Intensive and Extensive Margins of Mining and Development: Evidence from Sub-Saharan Africa

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CSAE, Oxford
Motivation

▶ Robust growth in sub-Saharan Africa, fueled by commodity exports
  – Mineral exports ballooned from $38 billion to $300 billion
  – Growth has shifted sectoral shares, resource sector gaining

▶ ToT turned to the advantage of commodity exporters:
Motivation
Resource Curse

▸ Several causes
  – Dutch Disease (Corden & Neary 1982, Krugman 1987)
  – Macroeconomic stability (Deaton 1999)

▸ Resource curse conditional on the quality of institutions (Mehlum et al., 2006; Robinson et al., 2006; Collier & Hoeffler, 2009; Bhattacharyya & Hodler, 2010, 2014; Bhattacharyya & Collier, 2014)

▸ Mining sector highly productive (McMillan & Rodrik 2014), but very limited forward and backward linkages (Singer 1950) been actively discussed by many scholars, thorough empirical analyses of the extent of spillovers are non-existent
Motivation

- Literature moved to local level analysis
  - Off-shore oil induced windfall & public goods provision in Brazilian municipalities: “missing money” (Caselli & Michaels 2013, *AEJ: AE*)
  - Oil and gas booms and busts in resource-abundant U.S. counties: No evidence of “Domestic Dutch disease” (Allcott & Keniston 2015, *REStud*)
  - Peruvian gold mine (Aragón & Rud 2013, *AEJ: AE*)
  - Female employment in sub-Saharan Africa (Kotsadam & Tolonen, 2016, *WD*)

- This paper: Did mineral extraction and discovery raise local living standards in sub-Saharan Africa?
Ihosy finds Sapphire in 1999
Innovations

- Focus on minerals as opposed to oil/gas; local level but covering an entire continent

- Distinction between intensive and extensive margin

- Tackling causality
  - Discoveries of mineral deposits as exogenous news shock
  - Proposing a plausible control group
  - Placebo tests

- Explicit modeling of General Equilibrium effects
  - Exclude lights emitted from mine itself
  - Spatial Spillovers, Aggregation
  - Directional (capital city)
Night-lights increase with expansion in mineral production (intensive margin):
- 2%-4% increase in night-lights for a 1% increase in production

Large effects are mainly associated with new discoveries and new production (extensive margin)
- 2 years prior to production start, 6 year post-discovery
- An average mine increases district GDP by ca. 16%

General equilibrium effects: Little evidence of large spillovers across districts boundaries, within the same administrative region, to capital cities, or major cities

Little persistence: When districts lose all their mines, night-lights drop to pre-mining levels
Data

- District (2nd level administrative unit) as unit of observation

- Mineral production quantity of 21 commodities for 548 industrial size mines from Intierra RMG database
  - Diamonds, iron, gold, silver, copper, nickel, aluminum, cobalt, zinc, lead, manganese, bauxite, tantalum, zircon, tin, chromite, antimony, platinum-group metals (PGE), vanadium, vermiculite and graphite

- Precise discovery dates and locations for 263 giant and major mineral discoveries 1950-2012 from MinEx consultancies

- 3,635 districts, 519 regions and 42 countries over 1992-2012
Data

District Level Boundary Map

Mining Industry Locations

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Mining and Development in Africa
Data

District Level Boundary Map

Mineral Deposit Locations
Data

- Measuring local economic activity from outer space: satellite data on **night-time lights** ("luminosity") from NOAA (2013)

- Available at a high spatial resolution (30-second grids - equivalent to 1 square kilometer)

- We construct **lights density** - lights adjusted for area controlling for population
  - Henderson, Storeygard and Weil (2012) in AER
  - Michalopoulos and Papaioannou (2013) in Econometrica
  - Hodler & Raschky (2014) in QJE
Luminosity and Measures of Income and Wealth

Regional GDP & luminosity

Source: Hodler & Raschky (2014)

