------------|
| | (1) | (2) | (3) | (4) |
| Canon | 6.9139 (4.6448) | 21.6714** (9.5905) | 21.7054** (9.6360) | 23.9953** (9.4336) |
| Squared | | -1.9654** (0.8429) | -1.9679** (0.8453) | -2.1736*** (0.8254) |
| Mining production | | | -0.0000 (0.0001) | -0.0000 (0.0001) |
| R-squared | 0.0062 | 0.0062 | 0.0062 | 0.0174 |
| Observations | 2,072,339 | 2,072,339 | 2,072,339 | 2,011,452 |
| Student controls | N | N | Y | Y |
| School controls | N | N | N | Y |

* Significant 10%; ** significant 5%; *** significant at 1%.

Effect of mining rents on reading scores

Table 3B: Effect of Rents and Production on Test Scores

| | Dependent variable: Reading scores | | | |
|-------------------|------------------------------------|---------------------|---------------------|---------------------|
| | (1) | (2) | (3) | (4) |
| Canon | -0.6112 (1.7751) | -2.6721 (4.3260) | -2.5545 (4.3682) | -2.7956 (4.4904) |
| Squared | | 0.2743 (0.3728) | 0.2656 (0.3743) | 0.2668 (0.3825) |
| Mining production | | | -0.0001 (0.0001) | -0.0001 (0.0001) |
| R-squared | 0.0266 | 0.0266 | 0.0266 | 0.0645 |
| Observations | 2,068,271 | 2,068,271 | 2,068,271 | 2,007,595 |
| Student controls | N | N | N | Y |
| School controls | N | N | N | Y |

* Significant 10%; ** significant 5%; *** significant at 1%.

Heterogeneous Effects

Table 4: Heterogeneous Responses (Math scores)

| | Sample | | | | |
|-------------------|-----------------------|------------------------|-----------------------|----------------------|------------------------|
| | All (1) | Urban (2) | Rural (3) | Private (4) | Public (5) |
| Canon | 21.7054** (9.6360) | 24.9423** (11.3530) | 18.3271* (10.1226) | -4.3993 (16.7948) | 23.6141*** (8.9815) |
| Squared | -1.9679** (0.8453) | -2.2199** (0.9878) | -1.9329** (0.8927) | -0.1085 (1.2641) | -2.0959** (0.8443) |
| Mining production | -0.0000 (0.0001) | 0.0002 (0.0001) | 0.0001 (0.0003) | 0.0001 (0.0003) | 0.0001 (0.0003) |
| R-squared | 0.0062 | 0.0092 | 0.0115 | 0.0103 | 0.0060 |
| Observations | 2,072,339 | 1,392,151 | 660,949 | 300,937 | 1,724,326 |

* Significant 10%; ** significant 5%; *** significant at 1%.

- Role of school characteristics. [▶ here](#)
 - No effect on enrollment
 - Non-monotonic effect on percentage of teachers with long-term contracts
 - Non-monotonic effect on school infrastructure (access to electricity and sanitation)
- Role of economic conditions. [▶ here](#)
 - Non-monotonic effect on public employment
 - No effect on consumption and income
- Role of health factors. [▶ here](#)
 - Non-monotonic effect on experiencing health complications

6. Robustness Checks

- Concern 1: endogenous production responses.
 - Excluding producer areas from the sample. [▶ here](#)
- Concern 2: quadratic parametric approximation may bias estimates.
 - Polynomial regressions + F-test. [▶ here](#)
- Concern 3: permutation test to check probability that results are due to pure chance.
 - Permutation test for different ways to randomly assign mining Canon and mining production across districts. [▶ here](#)

