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

by

Christian Nsiah

Baldwin Wallace University

Bichaka Fayissa

Middle Tennessee State University

Herman Sahni

Baldwin Wallace University
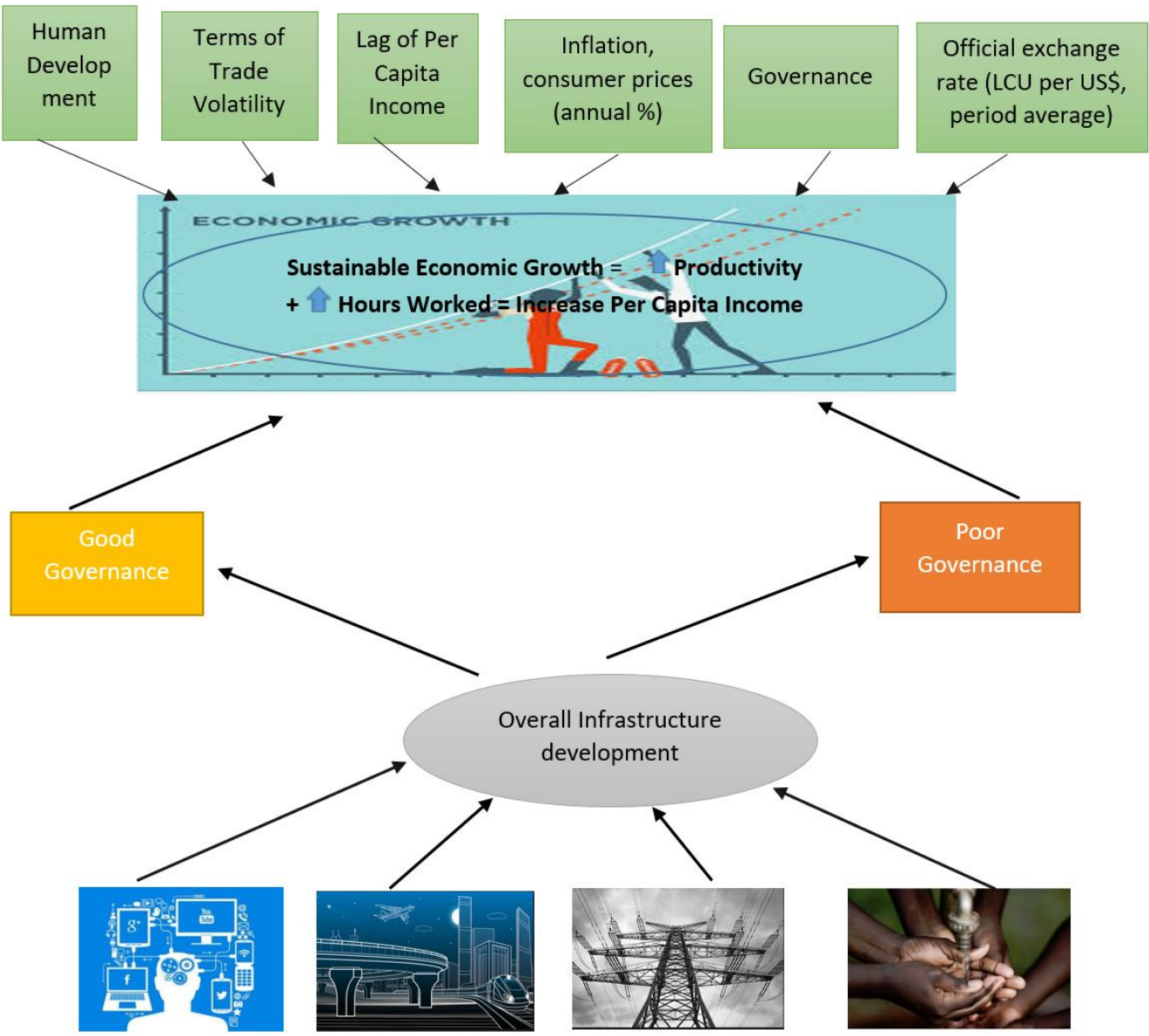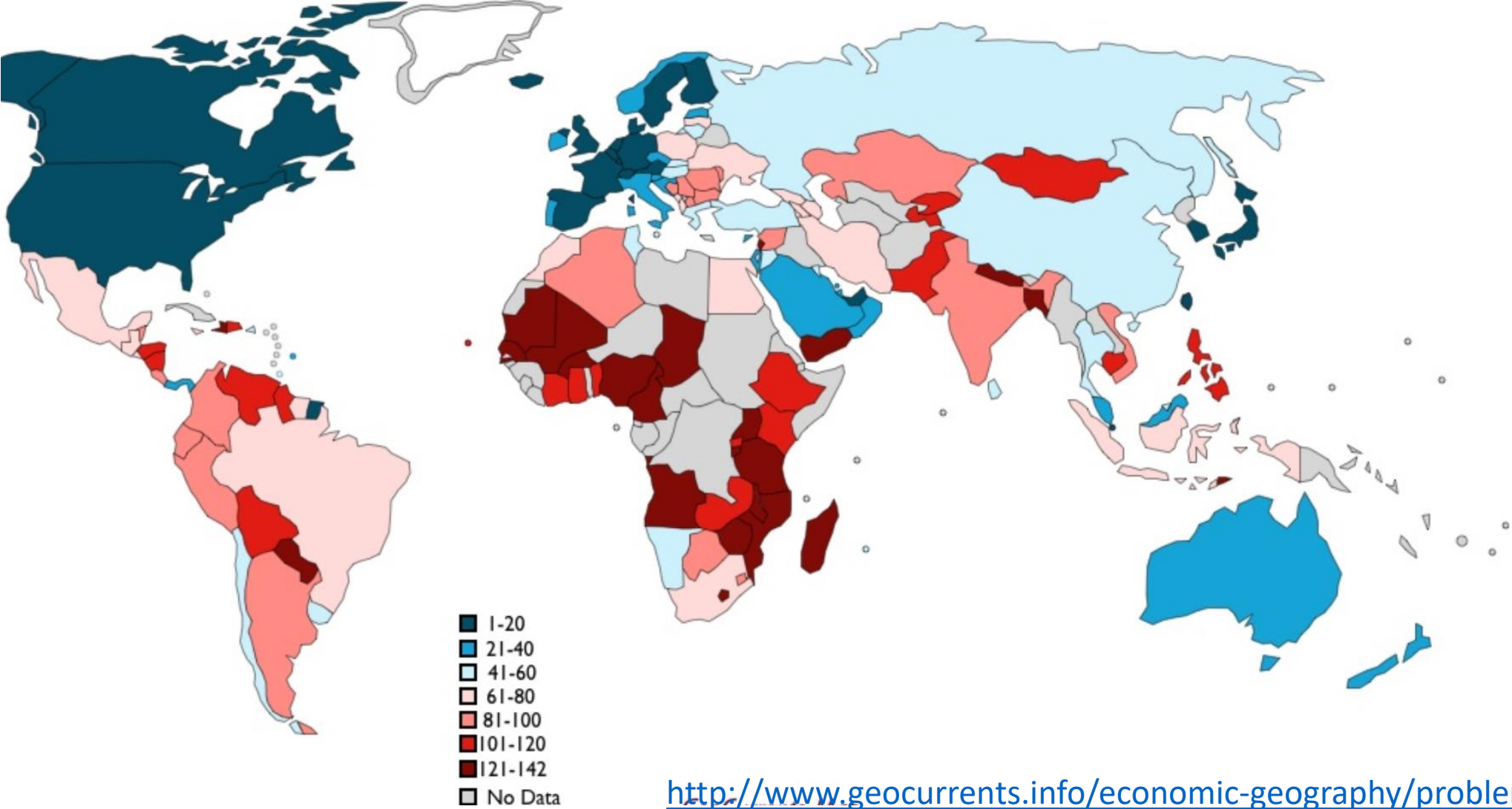
Outline

