The Heterogeneous Effects of Transportation Infrastructure: Evidence from Sub-Saharan Africa

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WORK IN PROGRESS

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Research Questions

- How has intercity road upgrading affected local economic development in Sub-Saharan Africa?
- What are the implications for current/future road-building efforts?
  - About 1/5 of World Bank lending on transport, 13% on roads.
  - Large fraction of network still unpaved
  - Trans-African Highway network as coordinating mechanism: 55,000 km of planned highways (vs. 1,000 km of highways in c. 2012).
    - Abidjan-Lagos Motorway: $8 billion
    - LAPSSET Project in Kenya-Ethiopia-South Sudan: $22 billion
    - Gauteng-Maputo Development Corridor: $5 billion
- What are the implications for African urbanization?
  - Expected increase 30% in 2010 to 50% in 2030: which cities?
Effects of Possible Future Highway Networks?
What We Do

- Build a **new panel data set** on road surface, city population and market access for 39 Sub-Saharan African countries 1960-2010.

- Estimate the average effects of **market access** changes (as induced by road surface changes) on city growth.
  - IV estimates: a doubling of market access induces a 5–18% increase in city population (vs. 3-5% OLS)
  - effect spread up to 30 years after road upgrading
Related work

- Highway infrastructure impacts in China, USA, India, Brazil: Baum-Snow et al. 2015; Faber, 2014; Allen & Arkolakis 2014; Morten & Oliveira 2014;
- Rail infrastructure impacts in China, USA, India, Ghana, Kenya (Jedwab & Moradi 2015; Jedwab et al. 2015; Baum-Snow et al. 2015; Donaldson forth.; Donaldson & Hornbeck 2015)
- Micro road surface/quality impacts
  - Agricultural prices in Sierra Leone (Casaburi et al. 2013),
  - Manufacturing employment in Indonesia (Gertler et al. 2014)
  - Household wealth in Mexico (Gonzalez-Navarro and Quintana-Domeque 2016)
- Transport and trade costs in Africa
  - rail (Jedwab & Moradi 2015; Jedwab, Kerby & Moradi 2015)
  - fuel prices (Storeygard 2016)
  - inferred from price changes (Atkin and Donaldson 2015; Porteous 2015)
Our contributions

▶ Scale: 39 countries, 6 time slices over 50 years

▶ Timing and heterogeneous effects.

▶ Not just building highways: paving and improving (gravelling)
Outline

▶ Data

▶ Estimation

▶ Results

▶ Conclusion
Data: Roads

**GIS database of roads:**

- *Michelin* paper road maps for 39 Sub-Saharan African countries from the early 1960s to date. Sources:
  - Government maps
  - Feedback from customers (large network of tire distributors and correspondents)

- Map ≈ every 3 years, so 833 country-years

- Surface of each road: *Highway, Paved, Improved* and *Dirt* (vs. Primary, secondary, tertiary)

- No city streets
Michelin Road Map Countries and Years
Roads in 1960

Road Type
- Highway
- Paved (Non-Highway)
- Improved
- Dirt
Roads in 2010

Road Type
- Highway
- Paved (Non-Highway)
- Improved
- Dirt
Road Length in Sub-Saharan Africa (39 Countries)
Data: Cities

**GIS database of cities:**


- Proxy for local economic development in the absence of other data (no land prices, no systematic rural populations before c. 1990, no night lights before 1992).

- Sources: *Africapolis I* and *II* for 33 countries + *Population Census* data for 6 countries (similar methodology)
Cities ($\geq 10,000$ Inh.) in 1960
Cities ($\geq 10,000$ Inh.) in 2010
Unit of analysis

- Grid squares: 0.1x0.1 degree (~11x11 km; computational constraints)

- Select the best (lowest-cost) road in the cell

- Sum of city populations within cell (98 of 2,879 populated cells have multiple cities)
Sample

- Full sample: 5,906 city-years for 2,127 cities (>10,000 in at least two years)
  - 2010: 2,119
  - 2000: 1,514
  - 1990: 1,094
  - 1980: 746
  - 1970: 433
- 4,725 city-years for 2,126 cities when including two lags
Estimation

- Estimating equation:

\[
\Delta \ln P_{ot} = \beta \Delta \ln MA_{ot} + lags + controls + u_{ot} \quad (1)
\]

- \( P_{ot} \) = urban population of cell \( o \) in year \( t \)
- Market access \( MA_{ot} = \sum_{d \neq o} P_d \tau_{od}^{-\sigma} \)
  - weighted sum of all people outside the city, weights declining with travel time (far places count less)
  - Improving roads increases market access (reduces travel time)
  - Improving roads to bigger cities increases market access more
- \( \tau_{od} \) is the cost of travel from \( o \) to \( d \)
  - Baseline (scaleable): Highway 80; Paved 60; Improved 40; Dirt 12
  - Results similar using other values from literature
- \( \sigma = 3.8 \) is the trade elasticity estimate from Donaldson (forth.)
Change in market access due to road changes, 1960-2010