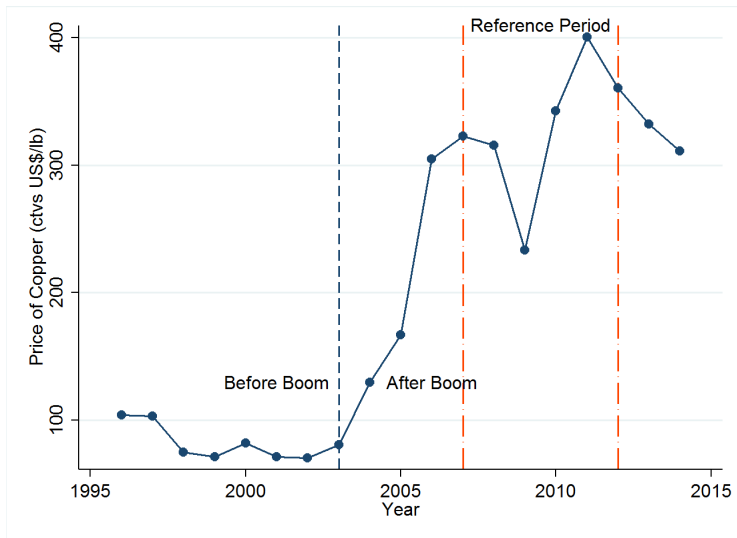
7. Concluding Remarks

- Non-monotonic effects of mining rents on math scores (but no effect on reading scores) after controlling for mining production:
 - Positive net effect for average municipality (22% of a S.D)
 - Negative net effect for extremely rich in mining transfers municipalities (top 1%)
- Results consistent with a political economy story in which mayors respond to electoral incentives
- No effect of production on learning outcomes: weak role for economic conditions to explain the results
- Resource boom seem to be a blessing for municipalities with modest transfers but a curse for extremely rich ones no matter regardless the institutional setting

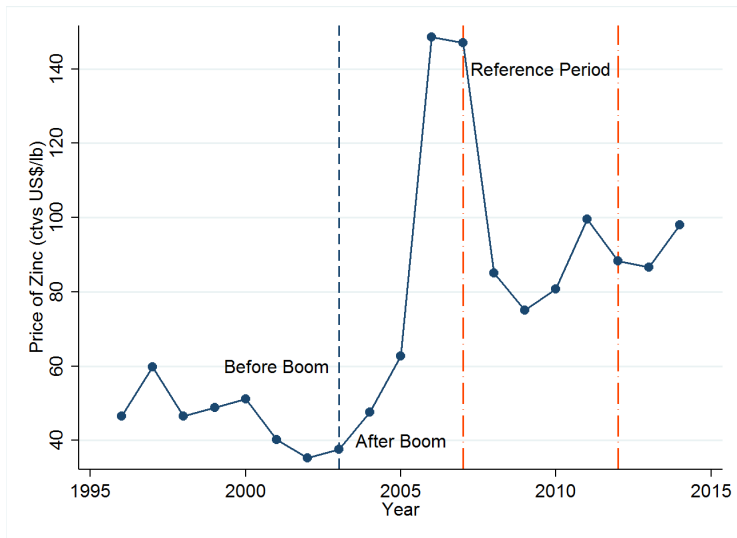
Thank you!

Comments: stanislao.maldonado@urosario.edu.co

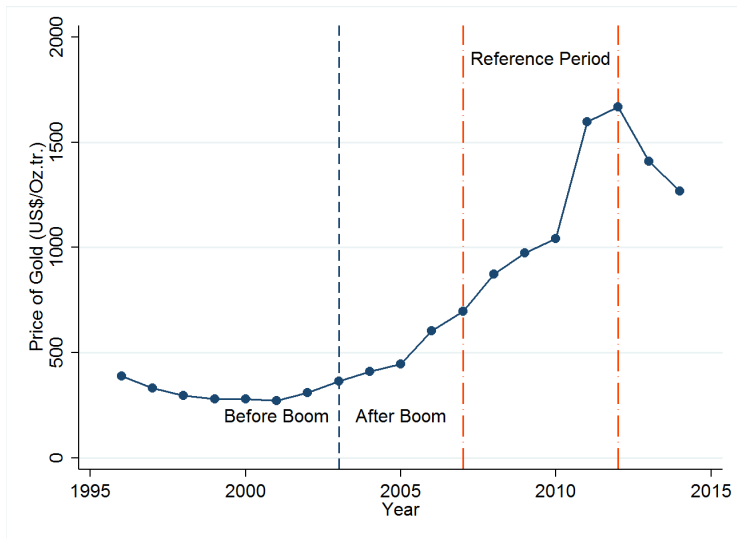
Dramatic increase of mineral prices: Copper