- 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

Human Development

Terms of Trade Volatility

Lag of Per Capita Income

Inflation, consumer prices (annual %)

Governance

Official exchange rate (LCU per US$, period average)

ECONOMIC GROWTH

Sustainable Economic Growth = ⬆ Productivity + ⬆ Hours Worked = Increase Per Capita Income

Good Governance

Poor Governance

Overall Infrastructure development

World Economic Forum's
Global Infrastructure Rankings

■	1-20
■	21-40
■	41-60
■	61-80
■	81-100
■	101-120
■	121-142
■	No Data

http://www.geocurrents.info/economic-geography/problems-with-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
  - Source: http://reports.weforum.org/global-competitiveness-index-2017-2018/downloads/

- 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).
  - Sassiand 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*
- $y_{it} = \alpha_i + \delta q_{it} + \beta_i X_{it} + \varepsilon_{it}$ (1)
- $y_{it} = \alpha_i + \delta_1 q_{it} I(q_{it} < \gamma) + \delta_2 q_{it} I(q_{it} \geq \gamma) + \beta_i X_{it} + \varepsilon_{it}$ (2)

- *Quantile Regression*
- $E[RIF(Y_{it}; q_\tau | X_{it})] = X_{i,t} \beta_{\tau,i}$ (3)

- 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, αi is fixed-effects parameter, δi is parameters of the infrastructure measures, β_i and ε_{it} is random error

