Road Network Upgrading And Overland Trade Expansion In Sub-Saharan Africa

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Study motivation

• Focus on infrastructure development

• Focus on Sub-Saharan Africa

• Most trade / infrastructure studies look at external trade

• This study asks how to promote *intra*-African trade

• Show what is potentially at stake with road network upgrading
Policy research questions

- By how much would intra-African trade increase with a major upgrading of the main continental highway network?
- How much would upgrading and annual maintenance of such a system cost?
Analysis

• Develop a spatially explicit model of pan-African highways

• Estimate benefits and costs based on a full network trade model connecting all major cities in continental sub-Saharan Africa

• Combines use of geographic information systems and econometric techniques
Sub-Saharan Africa: Continental capitals & cities > 500,000 population
Least-distance network of existing primary roads connecting 83 cities

Total length: 108,000 km
838 Road segments
3,403 Connected city pairs
The proposed pan-African highway corridors
Comparisons to pan-African highway corridors
Gravity trade model

• Standard tool in trade economics (and in transport sector analysis)

• There will be more trade between countries with larger economies (economic scale)

• There will be less trade between countries that are further apart (distance)

• But distance is not the only factor – quality of roads also matters, as do institutional factors such as trade agreements
Road network: Current network quality

• Very little reliable data on road quality
• Instead, we estimate a road quality index by country as a function of
  – Percent of roads paved
  – GDP per capita (local resources available)
  – Governance indicator (ability to spend wisely)
• Index corresponds well with observed road conditions information from ADB pan-African highways study
Road network: Estimated quality and importance of links

Road significance: number of times segment is used when connecting each city with all other cities
Gravity trade model estimation

- Data Source: IMF Directions of Trade between countries
- USD value of average 2000-2003 merchandise imports/exports
- Sample Size: 1128 Observations = country pairs, with each country both importer and exporter
Main estimation results

- **Economic scale** and **distance** between countries are very important (as expected)

- **Road quality** indicator highly significant
  - 1% improvement leads to 2% increase in trade

- **Membership** in WAEMU, CEMAC or EAC very important
  - far higher trade volume than otherwise expected
  - but other agreements (ECOWAS, SADCC, COMESA) do not influence trade flows significantly
Downscaling of trade flows to road links

• Model is estimated based on country-to-country trade flows

• Parameters are then applied to estimate city-to-city flows along the least-cost path through the highway network

• This yields estimates of current trade volumes on each road link

• We can then predict future trade volume after road upgrading
Road network: Estimated quality and importance of links

<table>
<thead>
<tr>
<th>Potential Road Significance</th>
<th>Current Road Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lowest</td>
<td>5</td>
</tr>
<tr>
<td>Low</td>
<td>4</td>
</tr>
<tr>
<td>Medium</td>
<td>3</td>
</tr>
<tr>
<td>High</td>
<td>2</td>
</tr>
<tr>
<td>Highest</td>
<td>1</td>
</tr>
</tbody>
</table>
Upgrading scenario (to Class 2)
Gravity model application: *Current* network trade flows

Current total for SSA: US$10 billion
Gravity model application: *Upgraded* network trade flows

Econometric projection: US$30 billion
Percent change in estimated trade flows
Gravity model application:  
Network trade flows ($US) 

Program: Network upgrade to class 2

Econometric projection:  Annual trade ($billion)

<table>
<thead>
<tr>
<th>Current</th>
<th>Upgraded</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.1</td>
<td>29.8</td>
</tr>
</tbody>
</table>

Almost half of increase is between major regions (West, Central, East, Southern, South Africa)
Costs

Econometric estimation of upgrading and maintenance costs
Sub-Saharan Africa: 470 road projects
Costs in $US ‘000/km of improvement