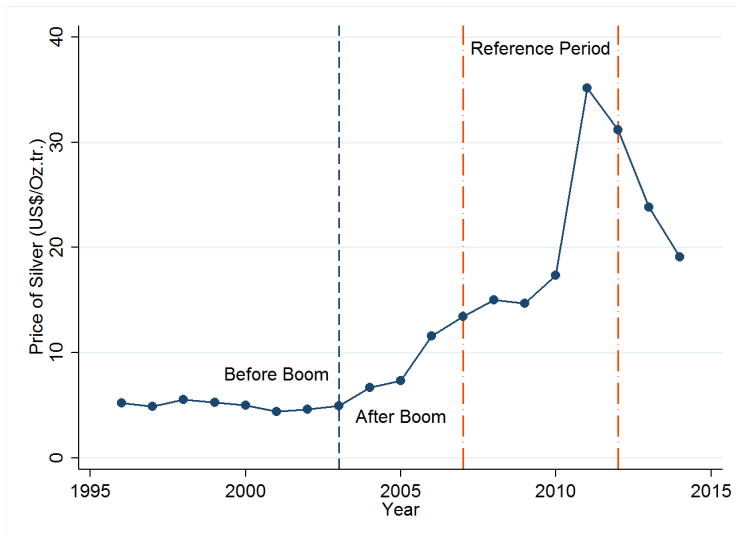
Dramatic increase of mineral prices: Zinc



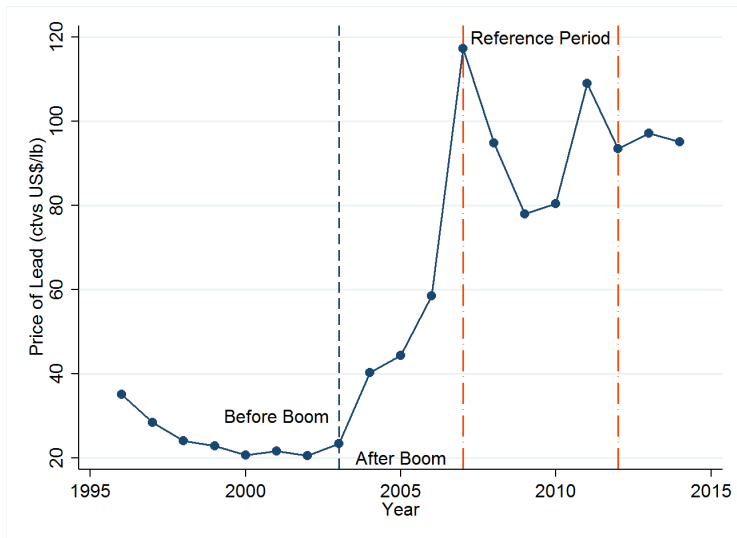
Dramatic increase of mineral prices: Gold



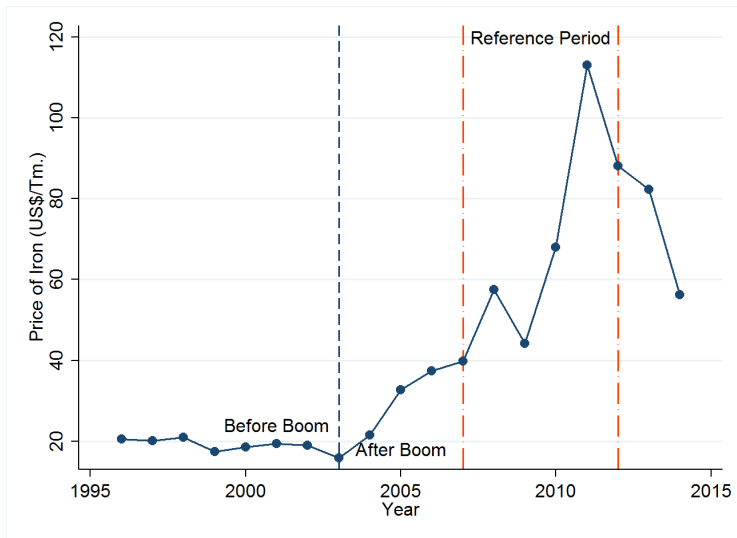
Dramatic increase of mineral prices: Silver