African Infrastructure Development Index
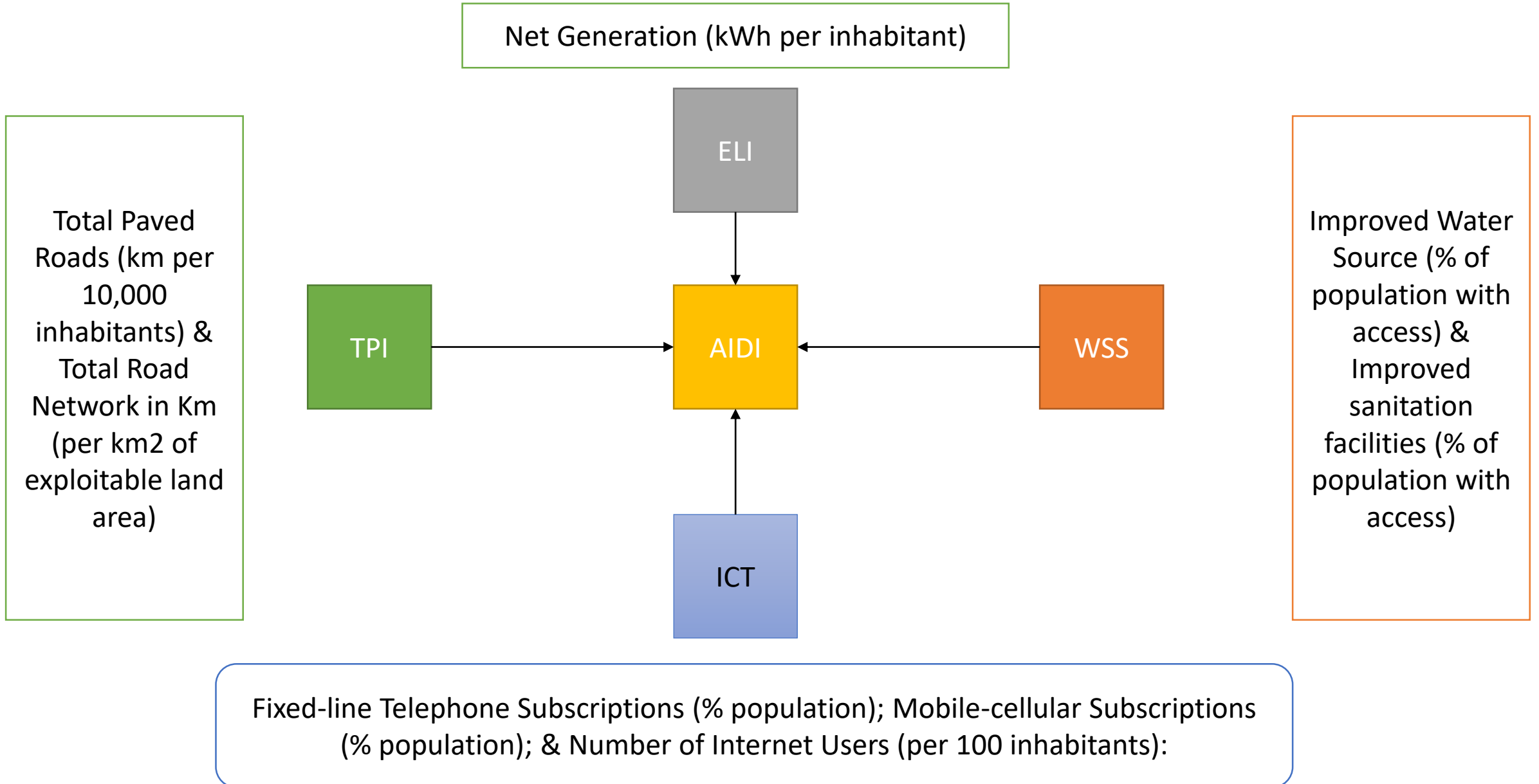
Governance Indicator (GINDEX) Formulization (GINDEX

- 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 - >
   - (xi-min)/(max-min)
2. Standardized indices are summed to form one governance index (GINDEX).

Table 1. Variable Description and Summary Statistics

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

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.

Tables 2 & 3 Estimation & Test for Unitary Thresholds.

Variable	Description	Threshold	95% CI	
			Lower	Upper
OII	Overall Infrastructure Composite Index	5.30	5.30	5.32
TPI	Transport Infrastructure Composite Index	5.32	5.30	5.32
ELI	Electricity Infrastructure Composite Index	5.32	5.29	5.32
ICT	ICT Infrastructure Composite Index	5.30	5.27	5.30
WSS	Water and Sanitation Composite Index	5.32	5.30	5.32

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

Variable	Variable Name	RSS	MSE	Fstat	Prob	Crit10	Crit5	Crit1
OII	Overall Infrastructure Composite Index	17,900	35.47	37.28	0.06	28.30	39.23	71.66
TPI	Transport Infrastructure Composite Index	17,600	34.69	52.31	0.03	29.71	38.36	114.14
ELI	Electricity Infrastructure Composite Index	18,200	35.99	34.07	0.07	25.97	42.09	95.94
ICT	ICT Infrastructure Composite Index	17,700	34.98	40.56	0.01	22.17	26.74	37.40
WSS	Water and Sanitation Composite Index	17,800	35.17	24.37	0.15	29.03	33.75	119.86

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

- $PCIG_{it} = \alpha_{it} + \delta_1 \log(INFRA_{fit}).I(GINDEX \leq \gamma) + \delta_2 \log(INFRA_{fit}).I(GINDEX_{it} > \gamma) + \beta_1 \log(PCI_{i,t-1}) + \beta_2 \log(MYSCH_{it}) + \beta_3 \log(XRATE_{it}) + + \beta_4 \log(TOTSD_{it}) + \beta_5 log\pi_{it} + \beta_6 \log(GINDEX_{it}) + \beta_7 \log(MONEY_{it}) + \varepsilon_{it}$

Table 4 Full Single Threshold Panel Regression Estimates.

