Nonlinearities in the Impact of Public-Private Infrastructure Investments the Long-Run Economic Growth: Evidence from African Countries

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Outline

• Graphical Abstract

• Motivation and Objectives of the Paper

• Review of Selected Literature & contributions to existing literature

• The Empirical Models

• Summary and Interpretations of Results

• Conclusions and Policy Implications
Graphical Abstract – Nonlinearity in the Infrastructure/Growth/Governance Nexus
World Economic Forum’s
Global Infrastructure Rankings

Infrastructure Quality Index

• Ranking
  • No African country in the top 20 country ranking
  • Highest ranked African countries:
    • Rwanda (40), Seychelles (41), Morocco (42), Namibia (45), Mauritius (50)
  • 14 African countries ranked in the bottom 20 countries

• Electricity Issues
  • Frequent power outages, restricting access to electricity to a third of Africa’s population, reducing its productivity by as much as 40%, and curtailing its annual economic growth by about 2% (PIDA, 2014)
  • Only 30% of African countries have access to electricity relative to 70-90% of other developing countries
Infrastructure and Growth: The Motivation

• Energy, transport, digital communications, waste disposal networks and water and sanitation facilities are essential ingredients for the success of a competitive modern economy.

• Research has shown that well-designed infrastructure investments have long-term economic benefits
  • they can raise productivity, decrease transportation and communication costs, land values, health, and Economic Growth
  • provides significant positive spillovers.

• However, investing wisely in infrastructure is critically important:
  • Over-investment can lead to projects that are inefficiently large, and, therefore, have low marginal returns.
  • Location and type of investment is important as well. E.g. Having a high-way in the middle of no where for political expediency.
Link between Infrastructure and Growth

- Economic policy analysts assert that there are five channels through which infrastructure may impact economic growth including:
  - as a direct input into the production process serving as a factor of production,
  - as a complement to other inputs into the production process,
  - as a stimulant to factor accumulation by providing facilities for human development, through
  - increased expenditure during construction and maintenance operations,
  - and as a tool to guide industrial policy (Wolassa, 2012).
Literature Review Overall (Infrastructure/Growth Nexus)

• Overall
  • Positive Impact of Infrastructure on Growth
    • Aschauer (1989), Munnell (1990, 1992), and Easterly and Rebelo (1993)
  • However, the results are mixed for those using public capital stock, or infrastructure spending as their proxy (Konongo and Ojah, 2016).
  • Sassi and Goaied (2013) – negative impact of mass ICT penetration for developing countries (lack of skilled labor, displacement of nonskilled labor)
  • Nonlinear Impact
    • The relationship may be nonlinear (Egert et al., 2009).
    • McKibbin (2017) - transport infrastructure (due to network externalities)
    • Röller and Waverman (2001) impact of telecommunications 21 OECD countries is substantially higher for countries with their penetration approaching universal coverage
    • De (2009) indicates that the level and quality of infrastructure in the Asian region is dependent on good governance.
African Infrastructure and Growth

• Single Country Analysis
  • The majority of the existing literature is done on a country to country basis, with a significant number focused on South Africa due to data availability (See, Reinikka and Svensson, 1999; Fedderke et al., 2006; Wolassa, 2012)

• Single Proxy Usage (telephone mainlines e.g.)
  • Ignoring the multidimensional measures of infrastructure and the possible heterogeneity of their impacts on remittances and economic growth (Konongo and Ojah, 2016).
  • Few exceptions (Estache et al., 2006; Calderón and Servén, 2010; Ndulu, 2011; Andrianaivo and Kpodar, 2011; Wamboye et al., 2015; Kodongo and Ojah, 2016; Albiman and Sulong, 2016.
  • Most of these studies have pointed to the low infrastructure development on the continent as a bane to economic growth because poor infrastructure reduces the trade competitiveness of the countries in the regions, increases the cost of doing business, and ultimately negatively impacts growth.

• Linear Models Findings
  • Calderon (2009) - PCA (telecommunications, electricity, and roads) -> infrastructure stocks and service quality boost economic growth
  • Kodongo and Ojah (2016) – AIDI
    • The main positive impact of infrastructure on growth is dependent mainly on infrastructure spending and increments in the access to infrastructure
    • Further, they find that infrastructure development is much more important for low-income African countries than other regions of the world
Attempts at Non-linear Impacts for Africa

• Andrianaivo and Kpodar (2011) - the economic impact of mobile phone use is stronger when paired with credit to the private sector.

• Wamboye et al. (2015) - financial deepening serves as the conduit through which mobile phone use can impact growth through inducing of labor productivity.