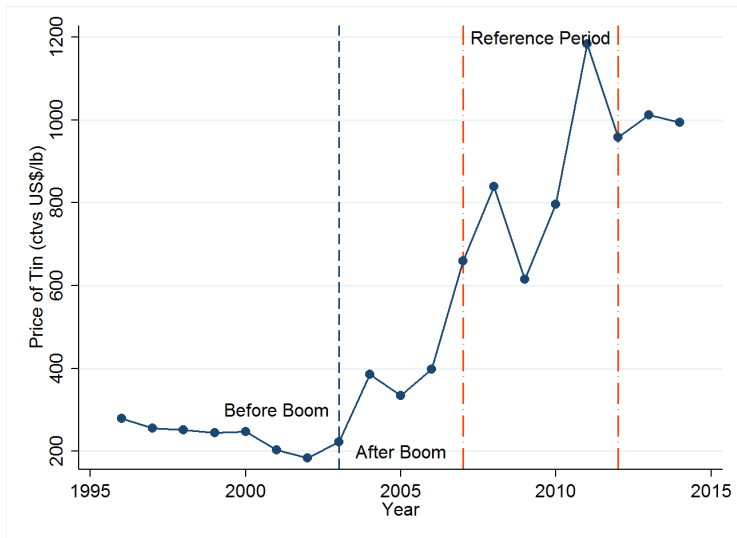
Dramatic increase of mineral prices: Lead



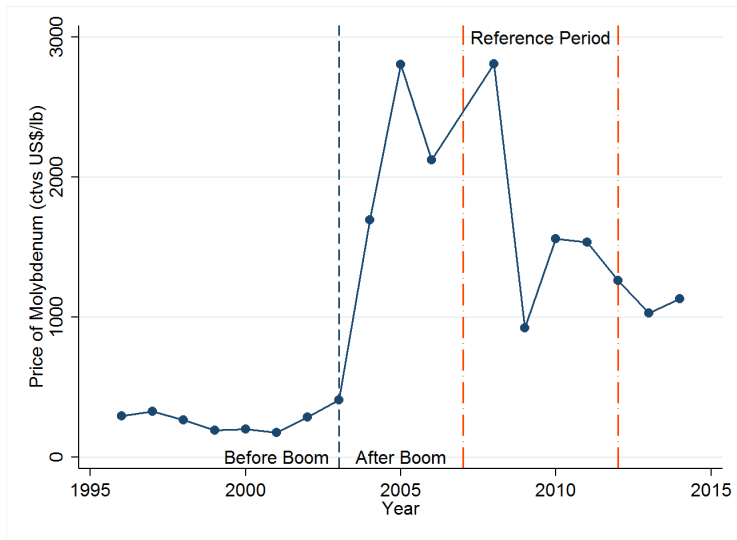
Dramatic increase of mineral prices: Iron



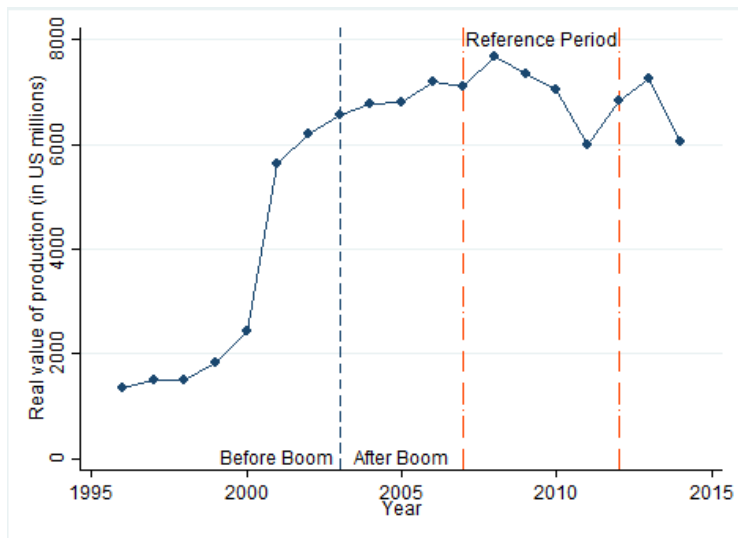
Dramatic increase of mineral prices: Tin