Change in market access 1960-2010
holding population at 1960 value

-0.53 - -0.1
-0.1 - 0
0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.7
Problems with determining causal impacts of road building on city population using market access

▶ Reverse causality
  ▶ Governments may build roads to places they expect to grow rapidly in the future
    ▶ High growth misattributed to roads (overestimation)
  ▶ Governments may build roads to places they expect to lag
    ▶ Low growth misattributed to roads (underestimation)

▶ All cities in a region may grow rapidly together for a reason unrelated to roads
  ▶ e.g. a local resource boom drives growth in my city and my neighbors
  ▶ Neighbors’ population increases my market access
  ▶ But I don’t grow because of my neighbors’ growth

▶ Our indicator of market access may be badly measured
Identification strategies

- Control for any national-level shocks that might be driving road building and city growth in a given decade (country-year fixed effects)
  - e.g. coups

- Control for smoothly varying spatial shocks (year-specific spatial polynomials)
  - e.g. climate

- Control for lagged population
  - mean reversion
Identification strategies

- Use restricted variation in market access change (instrumental variable)
  - Only changes due to roads, not population
  - Only changes to roads "far" away from the city in question
    - more than 50 km; more than 100 km;
    - outside country
    - example: Lagos-Ibadan road (Nigeria) affects market access for Cotonou (Benin)
  - valid if these "far" away roads are built for reasons unrelated to the city in question
Table 3: OLS estimates of the effect of market access on urban population, 1960–2010

<table>
<thead>
<tr>
<th>Dep. variable: ( \Delta_{t-10}^{t} \ln MA )</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \Delta_{t-10}^{t} \ln MA )</td>
<td>1.34***</td>
<td>1.27***</td>
<td>1.58***</td>
<td>1.63***</td>
<td>1.50***</td>
</tr>
<tr>
<td></td>
<td>[0.32]</td>
<td>[0.32]</td>
<td>[0.35]</td>
<td>[0.44]</td>
<td>[0.38]</td>
</tr>
<tr>
<td>( \Delta_{t-20}^{t} \ln MA )</td>
<td>1.02***</td>
<td>1.23***</td>
<td>1.55***</td>
<td>1.11***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>[0.24]</td>
<td>[0.26]</td>
<td>[0.34]</td>
<td>[0.30]</td>
<td></td>
</tr>
<tr>
<td>( \Delta_{t-30}^{t} \ln MA )</td>
<td>0.81***</td>
<td>0.89***</td>
<td>0.79***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>[0.23]</td>
<td>[0.29]</td>
<td>[0.27]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \Delta_{t-40}^{t} \ln MA )</td>
<td>0.27</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>[0.23]</td>
<td></td>
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</tr>
<tr>
<td>( \Delta_{t+10}^{t} \ln MA )</td>
<td></td>
<td></td>
<td></td>
<td>0.67</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>[0.49]</td>
<td></td>
</tr>
<tr>
<td>Overall effect ( (t - 40 \text{ to } t) )</td>
<td>1.34***</td>
<td>2.29***</td>
<td>3.62***</td>
<td>4.33***</td>
<td>3.40***</td>
</tr>
<tr>
<td></td>
<td>[0.32]</td>
<td>[0.45]</td>
<td>[0.59]</td>
<td>[0.83]</td>
<td>[0.65]</td>
</tr>
<tr>
<td>Observations</td>
<td>5,906</td>
<td>5,472</td>
<td>4,725</td>
<td>3,630</td>
<td>2,607</td>
</tr>
<tr>
<td>Adj. R-squared</td>
<td>0.26</td>
<td>0.22</td>
<td>0.19</td>
<td>0.18</td>
<td>0.22</td>
</tr>
</tbody>
</table>

Notes: Each column is a separate OLS regression of \( \Delta \ln \text{urban population} \) on market access measures shown, where the indexes years 1960 to 2010. Change in market access for city \( i \), \( \ln MA_i \) = \( \ln (\text{P}_{j=6}^{i=10} \text{pop}_{j,t} \times \text{P}_{j=30}^{i=10} \text{pop}_{j,t}) \), where \( \text{pop}_{j,t} \) is the population of city \( j \) in year \( t \), \( \text{pop}_{j,t} \) is the transport cost, in time, between city \( i \) and city \( j \) in year \( t \), and the trade elasticity \( = 3 \). Overall effect is the sum of the contemporaneous effect and all lags shown. Each regression controls for country-year fixed effects, \( \ln \text{pop}_{t} \) and third order polynomials in longitude and latitude interacted with year fixed effects. Robust standard errors, clustered by cell, are in brackets. *, **, *** mean significance at the ten, five, and one percent level, respectively.
Table 4: Market access and urban population: additional controls and instrumental variables, 1960–2010