• Albiman and Sulong (2016) apply threshold analysis to the impact of infrastructure on growth.
  • Mobile phones and the internet have a direct impact on growth,
  • Threshold analysis,
    • Overall mass penetration of ICT (mobile phones and internet) slows economic growth.
    • After a threshold of 4.5 percent is reached for both mobile phones and the internet, and 5 percent for fixed telephone mainlines.
Motivation for Paper & Contribution to Existing Literature

• Infrastructure Spending
  • $45 billion each year on infrastructure, two-thirds of which is domestically financed from taxes and user charges, leaving a gap of $48 million (Sy, 2013).
    • Significant portion of the financing of capital investment is obtained from external sources.
    • Vital that governments and external investors alike have a mechanism to ensure that their investments are yielding positive results on the ground and providing the best returns.

• Contribution to Literature
  • Add to the knowledge base on the African Infrastructure/Growth Nexus
    • Second study to employ the comprehensive AIDI in the growth analysis
    • Investigate nonlinearities in the infrastructure/growth nexus (Threshold and quantile regression)
Models

- **Threshold Analysis**
  \[ y_{it} = \alpha_i + \delta q_{it} + \beta_i X_{it} + \varepsilon_{it} \]  
  \[ y_{it} = \alpha_i + \delta_1 q_{it} I(q_{it} < \gamma) + \delta_2 q_{it} I(q_{it} \geq \gamma) + \beta_i X_{it} + \varepsilon_{it} \]

- **Quantile Regression**
  \[ E[RIF(Y_{it}; q_\tau | X_{it})] = X_{i,t} \beta_{\tau,i} \]

- Where \( y_{it} \) is GDP per capita growth rate of country i at period t, \( q_{it} \) is measures of infrastructure of country i at period t, and \( X_{it} \) is control variables for country i at period t, \( \alpha_i \) is fixed-effects parameter, \( \delta_i \) is parameters of the infrastructure measures, \( \beta_i \) and \( \varepsilon_{it} \) is random error.
African Infrastructure Development Index

- **ELI**: Improved Water Source (% of population with access) & Improved sanitation facilities (% of population with access)
- **AIDI**: Total Paved Roads (km per 10,000 inhabitants) & Total Road Network in Km (per km2 of exploitable land area)
- **ICT**: Fixed-line Telephone Subscriptions (% population); Mobile-cellular Subscriptions (% population); & Number of Internet Users (per 100 inhabitants)
Governance Indicator (GINDEX) Formulization (GINDEX)

• Index Content:
  • Voice Accountability, Political Stability, Government Effectiveness, Regulatory Quality, Corruption Control, Polity2 (a different measure of governance)
    • Sources: World Bank’s World Governance Index and from the Center for Systematic Peace (CSP).

• GINDEX

1. Indices are standardized to values between 0 and 100 - >
   • \((x_i - \text{min})/(\text{max} - \text{min})\)

2. Standardized indices are summed to form one governance index (GINDEX).
Table 1. Variable Description and Summary Statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Mean</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCIL</td>
<td>GDP per capita - one lag</td>
<td>2,524.38</td>
<td>3,293.23</td>
<td>219.96</td>
<td>20,512.94</td>
</tr>
<tr>
<td>PCIG</td>
<td>GDP capita rate growth rate (%)</td>
<td>1.98</td>
<td>7.38</td>
<td>-62.38</td>
<td>121.78</td>
</tr>
<tr>
<td>OII</td>
<td>Infrastructure Index</td>
<td>21.35</td>
<td>17.77</td>
<td>1.96</td>
<td>85.66</td>
</tr>
<tr>
<td>TPI</td>
<td>Transport Composite Index</td>
<td>10.03</td>
<td>11.81</td>
<td>0.38</td>
<td>58.70</td>
</tr>
<tr>
<td>ELI</td>
<td>Electricity Composite Index</td>
<td>9.75</td>
<td>18.35</td>
<td>0.01</td>
<td>100.00</td>
</tr>
<tr>
<td>ICT</td>
<td>ICT Composite Index</td>
<td>6.48</td>
<td>9.64</td>
<td>0.01</td>
<td>66.08</td>
</tr>
<tr>
<td>WSS</td>
<td>WSS Composite Index</td>
<td>50.10</td>
<td>20.59</td>
<td>12.35</td>
<td>99.01</td>
</tr>
<tr>
<td>GINDEX</td>
<td>Governance Index</td>
<td>381.76</td>
<td>118.20</td>
<td>134.42</td>
<td>666.94</td>
</tr>
<tr>
<td>MYSCH</td>
<td>Mean Years of Schooling</td>
<td>4.93</td>
<td>2.04</td>
<td>1.30</td>
<td>10.20</td>
</tr>
<tr>
<td>TOTV</td>
<td>Terms of trade variability</td>
<td>0.01</td>
<td>0.11</td>
<td>-0.54</td>
<td>0.33</td>
</tr>
<tr>
<td>INFLA</td>
<td>Inflation</td>
<td>6.61</td>
<td>8.83</td>
<td>-29.69</td>
<td>60.70</td>
</tr>
<tr>
<td>XRATE</td>
<td>Exchange Rate</td>
<td>623.51</td>
<td>1,241.58</td>
<td>0.94</td>
<td>9,088.32</td>
</tr>
<tr>
<td>MONEY</td>
<td>Broad money (% of GDP)</td>
<td>40.40</td>
<td>35.56</td>
<td>6.48</td>
<td>289.36</td>
</tr>
</tbody>
</table>