Household wealth & luminosity

Source: Michalopoulos & Papaioannou (2013)
## Summary Statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Obs</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Main Variables</strong></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\ln(0.01+\text{Lights density per sq. km})$</td>
<td>76335</td>
<td>-2.36</td>
<td>2.38</td>
<td>-4.61</td>
<td>4.51</td>
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<tr>
<td>$\ln(\text{Mineral production})$</td>
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<td>3.47</td>
<td>-0.23</td>
<td>27.63</td>
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<td>$\ln(\text{Min. prod. 1992 commodity prices})$</td>
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<td>0.10</td>
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<tr>
<td><strong>Controls: Population and Geography Variables</strong></td>
<td></td>
<td></td>
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<tr>
<td>$\ln(\text{Population density per sq. km})$</td>
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<td>3.98</td>
<td>1.61</td>
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<td>$\ln(\text{Altitude in m})$</td>
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<td>5.88</td>
<td>1.38</td>
<td>0.62</td>
<td>7.91</td>
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<td>$\ln(\text{Ruggedness})$</td>
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<td>0</td>
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<tr>
<td>Share of district with fertile soil</td>
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<td>18.60</td>
<td>29.45</td>
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<td>100</td>
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<td>$\ln(\text{Distance to the coast in km})$</td>
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<td>5.55</td>
<td>1.39</td>
<td>-4.23</td>
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<tr>
<td>$\ln(\text{Land surface area in sq. km})$</td>
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<td>7.41</td>
<td>1.72</td>
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<td>12.79</td>
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<tr>
<td><strong>Controls: Climate Variables</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\ln(\text{Annual average rainfall in mm})$</td>
<td>76335</td>
<td>5.12</td>
<td>0.76</td>
<td>0.13</td>
<td>6.38</td>
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<td>Share of district with tropical climate</td>
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<td>60.19</td>
<td>47.12</td>
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<td>Share of district with dry/arid climate</td>
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<td><strong>Controls: Urbanization and Political Economy Variables</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital city ($1=\text{yes}$)</td>
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<td>0.01</td>
<td>0.11</td>
<td>0</td>
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<tr>
<td>$\ln(\text{Distance to the capital city in km})$</td>
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<td>5.47</td>
<td>0.97</td>
<td>0.66</td>
<td>7.54</td>
</tr>
<tr>
<td>Ethnic Fractionalization</td>
<td>76335</td>
<td>0.21</td>
<td>0.24</td>
<td>0</td>
<td>0.93</td>
</tr>
<tr>
<td><strong>Controls: Infrastructure Variables</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\ln(\text{Paved road density per sq. km (2000)})$</td>
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<td>0.02</td>
<td>0.04</td>
<td>0</td>
<td>0.52</td>
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<tr>
<td>$\ln(\text{Railway density per sq. km (2000)})$</td>
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<td>1.01</td>
<td>1.72</td>
<td>0</td>
<td>6.79</td>
</tr>
<tr>
<td>$\ln(\text{Electric-grid density per sq. km (2000)})$</td>
<td>76335</td>
<td>0.07</td>
<td>0.17</td>
<td>0</td>
<td>2.25</td>
</tr>
</tbody>
</table>
We start with exploring the effect of mineral production in mineral producing districts (intensive margin):

\[ LD_{dt} = \alpha_d + \beta_t + \gamma MP_{dt} + X_{dt} \Phi + \epsilon_{dt} \]

where \( LD_{dt} \) is the natural log of night-lights density; \( MP_{dt} \) is the natural log of mineral production value summed up over 21 commodities; \( X_{dt} \) is a vector of district level control variables; \( \alpha_d \) are district fixed effects; \( \beta_t \) are year fixed effects

- We distinguish between value and quantity by expressing \( MP_{dt} \)
  - in 1992 constant dollars
  - in 1992 constant commodity prices
To study the **extensive margin**, we replace $MP_{dt}$ with a dummy variable equal to one if the district has a producing mine.

Identification comes from temporal variation within districts.

Validity of this strategy rests on the assumption that fluctuations in mineral production are driven by factors external to the district.
Identifying a suitable **control group** (that matches the treatment group in every respect except the treatment)
  - Districts that never had any mining activity (control 1)
  - Districts with mining potential as examined in a feasibility study, but where no mining has taken place yet (control 2).