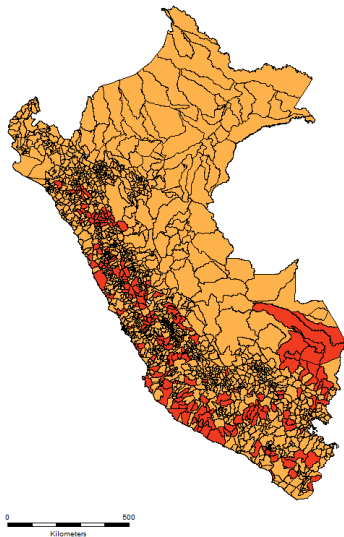
Dramatic increase of mineral prices: Molybdenum



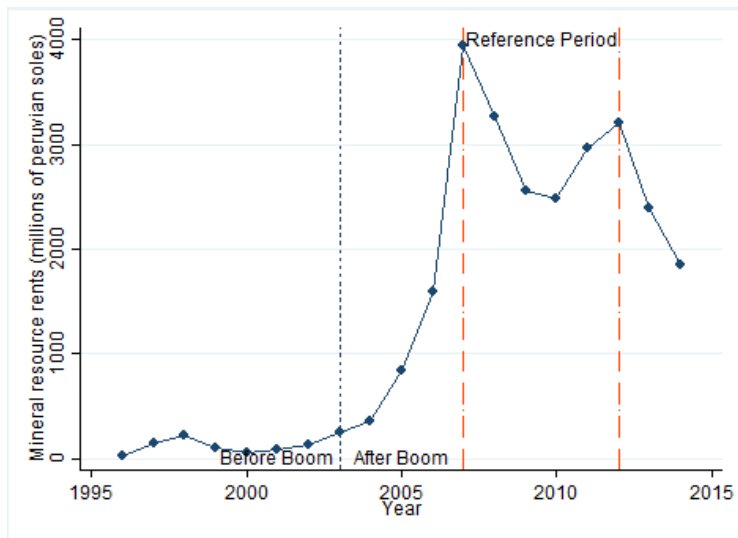
Important increase of mineral production (1996-2014)



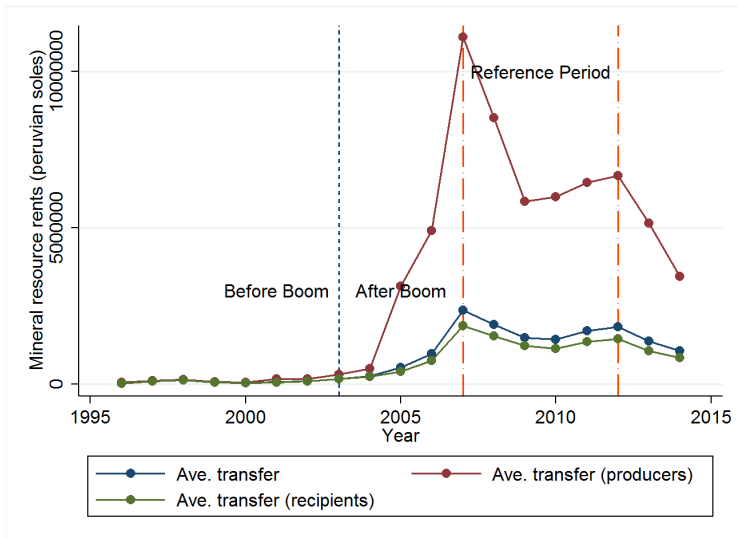
Mining production across districts: 1996-2014