Notes: The annual data for 47 African countries span over the 2007-2017 period. The first per capita income period lag is for 2006. All data are from the World Development Indicators apart from MYSCH (Human Development Indicators), the POLITY2 (Center for Systematic Peace), and the other governance indicators from the World Governance Index.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Threshold</th>
<th>95% CI</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Lower</td>
<td>Upper</td>
</tr>
<tr>
<td>OII</td>
<td>Overall Infrastructure Composite Index</td>
<td>5.30 0</td>
<td>5.30</td>
<td>5.32</td>
</tr>
<tr>
<td>TPI</td>
<td>Transport Infrastructure Composite Index</td>
<td>5.32 2</td>
<td>5.30</td>
<td>5.32</td>
</tr>
<tr>
<td>ELI</td>
<td>Electricity Infrastructure Composite Index</td>
<td>5.32 2</td>
<td>5.29</td>
<td>5.32</td>
</tr>
<tr>
<td>ICT</td>
<td>ICT Infrastructure Composite Index</td>
<td>5.30 2</td>
<td>5.27</td>
<td>5.30</td>
</tr>
<tr>
<td>WSS</td>
<td>Water and Sanitation Composite Index</td>
<td>5.32 2</td>
<td>5.30</td>
<td>5.32</td>
</tr>
</tbody>
</table>

Note: Threshold Estimator (Confidence level = 95%), with 1000 bootstrap estimates
Test for Multiple Thresholds

• Tested for the existence of a second and third threshold
• Test Results -> Only one threshold exist for OII TPI ELI & ICT
• Threshold Growth Model

\[ PCIG_{it} = \alpha_{it} + \delta_1 \log(\text{INFRA}_{fit}) \cdot I(\text{GINDEX} \leq \gamma) + \delta_2 \log(\text{INFRA}_{fit}) \cdot I(\text{GINDEX}_{it} > \gamma) + \beta_1 \log(\text{PCI}_{i,t-1}) + \beta_2 \log(\text{MYSCH}_{it}) + \beta_3 \log(\text{XRATE}_{it}) + \beta_4 \log(\text{TOTSD}_{it}) + \beta_5 \log(\pi_{it}) + \beta_6 \log(\text{GINDEX}_{it}) + \beta_7 \log(\text{MONEY}_{it}) + \epsilon_{it} \]
<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Model 1 Overall Composite Index</th>
<th>Model 2 Transport Composite Index</th>
<th>Model 3 Electricity Composite Index</th>
<th>Model 4 ICT Composite Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>log(PCIL)</td>
<td>Log of one period lag GDP per capita</td>
<td>-0.4215</td>
<td>0.0351</td>
<td>***</td>
<td>-0.4044</td>
</tr>
<tr>
<td>log(money)</td>
<td>Log of Broad money (% of GDP)</td>
<td>-0.0479</td>
<td>0.0127</td>
<td>***</td>
<td>-0.0392</td>
</tr>
<tr>
<td>TOTSTD</td>
<td>Square root of Net barter terms of trade index (2000 = 100)</td>
<td>0.0070</td>
<td>0.0318</td>
<td></td>
<td>0.0029</td>
</tr>
<tr>
<td>πlog</td>
<td>Semi-log transformation of inflation rate</td>
<td>0.0023</td>
<td>0.0011</td>
<td>**</td>
<td>0.0023</td>
</tr>
<tr>
<td>log(MYSCH)</td>
<td>Log of Mean years of schooling</td>
<td>0.1349</td>
<td>0.0529</td>
<td>***</td>
<td>0.1970</td>
</tr>
<tr>
<td>log(XRATE)</td>
<td>Log of exchange rate (Local currency to US dollar)</td>
<td>0.0076</td>
<td>0.0177</td>
<td></td>
<td>0.0192</td>
</tr>
<tr>
<td>log(GINDEX)</td>
<td>Log of Governance Index</td>
<td>0.1348</td>
<td>0.0596</td>
<td>**</td>
<td>0.1202</td>
</tr>
<tr>
<td>log Infrastructure</td>
<td>&lt;= GINDEX Threshold</td>
<td>0.0169</td>
<td>0.0240</td>
<td></td>
<td>-0.0205</td>
</tr>
<tr>
<td></td>
<td>&gt; GINDEX Threshold</td>
<td>0.0537</td>
<td>0.0233</td>
<td>**</td>
<td>0.0357</td>
</tr>
<tr>
<td>sigma_u</td>
<td></td>
<td>45.15</td>
<td>43.93</td>
<td></td>
<td>45.23</td>
</tr>
<tr>
<td>sigma_e</td>
<td></td>
<td>6.25</td>
<td>6.18</td>
<td></td>
<td>6.29</td>
</tr>
<tr>
<td>rho</td>
<td></td>
<td>0.98</td>
<td>0.98</td>
<td></td>
<td>0.98</td>
</tr>
<tr>
<td>P &gt; F</td>
<td></td>
<td>0.00</td>
<td>0.00</td>
<td></td>
<td>0.00</td>
</tr>
</tbody>
</table>