We define the **treatment group** as those districts that started mineral production for the first time between 2003 and 2012.

We have a symmetric pre- and post-treatment period of 1992-2002 and 2003-2012, respectively.

We rely on the same pre-treatment trends to lend confidence to the parallel trend assumption.
Identification strategies - Extensive margin

Identification using discoveries of mineral deposits: exogenous news shocks:

\[ LD_{dt} = \tilde{\alpha}_d + \tilde{\beta}_t + \sum_{j=0}^{10} \tilde{\gamma}_j MD_{dt-j} + X'_{dt} \tilde{\Lambda} + \tilde{\epsilon}_{dt} \]

where \( MD_{dt-j} \) is a dummy variable equal to 1 if a mineral discovery has been made in year \( t - j \), 0 if no discovery has been made (comparison group)

▶ We restrict \( MD_{dt-j} \) to first discoveries in districts that never had any mining activity before. This restriction serves two purposes:

- Existing mining may affect local development and it is difficult to disentangle this effect from the effect of a new discovery
- Anticipation due to past knowledge of discoveries. First discovery and its exact timing are much harder to predict

▶ Placebo: \( MD_{dt+j} \) Effects before discovery?
Spatial Patterns of Spillovers

Identify spillover effects using techniques from spatial econometrics:

\[ LD_{dt} = \alpha_d + \mu_t + \rho WLD_{dt} + \gamma MA_{dt} + \theta WMA_{dt} + X_{dt} \beta + WX_{dt} \delta + \epsilon_{dt} \]

where: \( W \) represents spatial weights matrix that defines potential interaction, and interaction is defined if districts share a common border (0/1 weights); \( WLD \) - spatially lagged dependent variable; \( WMA \) - spatially lagged explanatory variables.

Thus, spillovers can originate from two sources:

1. Mining activities in neighboring districts \( WMA \) may affect a district’s night-lights \( LD \)

2. Mining activities \( MA \) directly affect district’s night-lights \( LD \), and this represents a change in \( WLD \) to district’s neighbors
Table 2: Associations between Mineral Production and Night-Lights at District Level

<table>
<thead>
<tr>
<th></th>
<th>Intensive margin</th>
<th>Extensive margin</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>Ln(Mineral production)</td>
<td>0.024*</td>
<td>-0.061</td>
</tr>
<tr>
<td></td>
<td>(0.014)</td>
<td>(0.047)</td>
</tr>
<tr>
<td>Ln(Mineral production in</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1992 commodity prices)</td>
<td>0.038**</td>
<td>0.102*</td>
</tr>
<tr>
<td></td>
<td>(0.018)</td>
<td>(0.057)</td>
</tr>
<tr>
<td>Mineral production (1=yes)</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Population density &amp; Rainfall</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Year Fixed Effects</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>District Fixed Effects</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>N</td>
<td>1,802</td>
<td>1,802</td>
</tr>
<tr>
<td>N(Districts/Regions/Countries)</td>
<td>137/80/28</td>
<td>137/80/28</td>
</tr>
<tr>
<td>R-squared adj.</td>
<td>0.979</td>
<td>0.979</td>
</tr>
</tbody>
</table>

Notes: This table shows the association between night-lights and various measures of mining activity in a panel of district-year observations for the period 1992-2012. Dependent variable is Ln(0.01+Nighttime Lights Density per sq. km). Column (1) expresses the mineral production value in 1992 constant USD. Column 2 expresses the mineral production value in 1992 constant commodity prices. Column 3 includes both those indicators. Column 4 uses a dummy variable equal to one if the district had a producing mine thereby using the full sample. For a detailed variable description, see Data Appendix. Robust standard errors clustered by region are in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.
### Table 3: Where Do Mining Investments Go?