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
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</thead>
<tbody>
<tr>
<td><strong>Control:</strong></td>
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<td></td>
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<td></td>
<td></td>
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<tr>
<td>Own cost</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Exclude 5</td>
<td>1.58***</td>
<td>1.52***</td>
<td>2.98***</td>
<td>4.59***</td>
<td>5.75*</td>
<td>7.22*</td>
<td>1.79</td>
<td>8.43*</td>
</tr>
<tr>
<td>Exclude 10</td>
<td>[0.35]</td>
<td>[0.39]</td>
<td>[1.00]</td>
<td>[1.76]</td>
<td>[2.95]</td>
<td>[4.09]</td>
<td>[1.89]</td>
<td>[4.60]</td>
</tr>
<tr>
<td>Exclude 15</td>
<td>1.23***</td>
<td>1.24***</td>
<td>3.28***</td>
<td>5.76***</td>
<td>7.34***</td>
<td>9.01***</td>
<td>1.73</td>
<td>-2.49</td>
</tr>
<tr>
<td>Exclude 20</td>
<td>[0.26]</td>
<td>[0.29]</td>
<td>[0.87]</td>
<td>[1.59]</td>
<td>[2.46]</td>
<td>[3.13]</td>
<td>[1.43]</td>
<td>[2.66]</td>
</tr>
<tr>
<td>Foreign</td>
<td>0.81***</td>
<td>0.83***</td>
<td>2.57***</td>
<td>3.38**</td>
<td>4.60**</td>
<td>4.07**</td>
<td>1.09</td>
<td>2.06</td>
</tr>
<tr>
<td>Non-neighbor</td>
<td>[0.23]</td>
<td>[0.24]</td>
<td>[0.86]</td>
<td>[1.39]</td>
<td>[1.95]</td>
<td>[1.92]</td>
<td>[1.12]</td>
<td>[1.70]</td>
</tr>
<tr>
<td><strong>Instrumental variable (IV):</strong></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Overall effect</td>
<td>3.62***</td>
<td>3.58***</td>
<td>8.83***</td>
<td>13.74***</td>
<td>17.69***</td>
<td>20.30***</td>
<td>4.61*</td>
<td>8.00*</td>
</tr>
<tr>
<td>(t – 30 to t)</td>
<td>[0.59]</td>
<td>[0.65]</td>
<td>[1.89]</td>
<td>[3.31]</td>
<td>[4.64]</td>
<td>[5.77]</td>
<td>[2.38]</td>
<td>[4.82]</td>
</tr>
<tr>
<td>IV F-Stat</td>
<td></td>
<td></td>
<td>114</td>
<td>41.86</td>
<td>17.41</td>
<td>6.940</td>
<td>15.10</td>
<td>4.026</td>
</tr>
</tbody>
</table>
Robustness Checks

Results are robust to:

- Calculating MA based on fixed 1960 Pop or $\Delta_{t-10}^t\text{Pop}$
- Calculating MA using alternate speeds, closing borders
- Changing the trade elasticity (3–12; IV decreases for 1–2)
- Removing country-year FEs or lagged population, adding province*
  year FEs
- Add geog. controls: dist. to coast/rivers, rain, soils, altitude
- Controlling for railroads or railroad market access
- Controlling for 1960 market access by year
- Dropping the largest few cities and capital in each country
- Dropping South Africa neighbors, Maghreb neighbors, colonies, countries at war, extreme values, 1980s, 2000s
- Balancing panel with population estimates
- To be done:
  - Control for nearby road building directly
  - Test for far roads being in same direction as near roads
Comparison to literature

- Somewhat smaller than railroads in the 19th century US using similar method (Donaldson & Hornbeck 2015): $\approx 20\text{–}35\%$.

- Other contexts are too (Redding and Turner 2015)

- **Contextual differences:**
  - Not a transportation revolution like in the 19th century US. Railroads already existed in Africa before roads (and poor roads existed before good roads).
  - Migration costs likely higher at least for large distances.
  - Lower overall economic growth.
Channels? (in progress)

- Reallocation across cities?
  - aggregate to larger units
  - compare cities near, middle, far from new roads (Faber (2014); Chandra & Thompson (2000))

- Natural increase?
  - check DHS fertility and mortality histories

- Induced urbanization
  - province-level total population (more limited sample)
Heterogeneous Effects (in progress)

- High vs. low initial market access
  - LATE for relatively remote cities
- High vs. low initial city size
- Near vs. far from coast, borders, largest cities
  etc.
Conclusion

- Study the effects of road construction and market access on city population growth in Sub-Saharan Africa in 1960-2010.

- New panel data set on road surface and city population for 39 African countries every ten years in 1960-2010.

- Average effect of a 100% change in market access ≈ 5–18% IV vs. 3–5% OLS. Effect concentrated in first 3 decades.

- Still exploring channels and heterogeneity