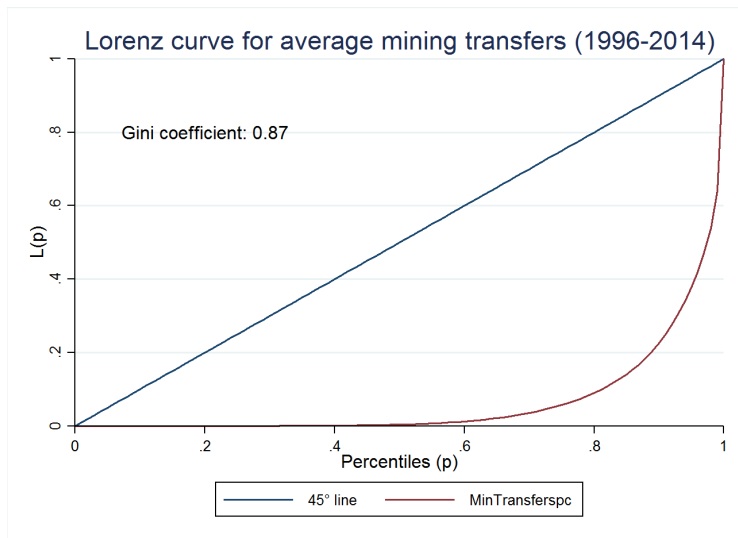


Dramatic increase in mineral rents (1996-2014)

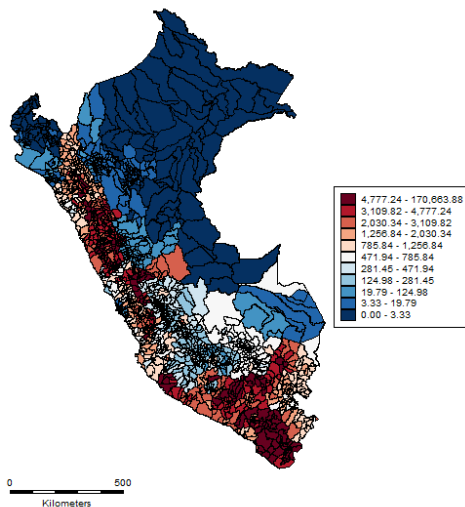


Producer districts were the most benefited





...with spatial inequalities



Mechanisms: Role of school characteristics

Table 5: School Characteristics

| | Dependent Variables | | |
|------------------------|---------------------|------------------------------------|------------------------------------------------------------------------------|
| | Enrollment | % teachers with long-term contract | % teachers with a tertiary education degree in a non-school-teaching program |
| Canon | 0.0188 (0.0159) | 0.1556*** (0.0501) | -0.0034 (0.0084) |
| Squared | 0.0070 (0.0099) | -0.0942*** (0.0247) | -0.0031 (0.0045) |
| Mining Production | -0.0011 (0.0009) | -0.0016 (0.0033) | -0.0002 (0.0007) |
| R-squared | 0.0011 | 0.0060 | 0.0009 |
| Number of observations | 284,867 | 142,318 | 142,318 |

* Significant 10%; ** significant 5%; *** significant at 1%.

Mechanisms: Role of school characteristics

Table 5: School Characteristics
Dependent Variables

| | % teachers with a tertiary education degree in a school teaching program | School has access to electricity | School has access to water | School has access to sanitation |
|------------------------|---------------------------------------------------------------------------------|-----------------------------------------|-----------------------------------|----------------------------------------|
| Canon | 0.0101 (0.0130) | 0.2032** (0.0841) | 0.0220 (0.0561) | 0.2909*** (0.1104) |
| Squared | 0.0077 (0.0061) | -0.0707* (0.0395) | -0.0158 (0.0306) | -0.1766** (0.0782) |
| Mining Production | -0.0016** (0.0008) | 0.0077** (0.0037) | 0.0066 (0.0042) | 0.0056 (0.0068) |
| R-squared | 0.0013 | 0.0387 | 0.0235 | 0.1941 |
| Number of observations | 142,318 | 234,074 | 234,072 | 234,035 |

* Significant 10%; ** significant 5%; *** significant at 1%.