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Number of districts at each stage</td>
<td>353</td>
<td>290</td>
<td>203</td>
<td>86</td>
<td>82</td>
<td>19</td>
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<tr>
<td>Ln(Nightlights density in 2000)</td>
<td>0.003</td>
<td>-0.001</td>
<td>-0.002</td>
<td>-0.001</td>
<td>0.002</td>
<td>0.001</td>
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<tr>
<td></td>
<td>(0.005)</td>
<td>(0.004)</td>
<td>(0.004)</td>
<td>(0.002)</td>
<td>(0.003)</td>
<td>(0.001)</td>
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<tr>
<td>Ln (Population density in 2000)</td>
<td>-0.007</td>
<td>-0.001</td>
<td>0.007</td>
<td>-0.002</td>
<td>0.007</td>
<td>0.003*</td>
</tr>
<tr>
<td></td>
<td>(0.008)</td>
<td>(0.006)</td>
<td>(0.006)</td>
<td>(0.003)</td>
<td>(0.004)</td>
<td>(0.002)</td>
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<tr>
<td>Ln(Paved road density in 2000)</td>
<td>0.083</td>
<td>0.093</td>
<td>-0.054</td>
<td>-0.061</td>
<td>0.077</td>
<td>-0.023</td>
</tr>
<tr>
<td></td>
<td>(0.096)</td>
<td>(0.082)</td>
<td>(0.084)</td>
<td>(0.053)</td>
<td>(0.055)</td>
<td>(0.041)</td>
</tr>
<tr>
<td>Ln(Railway density in 2000)</td>
<td>-0.005</td>
<td>0.002</td>
<td>-0.007*</td>
<td>-0.001</td>
<td>-0.002</td>
<td>0.001</td>
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<td></td>
<td>(0.005)</td>
<td>(0.005)</td>
<td>(0.004)</td>
<td>(0.003)</td>
<td>(0.003)</td>
<td>(0.001)</td>
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<tr>
<td>Ln(Electric grid density in 2000)</td>
<td>0.012</td>
<td>-0.048*</td>
<td>0.025</td>
<td>-0.011</td>
<td>-0.026</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>(0.024)</td>
<td>(0.026)</td>
<td>(0.033)</td>
<td>(0.016)</td>
<td>(0.016)</td>
<td>(0.005)</td>
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<td>Geographic Controls</td>
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<td>Yes</td>
<td>Yes</td>
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<td>Climatic Controls</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<td>Political Economy Controls</td>
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<td>Yes</td>
<td>Yes</td>
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<td>Region Fixed Effects</td>
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<td>3,635</td>
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<td>3,635</td>
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<tr>
<td>N(Districts/Regions/Countries)</td>
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<td>3,635/519/42</td>
<td>3,635/519/42</td>
<td>3,635/519/42</td>
<td>3,635/519/42</td>
<td>3,635/519/42</td>
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<td>R-squared adj.</td>
<td>0.291</td>
<td>0.294</td>
<td>0.233</td>
<td>0.251</td>
<td>0.205</td>
<td>0.171</td>
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</tbody>
</table>

**Notes:** This table reports the correlation between district characteristics in 2000 and different stages of mining exploration in 2012 in a cross-section of district observations. The stages of mining exploration data is derived from InterraRMG. We test for six stages that mining projects typically undergo, from grassroots exploration to construction. With the passing of each stage mineral production becomes more likely. In columns (1)-(6), the dependent variable is a dummy equal to one if a district experiences grassroots exploration, exploration, advanced exploration, pre-feasibility study, feasibility study and actual construction of a mine, respectively. Linear Probability Model is used for the estimation. Robust standard errors in parentheses are clustered by region. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.
Control-Treatment comparison, Dif-and-Dif

Table 4: Comparison of Treated and Control Districts (Mineral Production Treatment)