Variable	Description	Model 1 Overall Composite Index Coeff.	Std. Error		Model 2 Transport Composite Index Coeff.	Std. Error		Model 3 Electricity Composite Index Coeff.	Std. Error		Model 4 ICT Composite Index Coeff.	Std. Error	
Control Variables													
log(PCIL)	Log of one period lag GDP per capita	-0.4215	0.0351	***	-0.4044	0.0342	***	-0.4070	0.0349	***	-0.4737	0.0353	***
log(money)	Log of Broad money (% of GDP)	-0.0479	0.0127	***	-0.0392	0.0126	***	-0.0432	0.0128	***	-0.0537	0.0131	***
TOTSTD	Square root of Net barter terms of trade index (2000 = 100)	0.0070	0.0318		0.0029	0.0313		0.0005	0.0319		0.0028	0.0314	
πlog	Semi-log transformation of inflation rate	0.0023	0.0011	**	0.0023	0.0011	**	0.0022	0.1070	**	0.0018	0.0011	*
log(MYSCH)	Log of Mean years of schooling	0.1349	0.0529	***	0.1970	0.0448	***	0.1915	0.0461	***	0.0636	0.0565	
log(XRATE)	Log of exchange rate (Local currency to US dollar)	0.0076	0.0177		0.0192	0.0164		0.0207	0.0165		0.0119	0.0176	
log(GINDEX)	Log of Governance Index	0.1348	0.0596	**	0.1202	0.0586	**	0.1610	0.0590	***	0.2063	0.0554	***
log Infrastucture													
	<= GINDEX Threshold	0.0169	0.0240		-0.0205	0.0251		-0.0274	1.0850	**	-0.0277	0.0066	***
	> GINDEX Threshold	0.0537	0.0233	**	0.0357	0.0239		0.0076	0.9350		0.0121	0.0030	***
sigma_u		45.15			43.93			45.23			55.13		
sigma_e		6.25			6.18			6.29			6.20		
rho		0.98			0.98			0.98			0.99		
F-stats		24.75			26.55			23.80			26.12		
P > F		0.00			0.00			0.00			0.00		

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
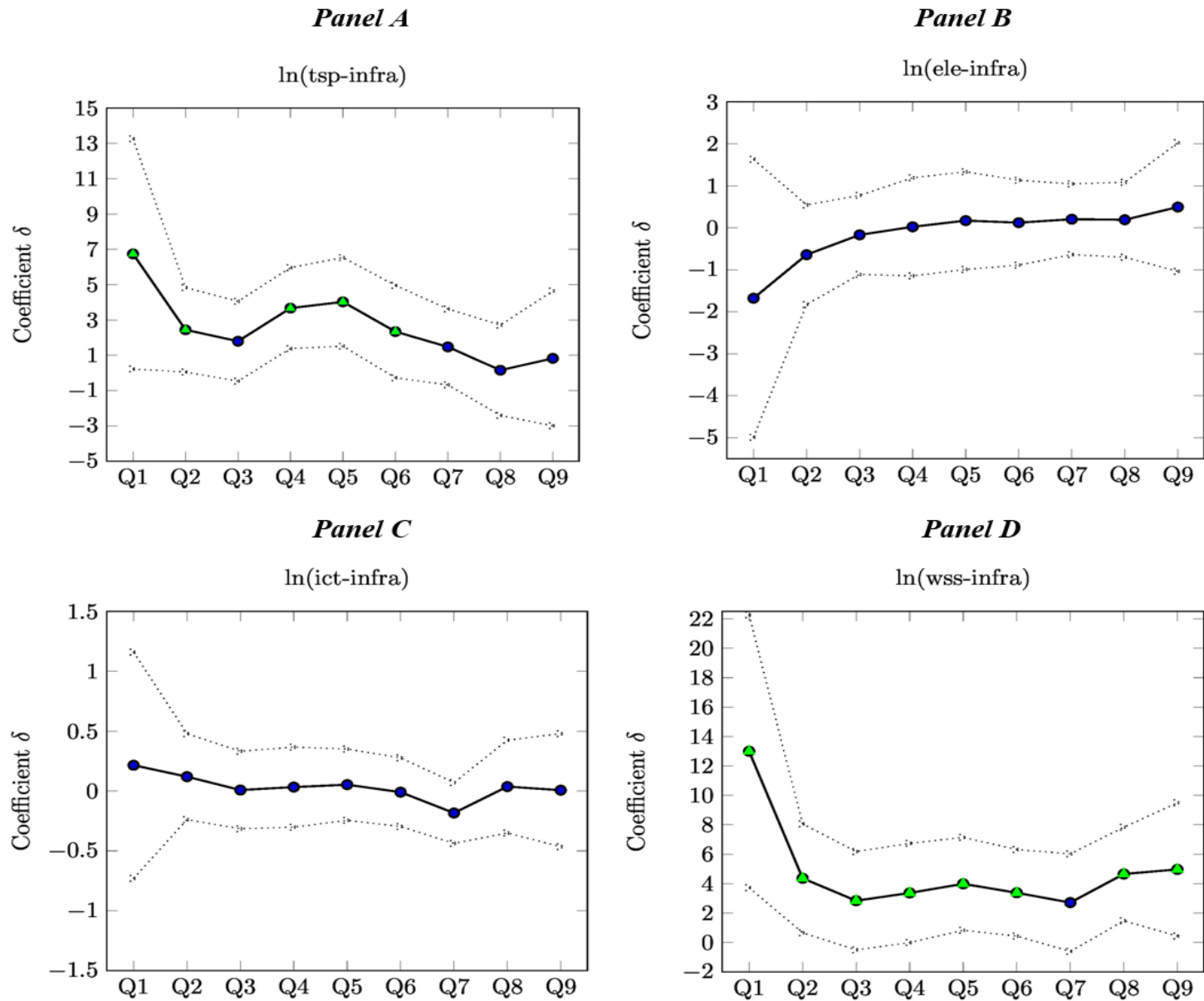
- Impacts