▶ return

Mechanisms: Role of economic conditions

Table 6: Economic Conditions

| | Dependent Variables | | | | |
|----------------------------|----------------------|-------------------------------|-----------------------|---------------------|---------------------|
| | Unemployment | Employed in the public sector | Spending on education | Consumption | Income |
| Canon | -0.0536* (0.0291) | 0.1042* (0.0610) | 0.0757 (0.1450) | -0.0654 (0.0716) | -0.0024 (0.0965) |
| Squared | 0.0166 (0.0123) | -0.0537** (0.0253) | -0.1425** (0.0685) | -0.0121 (0.0283) | -0.0187 (0.0678) |
| Mining Production | 0.0014 (0.0029) | -0.0085** (0.0039) | 0.0087 (0.0086) | 0.0046 (0.0088) | 0.0043 (0.0053) |
| Observable characteristics | N | N | N | N | N |
| R-squared | 0.0004 | 0.0034 | 0.0267 | 0.0263 | 0.0214 |
| Number of observations | 574,210 | 117,443 | 78,236 | 136,855 | 136,849 |

* Significant 10%; ** significant 5%; *** significant at 1%.

▶ return

Mechanisms: Role of health factors

Table 7: Health factors

Dependent variable

| | Individual experienced health complications in the past 4 weeks | | Individual was sick in the past 4 weeks | | Number of days individual couldn't work due to sickness | |
|------------------------|-----------------------------------------------------------------|------------------------|-----------------------------------------|---------------------|---------------------------------------------------------|----------------------|
| | (All) | (6 to 10) | (All) | (6 to 10) | (All) | (6 to 10) |
| Canon | -0.2372*** (0.0646) | -0.3575*** (0.0946) | -0.1730*** (0.0525) | -0.1104 (0.0930) | -0.0261 (0.0882) | 0.0399 (0.1504) |
| Squared | 0.1248*** (0.0226) | 0.2701*** (0.0480) | 0.0528** (0.0218) | 0.0364 (0.0464) | -0.0212 (0.0323) | -0.1189 (0.0809) |
| Mining Production | 0.0029 (0.0040) | 0.0073 (0.0063) | 0.0070** (0.0030) | 0.0057 (0.0046) | 0.0008 (0.0043) | 0.0109** (0.0047) |
| R-squared | 0.0299 | 0.0019 | 0.0023 | 0.0019 | 0.0013 | 0.0006 |
| Number of observations | 528,064 | 56,349 | 528,064 | 56,349 | 434,325 | 46,841 |

* Significant 10%; ** significant 5%; *** significant at 1%.

▶ return

Robustness Check: Evaluating the parametric approximation

Table 8: Evaluating the parametric approximation
Dependent Variable: Math scores

| | (1) | (2) | (3) | (4) | (5) |
|-------------------------------------------------------------------------------|--------------------|-----------------------|-----------------------|----------------------|---------------------|
| Canon | 3.5246 (4.6428) | 17.3868* (10.5255) | 17.5242* (10.5110) | 12.7588 (15.1555) | 6.5527 (19.6666) |
| Squared canon | | -1.7345* (0.8924) | -1.7567** (0.8943) | 1.0082 (3.9760) | 8.3454 (10.3484) |
| Production | | | -0.0001 (0.0001) | -0.0001 (0.0001) | -0.0001 (0.0001) |
| Cubic canon | | | | -0.2372 (0.2774) | -1.8782 (1.7670) |
| Quartic canon | | | | | 0.1000 (0.0930) |
| F-test for quadratic specification | | | 3.67 [0.0257] | | |
| F-test for nested models comparison: <i>Quadratic versus Cubic model</i> | | | | 0.73 [0.3926] | |
| F-test for nested models comparison: <i>Quadratic versus Quartic model</i> | | | | | 0.59 [0.5561] |
| Observations | 2,325,127 | 2,325,127 | 2,325,127 | 2,325,127 | 2,325,127 |

* Significant 10%; ** significant 5%; *** significant at 1%.