<table>
<thead>
<tr>
<th></th>
<th>Treated</th>
<th>Treated-Control 1</th>
<th>Treated-Control 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td>Number of Districts</td>
<td>53</td>
<td>3284</td>
<td>156</td>
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<tr>
<td>Panel A: Time-Invariant Cross-Sectional Variables</td>
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<td></td>
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<tr>
<td>Ln(Altitude in m)</td>
<td>6.18</td>
<td>0.14*</td>
<td>-0.00</td>
</tr>
<tr>
<td>Ln(Ruggedness)</td>
<td>4.31</td>
<td>0.14*</td>
<td>-0.04</td>
</tr>
<tr>
<td>Share of district with fertile soil</td>
<td>16.09</td>
<td>-0.04</td>
<td>-0.09</td>
</tr>
<tr>
<td>Ln(Distance to the Coast in km)</td>
<td>5.76</td>
<td>0.09</td>
<td>0.05</td>
</tr>
<tr>
<td>Ln(Land surface area in sq. km)</td>
<td>8.40</td>
<td>0.36***</td>
<td>-0.03</td>
</tr>
<tr>
<td>Ln(Average annual rainfall in mm)</td>
<td>4.73</td>
<td>-0.15**</td>
<td>0.03</td>
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<tr>
<td>Share of district with tropical climate</td>
<td>50.88</td>
<td>-0.11*</td>
<td>-0.09</td>
</tr>
<tr>
<td>Share of district with dry/arid climate</td>
<td>27.17</td>
<td>0.03</td>
<td>0.00</td>
</tr>
<tr>
<td>Share of district with temperate climate</td>
<td>21.94</td>
<td>0.12**</td>
<td>0.11</td>
</tr>
<tr>
<td>Capital city (1=yes)</td>
<td>0</td>
<td>-0.11</td>
<td>-0.08</td>
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<tr>
<td>Ln (Distance to the capital city in km)</td>
<td>5.56</td>
<td>0.05</td>
<td>-0.03</td>
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<tr>
<td>Ethnic Fractionalization</td>
<td>0.31</td>
<td>0.24***</td>
<td>0.02</td>
</tr>
<tr>
<td>Ln(Paved road density per sq. km in 2000)</td>
<td>0.02</td>
<td>-0.05</td>
<td>0.10</td>
</tr>
<tr>
<td>Ln(Railway density per sq. km in 2000)</td>
<td>1.66</td>
<td>0.21***</td>
<td>0.03</td>
</tr>
<tr>
<td>Ln(Electric-grid density per sq. km in 2000)</td>
<td>0.06</td>
<td>-0.05</td>
<td>0.16**</td>
</tr>
<tr>
<td>Panel B: Trend Comparison</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Ln (0.01+Nighttime Lights Density)</td>
<td>0.60</td>
<td>-0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Pre-treatment growth 1992-2002</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Post-treatment growth 2003-2012</td>
<td>1.33</td>
<td>0.41***</td>
<td>0.53***</td>
</tr>
<tr>
<td>Ln (0.01+Nighttime Lights Per Capita)</td>
<td>0.40</td>
<td>0.01</td>
<td>0.02</td>
</tr>
<tr>
<td>Pre-treatment growth 1992-2002</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-treatment growth 2003-2012</td>
<td>1.17</td>
<td>0.44**</td>
<td>0.55***</td>
</tr>
</tbody>
</table>
Districts that started mining post 2002: Parallel Trends

![Graph showing trends in mean of logged lights density for different mining districts.](image)

- **Never mined districts**
- **Prospective mining districts**
- **Mining districts**
Districts that started mining post 2002: Parallel Trends

The graph shows the natural logarithm of lights density over years before/after the start of production (IntierraRMG). The years range from -10 to 10, with 0 indicating the start of production. The graph includes a 95% confidence interval (CI) and a smooth line (lploy) indicating trends.
## Mineral Discovery