<table>
<thead>
<tr>
<th>Work Type</th>
<th>Class</th>
<th>#</th>
<th>10.0</th>
<th>25.0</th>
<th>50.0</th>
<th>75.0</th>
<th>90.0</th>
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<tbody>
<tr>
<td>Grading</td>
<td>Maintenance</td>
<td>3</td>
<td>0.2</td>
<td>0.2</td>
<td>0.5</td>
<td>0.9</td>
<td>0.9</td>
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<tr>
<td>Routine Maintenance</td>
<td>Maintenance</td>
<td>22</td>
<td>0.6</td>
<td>1.7</td>
<td>2.0</td>
<td>3.0</td>
<td>3.5</td>
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<tr>
<td>Unsealed Preventive Maintenance</td>
<td>Maintenance</td>
<td>98</td>
<td>2.8</td>
<td>3.3</td>
<td>4.3</td>
<td>5.1</td>
<td>5.7</td>
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<tr>
<td>Bituminous Pavement Preventive Treatment</td>
<td>Maintenance</td>
<td>39</td>
<td>2.3</td>
<td>3.3</td>
<td>5.0</td>
<td>7.7</td>
<td>18.8</td>
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<tr>
<td>Gravel Resurfacing</td>
<td>Maintenance</td>
<td>112</td>
<td>3.9</td>
<td>7.1</td>
<td>10.1</td>
<td>17.4</td>
<td>37.9</td>
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<tr>
<td>Surface Treatment Resurfacing</td>
<td>Maintenance</td>
<td>26</td>
<td>13.0</td>
<td>18.4</td>
<td>20.3</td>
<td>32.2</td>
<td>38.5</td>
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<tr>
<td>Asphalt Mix Resurfacing</td>
<td>Upgrading</td>
<td>27</td>
<td>22.7</td>
<td>39.2</td>
<td>54.7</td>
<td>70.4</td>
<td>95.1</td>
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<td>Reconstruction</td>
<td>Upgrading</td>
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<td>22.8</td>
<td>78.6</td>
<td>128.9</td>
<td>218.1</td>
<td>333.8</td>
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<td>Upgrading</td>
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<td>80.8</td>
<td>103.0</td>
<td>130.3</td>
<td>162.1</td>
<td>203.7</td>
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<td>Partial Widening</td>
<td>Upgrading</td>
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<td>136.0</td>
<td>136.0</td>
<td>136.0</td>
<td>136.0</td>
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<tr>
<td>Upgrading</td>
<td>Upgrading</td>
<td>35</td>
<td>53.0</td>
<td>109.1</td>
<td>262.5</td>
<td>331.1</td>
<td>473.3</td>
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<tr>
<td>New Two-Lane Highway</td>
<td>Upgrading</td>
<td>2</td>
<td>660.2</td>
<td>660.2</td>
<td>1,023.4</td>
<td>1,386.5</td>
<td>1,386.5</td>
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<tr>
<td>Widening and Reconstruction</td>
<td>Upgrading</td>
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<td>989.1</td>
<td>989.1</td>
<td>1,331.1</td>
<td>1,568.4</td>
<td>1,568.4</td>
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<tr>
<td>Total</td>
<td></td>
<td>470</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Road Costs Knowledge System (ROCKS) does not include all countries, so we use these data to estimate a generic cost function
Cost function estimation

**Dependent variable:** Unit improvement cost

**Independent variables:**

- Existing road condition (percent paved)
- Wage rates (per capita income)
- Governance (CPIA for accountability, corruption)
- Rainfall intensity (mm per day of rainfall along network)
- Regional controls (West, Central, East Africa)
- Project type controls:
  - 7 Upgrading categories
  - 6 Maintenance categories
Projection from estimated cost function

Upgrade Cost
(thousands USD per km)
- 70 - 100
- 101 - 200
- 201 - 350
- 351 - 600
- 601 - 1,588

Kilometers
Program: Network upgrade to class 2

Econometric projection: Upgrade cost ($billion)

<table>
<thead>
<tr>
<th></th>
<th>Upgrade</th>
<th>Annual maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upgrade</td>
<td>28.4 [+1 Std. Error]</td>
<td>1.2 [+1 Std. Error]</td>
</tr>
<tr>
<td></td>
<td>15.6 [-1 Std. Error]</td>
<td>0.7 [-1 Std. Error]</td>
</tr>
<tr>
<td>Cost 20.7</td>
<td>0.9</td>
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</tbody>
</table>
## Network upgrade program:
### 5-Year upgrade; 10-Year operation