	Good Governance		Bad Governance	
OIDI	0.054	***	0.017	
TSP	0.036		-0.020	
ELI	0.008		-0.027	**
ICT	0.012	***	-0.028	***

Figure 1: Quantile Regression for Overall Infrastructure Index Impact on Growth
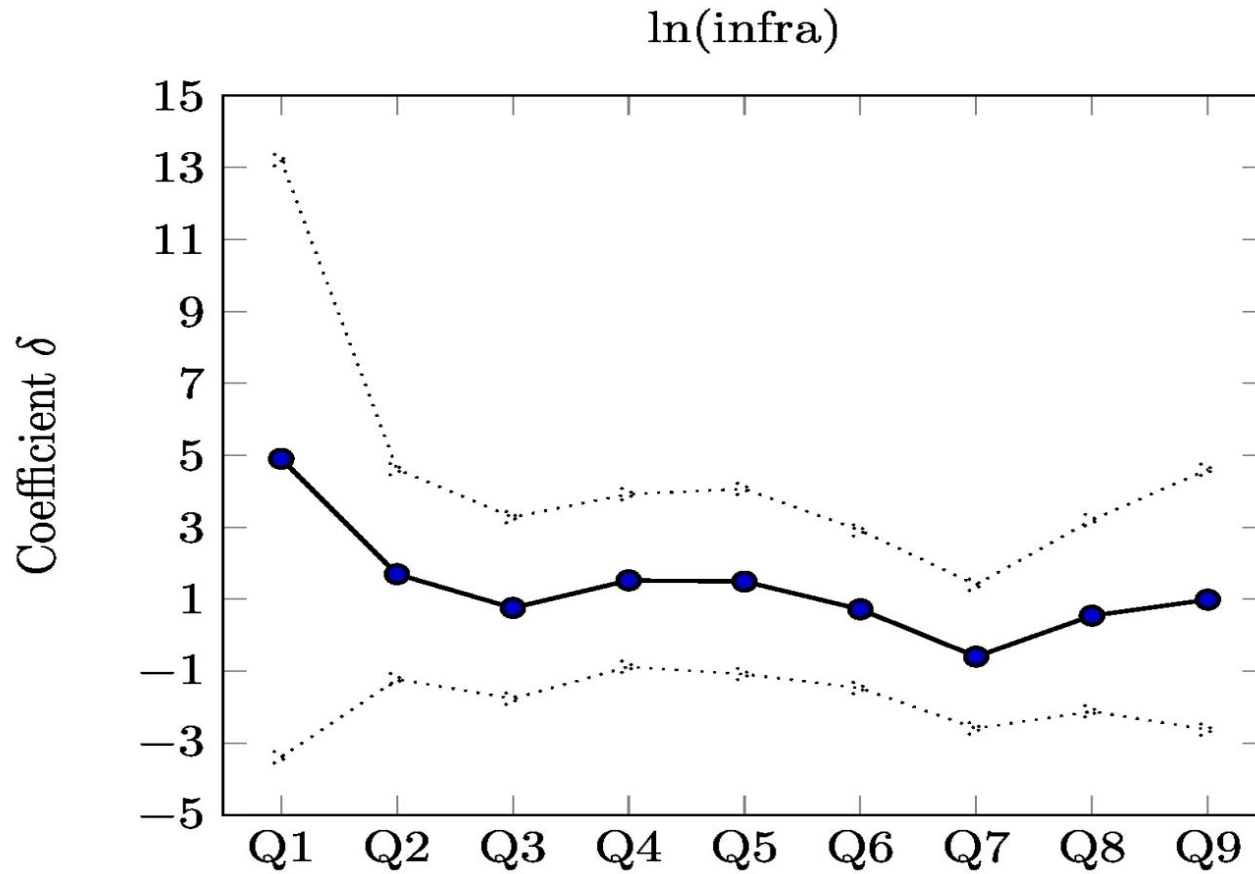
Figure 2: Quantile Regression Results for the Infrastructure Indicators' Impact on Economic Growth