Robustness Check: Non-producing districts

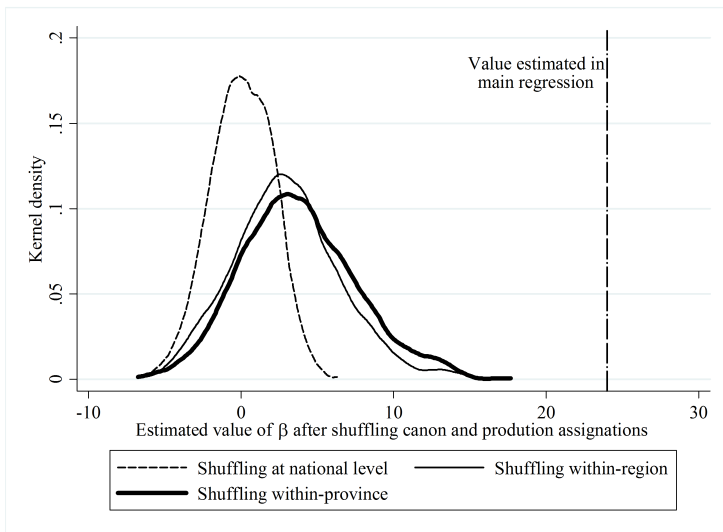
Table 9: Non-producing districts in producer provinces

| | Dependent Variable: Math Score | | |
|------------------|--------------------------------|------------------------|------------------------|
| | (1) | (2) | (3) |
| Canon | 12.2036* (6.4257) | 33.6240*** (9.4382) | 34.6193*** (9.2067) |
| Squared | | -3.2263*** (0.8302) | -3.3731*** (0.8039) |
| R-squared | 0.0061 | 0.0064 | 0.0175 |
| Observations | 538,590 | 538,590 | 527,789 |
| Student controls | N | N | Y |
| School controls | N | N | Y |

* Significant 10%; ** significant 5%; *** significant at 1%.

▶ return

Permutation test



No effect of production on math scores

Table 2A: Effect of Mining Production on Test Scores

| | Dependent variable: Math scores | | | |
|-------------------|---------------------------------|---------------------|---------------------|---------------------|
| | (1) | (2) | (3) | (4) |
| Mining production | 0.0000 (0.0001) | 0.0001 (0.0002) | 0.0001 (0.0002) | 0.0001 (0.0002) |
| Squared | | -0.0000 (0.0000) | -0.0000 (0.0000) | -0.0000 (0.0000) |
| R-squared | 0.0062 | 0.0062 | 0.0146 | 0.0173 |
| Observations | 2,072,339 | 2,072,339 | 2,015,428 | 2,011,452 |
| Student controls | N | N | Y | Y |
| School controls | N | N | N | Y |

* Significant 10%; ** significant 5%; *** significant at 1%.

No effect of production on reading scores

Table 2B: Effect of Mining Production on Test Scores

| | Dependent variable: Reading scores | | | |
|-------------------|------------------------------------|-----------------------|-----------------------|-----------------------|
| | (1) | (2) | (3) | (4) |
| Mining production | -0.0001 (0.0001) | 0.0001 (0.0001) | 0.0001 (0.0001) | 0.0001 (0.0001) |
| Squared | | -0.0000** (0.0000) | -0.0000** (0.0000) | -0.0000** (0.0000) |
| R-squared | 0.0266 | 0.0266 | 0.0603 | 0.0645 |
| Observations | 2,068,271 | 2,068,271 | 2,011,576 | 2,007,595 |
| Student controls | N | N | Y | Y |
| School controls | N | N | N | Y |

* Significant 10%; ** significant 5%; *** significant at 1%.

Threats to identification

- Mineral prices can be endogenous.
 - Peru is top mineral producer \Rightarrow It can influence international prices.
 - However:
 - Many private mining companies operate in the country (854).
 - Consensus about the role of China's industrialization.
- Mineral production can be endogenous.
 - Local governments: attract mining companies to get rents.
 - Mining companies: expand production and start new production units.
 - However:
 - Local governments play no role in granting rights/permits.
 - Starting new projects takes 7 years on average.

Graphical explanation of mechanisms