**Notes:** The standard errors are bootstrapped (1,000 reps). Our estimates cover 11 years of annual data for 47 African countries for which complete data are available. The number of stars is in the order of decreasing statistical significance: *** = 1%, ** = 5%, and * = 10%.
Results Summary: Threshold Analysis

• Single governance threshold for OIDI, TSP, ELI, & ICT
• No threshold for WSS
• Cannot reject the null hypothesis for multiple thresholds (two and three) for all infrastructure proxies

<table>
<thead>
<tr>
<th></th>
<th>Good Governance</th>
<th>Bad Governance</th>
</tr>
</thead>
<tbody>
<tr>
<td>OIDI</td>
<td>0.054 ***</td>
<td>0.017</td>
</tr>
<tr>
<td>TSP</td>
<td>0.036</td>
<td>-0.020</td>
</tr>
<tr>
<td>ELI</td>
<td>0.008 **</td>
<td>-0.027 **</td>
</tr>
<tr>
<td>ICT</td>
<td>0.012 ***</td>
<td>-0.028 ***</td>
</tr>
</tbody>
</table>
Figure 1: Quantile Regression for Overall Infrastructure Index Impact on Growth
Figure 2: Quantile Regression Results for the Infrastructure Indicators’ Impact on Economic Growth

Panel A

Panel B

Panel C

Panel D

Note: The solid lines denote the estimated coefficients, and the dotted lines represent the upper and lower confidences bands.
Quantile Regressions Without Thresholds

• OIDI – Positive impact for all growth quantiles (Largest impact on lower growth quantiles)

• TSP – Positive impact for all growth quantiles (Largest impact on lower growth quantiles)

• ELI – Negative for lower quantiles, but positive for middle to higher quantiles of growth

• ICT – very small impact on all quantiles with some negative observations

• WSS – relatively larger positive impacts for all quantiles, with the largest impact in lower growth quantiles
Figure 3 Quantile Regression for Overall Infrastructure Index by Governance Threshold
Figure 4 Quantile Regression for Transport Infrastructure Index by Governance Threshold

GINDEX ≤ 203.5

GINDEX > 203.5
Figure 5 Quantile Regression for Electricity Infrastructure Index by Governance Threshold
Figure 6 Quantile Regression for ICT Infrastructure Index by Governance Threshold
Figure 7 Quantile Regression for Access to Improved Water Sources and Sanitation Facilities Index by Governance Threshold
Quantile Regressions Without Thresholds

• OIDI – Positive impact for all growth quantiles (Largest impact on lower growth quantiles). Impacts larger in High governance countries.
• TSP – Positive impact for all growth quantiles (Largest impact on lower growth quantiles). Impacts larger in High governance countries.
• ELI – Smaller negative impact for good governance countries.
• ICT – Negative observations for all growth quantiles in bad governance countries. Slight positive impact in good governance countries for all quantiles.
• WSS – Relatively larger positive impacts for all quantiles, with the largest impact in lower growth quantiles. The impacts are the same for both good and bad governance countries for each quantile (Exception first quantile)
Conclusions & Policy Implications

• Conclusion
  1. While we generally observe positive impacts of infrastructure on growth, the impact is dependent on the type of infrastructure.
  2. Good governance may play an important role in the impact of infrastructure on growth
     a. Good governance matter with respect to the effectiveness of the overall infrastructure index, transport infrastructure, electricity, and ICT infrastructure indices on growth, but not so for access to improved water sources and sanitation facilities.
     b. the proper sourcing, dissemination, and management of the different aspects of infrastructure for a sustainable growth path in African countries.
  3. The growth impact of infrastructure may depend on the level of growth

• Implications
  • African countries may benefit enormously from investment in the various infrastructure factors
  • Focusing, not only on how much they can invest in public and private infrastructure without crowding out private investments, but also paying particular attention to the prevailing quality of their governance structure is important.
A1. Country List (47)