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.
  - market access is a measure summarizing a city’s access to all other cities.
  - a doubling of market access induces a 5–18% increase in city population
  - effect spread up to 30 years after road upgrading

- Also investigate the **heterogeneous effects** of road changes:
Related work

- Highway infrastructure impacts in China, USA, India, Brazil,
- Rail infrastructure impacts in China, USA, India, Ghana, Kenya
- Micro road surface/quality impacts in Sierra Leone (agricultural prices), Indonesia (manufacturing employment), Mexico (household wealth)
- Transport and trade costs in Africa - variation from other sources:
  - Fuel prices
  - inferred from price changes of very specific goods
- 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
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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

Region
- Northwest
- Northeast
- Central/South

Year
- 1960
- 1970
- 1980
- 1990
- 2000
- 2010

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Michelin Road Map for Liberia in 1965

Surfaces aggregated into 4 categories: *Highway*, *Paved*, *Improved* and *Dirt*
Four Road Surface Categories

Highway

Paved

Improved

Dirt
Roads in 1960

Road Type
- Highway
- Paved (Non-Highway)
- Improved
- Dirt

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Roads in 1970
Roads in 1980

Road Type
- Highway
- Paved (Non-Highway)
- Improved
- Dirt

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Road Length: Michelin vs. Canning (2008) vs. World Bank

Angola

- Total Length of Paved Roads (000s Km)
- Years: 1960 to 2010

- Jedwab-Storeygard
- Canning
- World Bank-WDI
Road Length: Michelin vs. Canning (2008) vs. World Bank

Kenya

Total Length of Paved Roads (000s Km)

- Jedwab-Storeygard
- Canning
- World Bank-WDI

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Road Length in Sub-Saharan Africa (39 Countries)

The graph shows the increase in road length in Sub-Saharan Africa from 1960 to 2010. The data are categorized into three types: Highway, Paved, and Improved. The graph indicates a steady increase in all categories, with Paved roads showing the most significant growth.
Percentage Share in the Road Network (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 (≥ 10,000 Inh.) in 1960

Cities (000s)
- 500+
- 100-500
- 50-100
- 10-50
Cities (≥ 10,000 Inh.) in 1970

Cities (000s)
- 500-+
- 100-500
- 50-100
- 10-50

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Cities ($\geq 10,000$ Inh.) in 1980

Cities (000s)
- 500-+
- 100-500
- 50-100
- 10-50

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Cities ($\geq 10,000$ Inh.) in 1990
Cities (≥ 10,000 Inh.) in 2000

Cities (000s)

- 500-+
- 100-500
- 50-100
- 10-50
Cities (≥ 10,000 Inh.) in 2010

Cities (000s)
- 500+
- 100-500
- 50-100
- 10-50
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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
Defining Market Access

- Roads matter beyond the cities they pass through

- First cut: how many people can I reach within a two hour journey from e.g. 1818 H St NW?
  - How many more can I reach if I build a new road or rail?

- **Market access** generalizes this for concentric rings of travel time:
  - weighted sum of all people outside the city
  - weights decline with travel time (far places count less)

- Building/improving roads increases market access by reducing travel time
  - Building roads to bigger cities increases market access more

- We don’t consider congestion (lack of data, conceptual issues)
Example for Sierra Leone, 1970-1980
Example for Sierra Leone, 1970-1980

Shortest routes to Makeni, 1970
Shortest routes to Makeni, 1980
Shortest routes to Bo, 1980
MA 1970
MA 1980
Change in MA 1970-80 holding roads at 1970
Change in market access due to road changes, 1960-2010

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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
Proposed solutions

- 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
Proposed solutions

- 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
Outline

▶ Data
▶ Estimation
▶ Results
▶ Conclusion
### Table 3: OLS estimates of the effect of market access on urban population, 1960–2010