<table>
<thead>
<tr>
<th>Trade Category</th>
<th>Annual Trade Growth ($Bill.)</th>
<th>Upgrade Cost Category</th>
<th>Upgrade Cost ($Billion)</th>
<th>Maint. Cost Category</th>
<th>Maint. Cost ($Bill.)</th>
<th>Total Trade Growth ($Bill.)</th>
<th>Total Cost ($Bill.)</th>
<th>Net ($Bill.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>6.2</td>
<td>High</td>
<td>28.4</td>
<td>High</td>
<td>1.2</td>
<td>77.5</td>
<td>43.4</td>
<td>34.1</td>
</tr>
<tr>
<td>Low</td>
<td>6.2</td>
<td>Benchmark</td>
<td>20.7</td>
<td>Benchmark</td>
<td>0.9</td>
<td>77.5</td>
<td>32.0</td>
<td>45.6</td>
</tr>
<tr>
<td>Low</td>
<td>6.2</td>
<td>Low</td>
<td>15.6</td>
<td>Low</td>
<td>0.7</td>
<td>77.5</td>
<td>24.4</td>
<td>53.2</td>
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<tr>
<td>Benchmark</td>
<td>19.7</td>
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<td>28.4</td>
<td>High</td>
<td>1.2</td>
<td>246.25</td>
<td>43.4</td>
<td>202.9</td>
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<tr>
<td><strong>Benchmark</strong></td>
<td><strong>19.7</strong></td>
<td><strong>Benchmark</strong></td>
<td><strong>20.7</strong></td>
<td><strong>Benchmark</strong></td>
<td><strong>0.9</strong></td>
<td><strong>246.25</strong></td>
<td><strong>32.0</strong></td>
<td><strong>214.3</strong></td>
</tr>
<tr>
<td>Benchmark</td>
<td>19.7</td>
<td>Low</td>
<td>15.6</td>
<td>Low</td>
<td>0.7</td>
<td>246.25</td>
<td>24.4</td>
<td>221.9</td>
</tr>
<tr>
<td>High</td>
<td>45.3</td>
<td>High</td>
<td>28.4</td>
<td>High</td>
<td>1.2</td>
<td>566.25</td>
<td>43.4</td>
<td>522.9</td>
</tr>
<tr>
<td>High</td>
<td>45.3</td>
<td>Benchmark</td>
<td>20.7</td>
<td>Benchmark</td>
<td>0.9</td>
<td>566.25</td>
<td>32.0</td>
<td>534.3</td>
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<tr>
<td>High</td>
<td>45.3</td>
<td>Low</td>
<td>15.6</td>
<td>Low</td>
<td>0.7</td>
<td>566.25</td>
<td>24.4</td>
<td>541.9</td>
</tr>
</tbody>
</table>

**Benchmark 15 year scenario suggests almost $ 250 billion of additional intra-African trade at a cost of $ 32 billion**
Trade expansion vs. welfare gain

• Value of increased trade does not equal welfare gain

• But most studies show a link between trade and growth, and between growth and poverty reduction
  – e.g., Frankel and Romer, *AER* (1999): 1% increase in trade share increases incomes by 0.5 - 2%
Trade expansion vs. welfare gain

• Also: Our benefit estimates are likely conservative as they do not include:
  – Rural and inter-city trade expansion within countries
  – Additional trade with the rest of the world
  – Induced growth as economies become more dynamic
  – Rural labor benefits from labor intensive construction and maintenance
Implementation issues

Beneficiary estimation for transport projects
Implementation issues

• Beneficiary estimation
  – Possibly tremendous employment benefits from labor intensive construction methods
  – 8.4 million person years employment for upgrading
  – 365,000 permanent jobs for maintenance
  – These estimates are based on experience from other labor intensive infrastructure projects
Summary

• If African economies respond to opportunities in the same way as the rest of the world (no reason to doubt this!), upgrading of a pan-African highway network could yield tremendous benefits

• $215 billion “surplus” over 15 years
Summary

• Key assumptions
  – Implementation as a *network* approach
  – Road quality improvements are accompanied by removal of non-physical trade barriers
The proposed pan-African highway corridors
## Linking North Africa

- **Current trade pattern (avg. 2000-2003)**

### Table: Trade and Population

<table>
<thead>
<tr>
<th></th>
<th>Mainland SSA</th>
<th>North Africa</th>
<th>Population (millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Exports (mill. USD)</strong></td>
<td><strong>Exports (mill. USD)</strong></td>
<td><strong>Exports (mill. USD)</strong></td>
<td><strong>Exports (mill. USD)</strong></td>
</tr>
<tr>
<td><strong>to</strong></td>
<td>10,562</td>
<td>492</td>
<td>710</td>
</tr>
<tr>
<td><strong>from</strong></td>
<td>494</td>
<td>1,598</td>
<td>153</td>
</tr>
</tbody>
</table>

*Source: IMF Directions of Trade (merchandise trade)*
Linking North Africa

• Model should apply in same way

• But magnitude of impacts likely smaller
  – relatively larger economies
  – intra-region: better existing infrastructure and alternative modes (rail, sea)
  – with SSA: Very large distance across Sahara
Way forward

• Use analytical results to promote ADB Corridor study and possible extensions

• Build support among donors through briefings and presentations
  – Infrastructure Consortium for Africa
  – World Bank & IMF African Executive Directors
  – SSATP
  – Others incl. MCC, think tanks, private sector
Way forward

• Build support and ownership in regions and countries
  – Policy package for local decision makers
  – Address non-physical barriers more forcefully
  – Strengthen regional coordination mechanisms
  – Assess financing mechanisms
Thank you!

For a copy of the working paper or presentation, email udeichmann@worldbank.org