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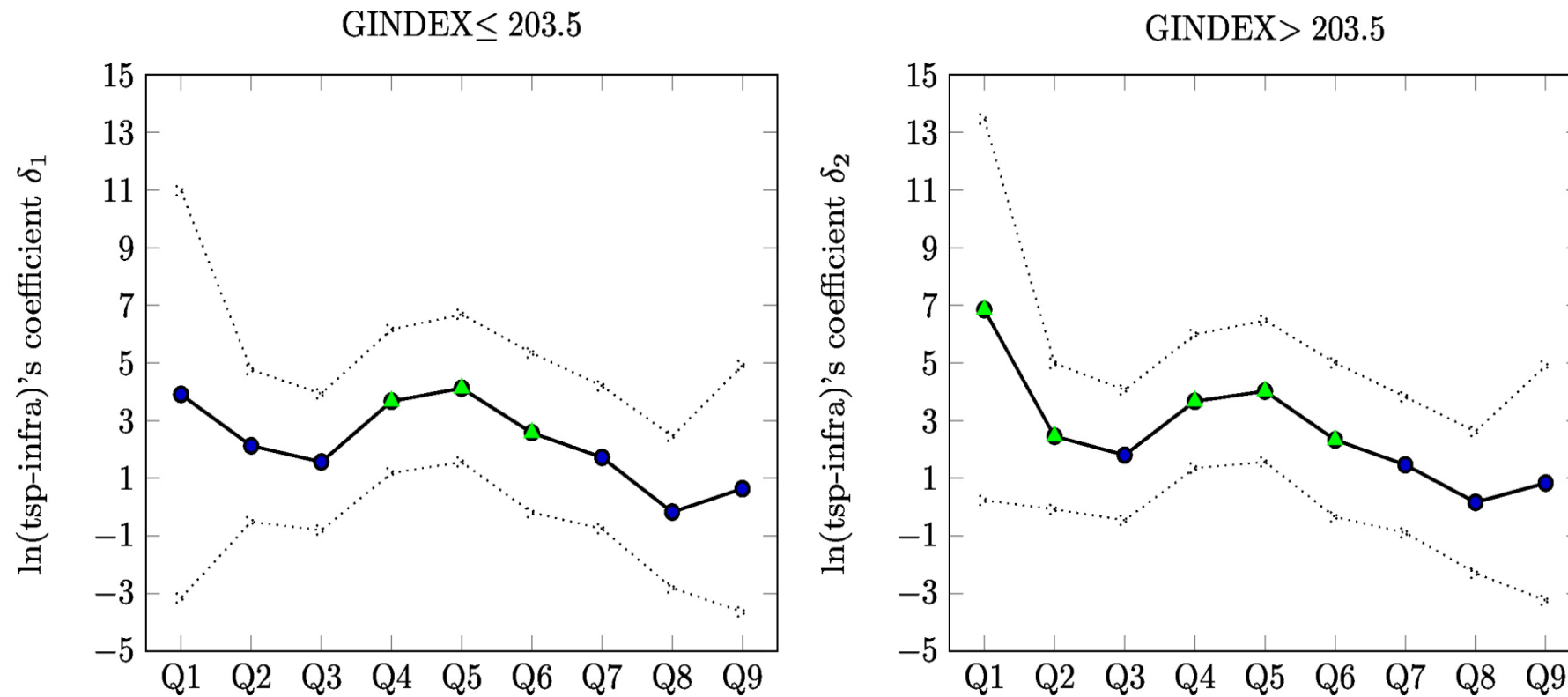
Quantile Regressions Without Thresholds