<table>
<thead>
<tr>
<th>Dep. variable: ((\Delta^t_{t-10} \ln \text{urban population})/100)</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\Delta^t_{t-10} \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_{t-20} \ln MA)</td>
<td></td>
<td></td>
<td>1.02***</td>
<td>1.23***</td>
<td>1.55***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>[0.24]</td>
<td>[0.26]</td>
<td>[0.34]</td>
</tr>
<tr>
<td>(\Delta^t_{t-30} \ln MA)</td>
<td></td>
<td></td>
<td></td>
<td>0.81***</td>
<td>0.89***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>[0.23]</td>
<td>[0.29]</td>
</tr>
<tr>
<td>(\Delta^t_{t-40} \ln MA)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.27</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>[0.23]</td>
</tr>
<tr>
<td>(\Delta^t_{t+10} \ln MA)</td>
<td></td>
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<tr>
<td></td>
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<td></td>
<td></td>
<td></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 \(\Delta \ln \text{urban population}\). 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>Control:</th>
<th>Instrumental variable (IV):</th>
</tr>
</thead>
<tbody>
<tr>
<td>Own cost</td>
<td>Exclude 5</td>
</tr>
<tr>
<td></td>
<td>Exclude 10</td>
</tr>
<tr>
<td></td>
<td>Exclude 15</td>
</tr>
<tr>
<td></td>
<td>Exclude 20</td>
</tr>
<tr>
<td></td>
<td>Foreign</td>
</tr>
<tr>
<td></td>
<td>Non-neighbor</td>
</tr>
</tbody>
</table>

| Δ_{t-10} MA  | 1.58*** | 1.52*** | 2.98*** | 4.59*** | 5.75*   | 7.22*   | 1.79    | 8.43*   |
|             | [0.35]  | [0.39]  | [1.00]  | [1.76]  | [2.95]  | [4.09]  | [1.89]  | [4.60]  |
| Δ_{t-20} MA  | 1.23*** | 1.24*** | 3.28*** | 5.76*** | 7.34*** | 9.01*** | 1.73    | -2.49   |
|             | [0.26]  | [0.29]  | [0.87]  | [1.59]  | [2.46]  | [3.13]  | [1.43]  | [2.66]  |
| Δ_{t-30} MA  | 0.81*** | 0.83*** | 2.57*** | 3.38**  | 4.60**  | 4.07**  | 1.09    | 2.06    |
|             | [0.23]  | [0.24]  | [0.86]  | [1.39]  | [1.95]  | [1.92]  | [1.12]  | [1.70]  |
| Overall effect | 3.62*** | 3.58*** | 8.83*** | 13.74*** | 17.69*** | 20.30*** | 4.61*   | 8.00*   |
| (t - 30 to t) | [0.59]  | [0.65]  | [1.89]  | [3.31]  | [4.64]  | [5.77]  | [2.38]  | [4.82]  |
| IV F-Stat    | 114     | 41.86   | 17.41   | 6.940   | 15.10   | 4.026   |         |         |
Summary of Average Effects

- Naive effect of a 100% change in market access: \( \approx 1\% - 1.5\% \) per decade for three decades (total 30-year effect: 3-4%).

- **Better identified effect:** \( \approx 5\% - 18\% \) over 30 years.

- Concentrated in first two decades (i.e. decade of construction and following decade)

- No measurable effect in fourth decade.

- Source of growth: rural areas or other cities? To be considered...
Comparison to literature

- Somewhat smaller than railroads in the 19th century US using similar method (Donaldson & Hornbeck 2015): ≈20–35%.

- Other contexts are too

- **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.
  - Context of lower economic growth.
Heterogeneous Effects?

- Heterogenous effects? Focusing on space right now.
- We classify the cities into two groups depending on:
  - High vs. low initial city size
  - High vs. low initial market access
  - Near vs. far from coast, borders, largest cities etc.

and see if the effect of a same change in road market access varies across the two groups.

- This will allow us to test various existing theories in trade and urban economics.
Heterogeneous Effects?

- No consistent robust effects for any of them
- Instruments get weaker.
- Still work in progress
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 $\approx 5-18\%$. Effect concentrated in first 3 decades.

- Still exploring the heterogeneous spatial and temporal effects of the same road investments.