<table>
<thead>
<tr>
<th>$MD_{d_t-j}$: Mineral discovery made in year $t-j$</th>
<th>First Discoveries</th>
<th>Single, First Discoveries</th>
<th>Giant Discoveries</th>
<th>Major Discoveries</th>
</tr>
</thead>
<tbody>
<tr>
<td>$j = 0$</td>
<td>-0.029</td>
<td>-0.028</td>
<td>-0.032</td>
<td>-0.024</td>
</tr>
<tr>
<td></td>
<td>(0.061)</td>
<td>(0.063)</td>
<td>(0.098)</td>
<td>(0.081)</td>
</tr>
<tr>
<td>$j = 1$</td>
<td>0.023</td>
<td>0.024</td>
<td>0.100</td>
<td>-0.005</td>
</tr>
<tr>
<td></td>
<td>(0.073)</td>
<td>(0.075)</td>
<td>(0.111)</td>
<td>(0.091)</td>
</tr>
<tr>
<td>$j = 2$</td>
<td>-0.011</td>
<td>-0.008</td>
<td>0.075</td>
<td>-0.043</td>
</tr>
<tr>
<td></td>
<td>(0.079)</td>
<td>(0.081)</td>
<td>(0.106)</td>
<td>(0.098)</td>
</tr>
<tr>
<td>$j = 3$</td>
<td>0.019</td>
<td>0.006</td>
<td>-0.015</td>
<td>0.039</td>
</tr>
<tr>
<td></td>
<td>(0.086)</td>
<td>(0.087)</td>
<td>(0.131)</td>
<td>(0.094)</td>
</tr>
<tr>
<td>$j = 4$</td>
<td>0.071</td>
<td>0.068</td>
<td>0.085</td>
<td>0.070</td>
</tr>
<tr>
<td></td>
<td>(0.100)</td>
<td>(0.104)</td>
<td>(0.167)</td>
<td>(0.111)</td>
</tr>
<tr>
<td>$j = 5$</td>
<td>0.126</td>
<td>0.114</td>
<td>0.146</td>
<td>0.122</td>
</tr>
<tr>
<td></td>
<td>(0.104)</td>
<td>(0.109)</td>
<td>(0.174)</td>
<td>(0.114)</td>
</tr>
<tr>
<td>$j = 6$</td>
<td>0.194**</td>
<td>0.190*</td>
<td>0.314</td>
<td>0.134</td>
</tr>
<tr>
<td></td>
<td>(0.112)</td>
<td>(0.118)</td>
<td>(0.220)</td>
<td>(0.118)</td>
</tr>
<tr>
<td>$j = 7$</td>
<td>0.242**</td>
<td>0.218*</td>
<td>0.342</td>
<td>0.190</td>
</tr>
<tr>
<td></td>
<td>(0.121)</td>
<td>(0.126)</td>
<td>(0.235)</td>
<td>(0.123)</td>
</tr>
<tr>
<td>$j = 8$</td>
<td>0.387***</td>
<td>0.391***</td>
<td>0.484**</td>
<td>0.331**</td>
</tr>
<tr>
<td></td>
<td>(0.137)</td>
<td>(0.147)</td>
<td>(0.235)</td>
<td>(0.161)</td>
</tr>
<tr>
<td>$j = 9$</td>
<td>0.401***</td>
<td>0.402***</td>
<td>0.477**</td>
<td>0.355**</td>
</tr>
<tr>
<td></td>
<td>(0.149)</td>
<td>(0.155)</td>
<td>(0.247)</td>
<td>(0.171)</td>
</tr>
<tr>
<td>$j = 10$</td>
<td>0.438***</td>
<td>0.431***</td>
<td>0.538**</td>
<td>0.373**</td>
</tr>
<tr>
<td></td>
<td>(0.149)</td>
<td>(0.156)</td>
<td>(0.253)</td>
<td>(0.166)</td>
</tr>
</tbody>
</table>

**Pop. density & Rainfall**
- Yes
- Yes
- Yes
- Yes

**Year Fixed Effects**
- Yes
- Yes
- Yes
- Yes

**District Fixed Effects**
- Yes
- Yes
- Yes
- Yes

**N**
- 74,234
- 74,178
- 73,150
- 73,828

**N(Discoveries)**
- [66, 79]
- [57, 77]
- [21, 28]
- [38, 55]

**N(Districts/Regions/Countries)**
- 3,560/516/42
- 3,557/516/42
- 3,493/515/42
- 3,530/515/42

**R-squared adj.**
- 0.944
- 0.944
- 0.944
- 0.944

Nemera Mamo, Sambit Bhattacharyya, Alexander Moradi  Mining and Development in Africa
From Discovery to Production

![Graph showing the proportion of discoveries entering production over analysis time. The graph distinguishes between giant deposits, major deposits, and all deposits.](image-url)
Spillovers, Linkages, or an ‘Enclave’?

- Extreme form: Just the light emitted from the mine itself

South Deep gold mine in Mpumalanga, South Africa
Extreme form: Just the light emitted from mine itself?