- 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
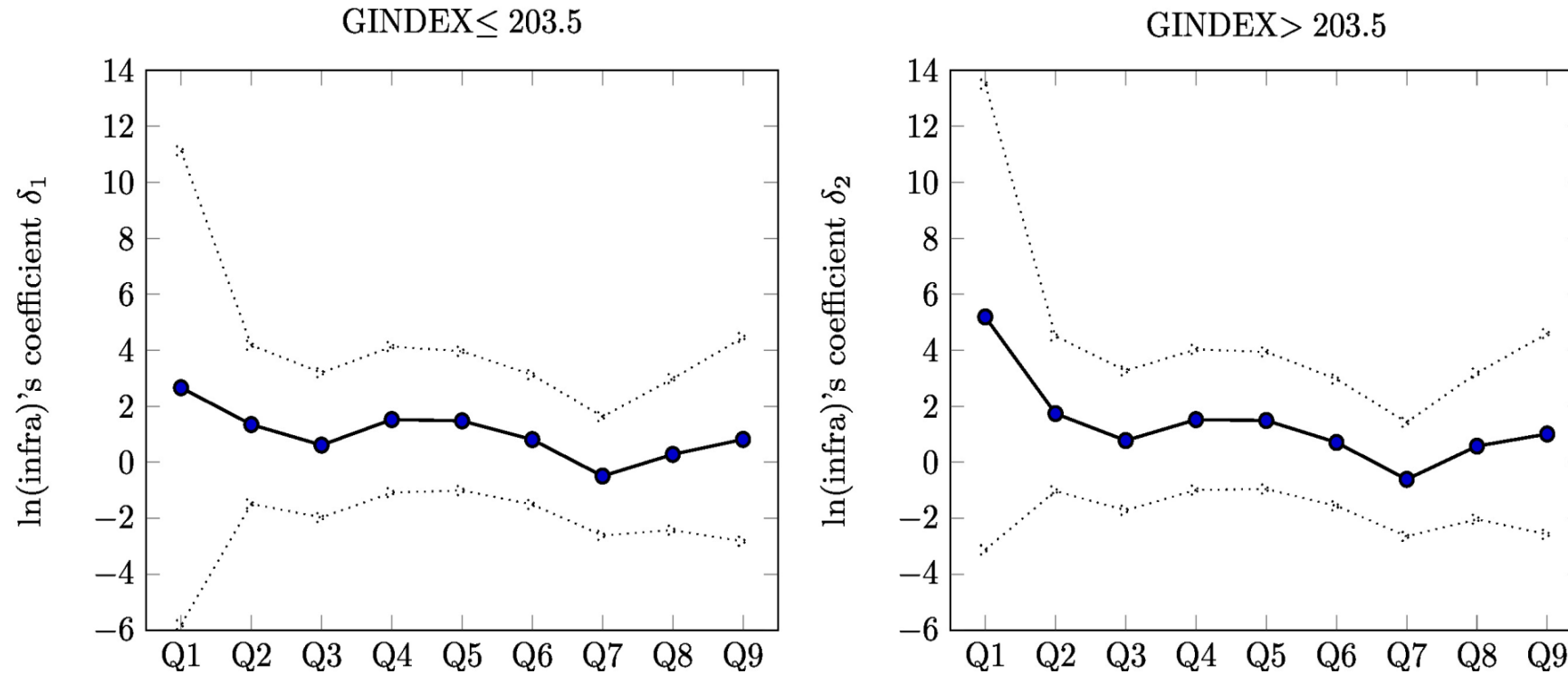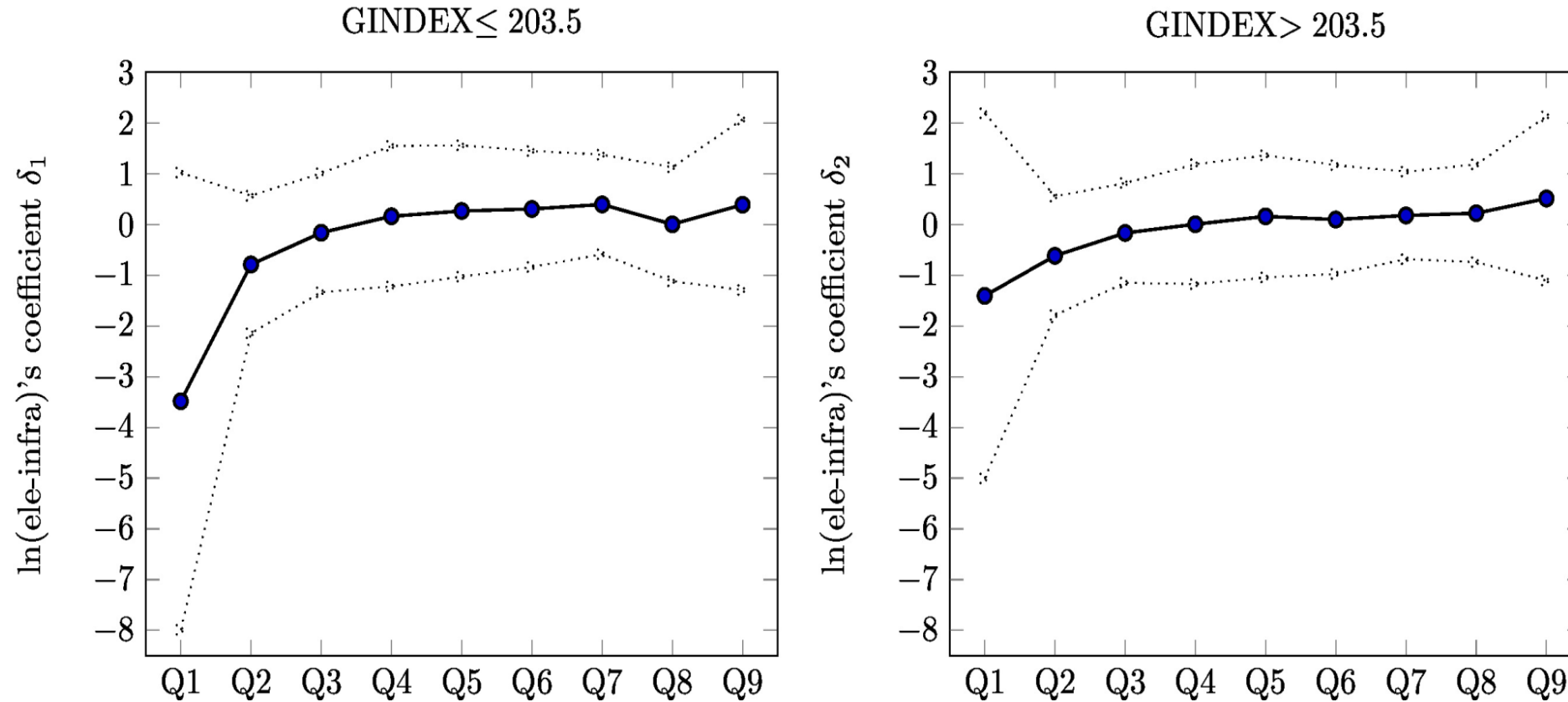