- Drop lights emitted within a 2 km radius of the mine

- Coefficients decrease slightly, but remain significant
## Spatial Spillovers

### Panel A: Estimated Coefficients

<table>
<thead>
<tr>
<th></th>
<th>Start-up of Mineral Production</th>
<th>First Mineral Discovery</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OLS (1)</td>
<td>SDM (2)</td>
</tr>
<tr>
<td>District has a producing mine</td>
<td>0.554*** (0.117)</td>
<td>0.559*** (0.115)</td>
</tr>
<tr>
<td>W(District has a producing mine)</td>
<td>-0.153 (0.182)</td>
<td></td>
</tr>
<tr>
<td>Discovery in the past 5 years</td>
<td></td>
<td>0.009 (0.072)</td>
</tr>
<tr>
<td>W(Discovery in the past 5 years)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discovery in the past 6-10 years</td>
<td></td>
<td>0.257** (0.113)</td>
</tr>
<tr>
<td>W(Discovery in the past 6-10 years)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discovery more than 10 years ago</td>
<td></td>
<td>0.593*** (0.150)</td>
</tr>
<tr>
<td>W(Discovery more than 10 years ago)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Population density &amp; Rainfall</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Year Fixed Effects</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>District Fixed Effects</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>$\rho$</td>
<td>0.232*** (0.016)</td>
<td>0.232*** (0.016)</td>
</tr>
<tr>
<td>$\delta = 0$ ($\chi^2$-Test, p-val)</td>
<td>0.66</td>
<td></td>
</tr>
<tr>
<td>$\theta = \delta = 0$ ($\chi^2$-Test, p-val)</td>
<td>0.38</td>
<td>0.45</td>
</tr>
<tr>
<td>$\theta = -\rho \bar{y}$ and $\bar{y} = -\rho' y$ ($\chi^2$-Test, p-val)</td>
<td>0.19</td>
<td>0.43</td>
</tr>
<tr>
<td>N</td>
<td>76,335</td>
<td>76,335</td>
</tr>
<tr>
<td>N(Districts/Regions/Countries)</td>
<td>3,635/519/42</td>
<td>3,635/519/42</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.947</td>
<td>0.173</td>
</tr>
</tbody>
</table>

### Panel B: Direct & Indirect Effects of Mining from SDM

<table>
<thead>
<tr>
<th></th>
<th>Direct</th>
<th>Indirect</th>
<th>Direct</th>
<th>Indirect</th>
</tr>
</thead>
<tbody>
<tr>
<td>District has a producing mine</td>
<td>0.573*** (0.115)</td>
<td>0.004 (0.264)</td>
<td>0.013 (0.064)</td>
<td>-0.172 (0.276)</td>
</tr>
<tr>
<td>Discovery in the past 5 years</td>
<td></td>
<td></td>
<td>0.230** (0.104)</td>
<td>-0.139 (0.242)</td>
</tr>
<tr>
<td>Discovery in the past 6-10 years</td>
<td></td>
<td></td>
<td>0.518*** (0.129)</td>
<td>0.172 (0.296)</td>
</tr>
<tr>
<td>Discovery more than 10 years ago</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Table 7: Associations between Mineral Production, Discovery and Night-Lights at Region Level

<table>
<thead>
<tr>
<th>Region excluding districts with mineral activities</th>
<th>Intensive margin</th>
<th>Extensive margin</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>Ln(Mineral production)</td>
<td>0.018</td>
<td>-0.006</td>
</tr>
<tr>
<td></td>
<td>(0.018)</td>
<td>(0.019)</td>
</tr>
<tr>
<td>Ln(Mineral production in 1992 commodity prices)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mineral production (1=yes)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discovery in the past 5 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discovery in the past 6-10 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discovery more than 10 years ago</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Population density &amp; Rainfall</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Year Fixed Effects</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Region Fixed effects</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>N</td>
<td>1,057</td>
<td>948</td>
</tr>
<tr>
<td>N (Regions/Countries)</td>
<td>80/28</td>
<td>72/27</td>
</tr>
<tr>
<td>R-squared adj.</td>
<td>0.984</td>
<td>0.983</td>
</tr>
</tbody>
</table>

**Notes:** This table shows associations between mining activities and night-lights in a panel of region-year observations for the period 1992-2012. Dependent variable is Ln(0.01+Nighttime Lights Density per sq. km). Column (1) & (2) expresses the mineral production value in 1992 constant USD. Column (3) & (4) expresses the mineral production value in 1992 constant commodity prices. Column (5) & (6) uses a dummy variable equal to one if the region had a producing mine thereby using the full sample. Column (7) & (8) expresses mining activity as a dummy equal to one if the region had at least one discovery in the last 5, 6-10, and more than 10 years ago. In every odd column, the unit of observation is a region aggregated over all districts, whereas in every even column region aggregate excludes districts with any recorded mining activity. Robust standard errors clustered by region are in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.
Spillovers to Cities

- Rents may be consumed in cities (Gollin et al. 2016)

- Lights of capital city & two largest cities in 1992 NOT correlated with mineral exports value or mineral rents as a percentage of GDP
## Persistence after mines shut down

### Table 8: Mine Closure and Development

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>District has been mined</td>
<td>0.722***</td>
<td>0.725***</td>
<td>0.722***</td>
</tr>
<tr>
<td></td>
<td>(0.162)</td>
<td>(0.161)</td>
<td>(0.162)</td>
</tr>
<tr>
<td>Shutdown</td>
<td>-0.491*</td>
<td>-0.224</td>
<td>-0.224</td>
</tr>
<tr>
<td></td>
<td>(0.264)</td>
<td>(0.137)</td>
<td>(0.137)</td>
</tr>
<tr>
<td>Shutdown and not reopened by 2012</td>
<td>-0.837</td>
<td>-0.531</td>
<td>(0.700)</td>
</tr>
<tr>
<td>Population density &amp; Rainfall</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Year Fixed Effects</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>District Fixed Effects</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>N</td>
<td>76,335</td>
<td>76,335</td>
<td>76,314</td>
</tr>
<tr>
<td>N(Districts/Regions/Countries)</td>
<td>3,635/519/42</td>
<td>3,635/519/42</td>
<td>3,634/519/42</td>
</tr>
<tr>
<td>R-squared adj.</td>
<td>0.947</td>
<td>0.947</td>
<td>0.947</td>
</tr>
</tbody>
</table>

**Notes:** This table shows the association between a stop in mining activities and night-lights in a panel of district-year observations for the period 1992-2012. The dependent variable is \(\ln(0.01 + \text{Nighttime Lights Density per sq. km})\). "District has been mined" is a dummy variable equal to 1, once a district had at least one producing mine. "Shutdown" is a dummy variable equal to 1, if all mines in a district shut down (it may be temporary or persistent). "Shutdown and not reopened by 2012" is a dummy variable equal to 1 if all mines in a district shut down and none has reopened by 2012. Column (1) and (2) include all districts. Column (3) excludes Bonte District in Sierra Leone, where the closure was reportedly caused by rebels during the civil war. Data from MinEx. Robust standard errors clustered by region are in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.
Robustness

- **Missing production data**
  - Drop district-year observations if quantity of a single commodity is missing

- **Light intensity in sparsely populated areas (Min 2008; Cogneau & Dupraz, 2015)**
  - Drop sparsely populated districts (< 4 people per km$^2$)
  - Drop zero luminosity districts

- **Implicit weighting using districts as unit of observation**
  - Weight districts by population size
  - Weight districts by the inverse of the total number of districts in a country

- **Districts possibly endogenous**
  - Use 0.5 x 0.5 degree grid cells (ca 55 x 55 km at the equator)
Findings

- Night-lights increase with expansion in mineral production (intensive margin):
  - 2%-4% increase in night-lights for a 1% increase in production

- Large effects are mainly associated with new discoveries and new production (extensive margin)
  - 2 years prior to production start, 6 year post-discovery
  - An average mine increases district GDP by ca. 16%

- General equilibrium effects: Little evidence of large spill-overs across districts boundaries, within the same administrative region, to capital cities, or major cities

- Little persistence: When districts lose all their mines, night-lights drop to pre-mining levels