Figure 4 Quantile Regression for Transport Infrastructure Index by Governance Threshold
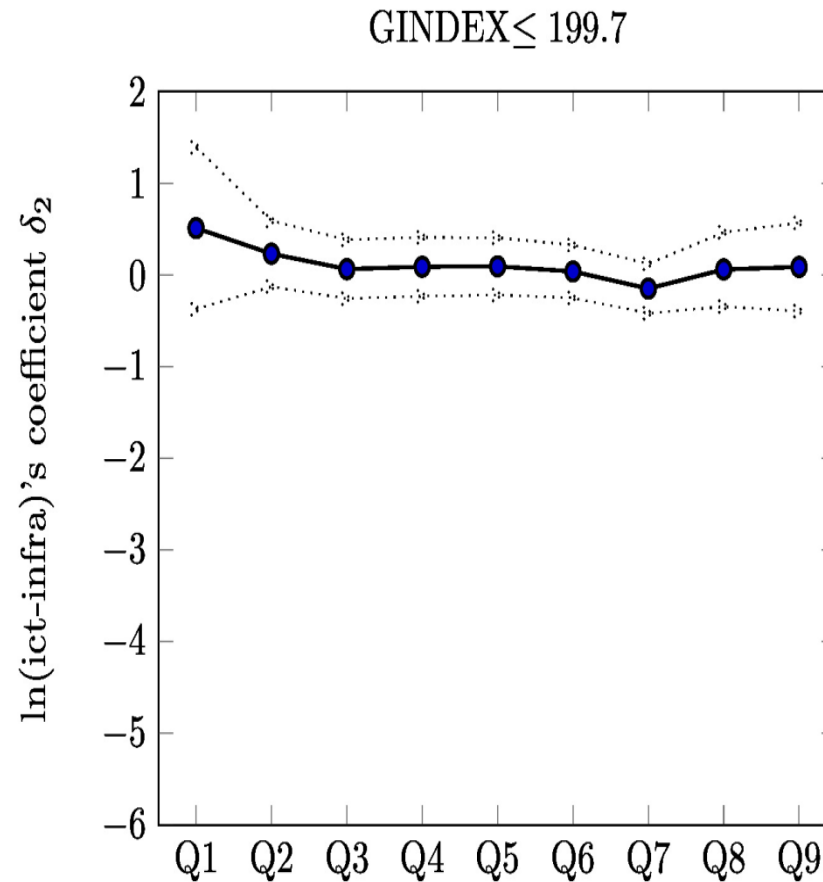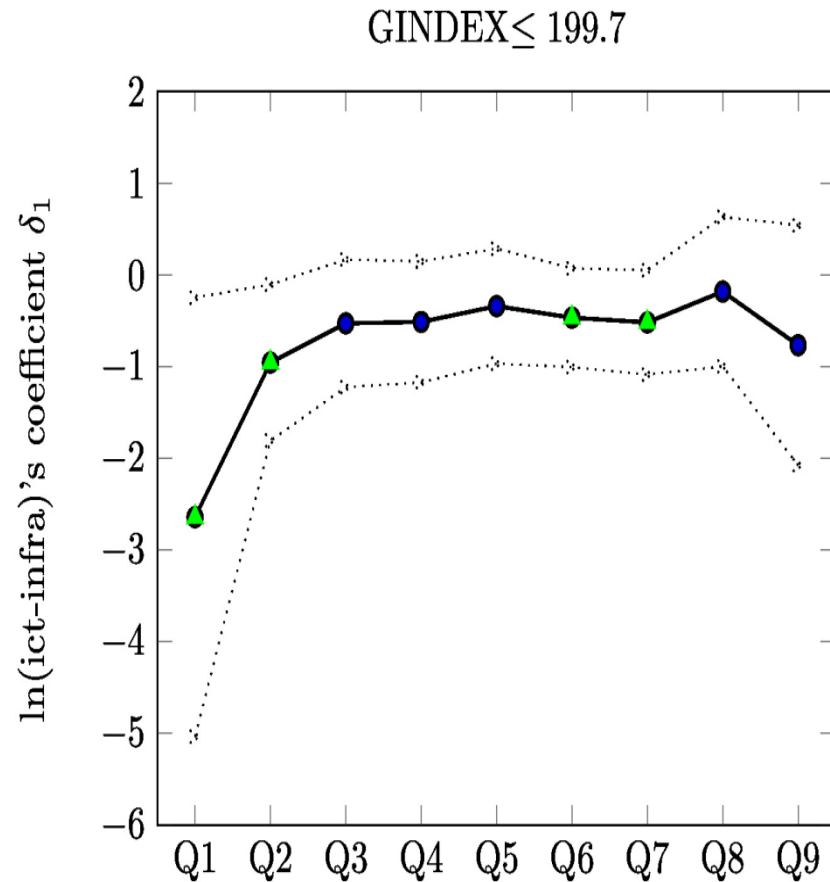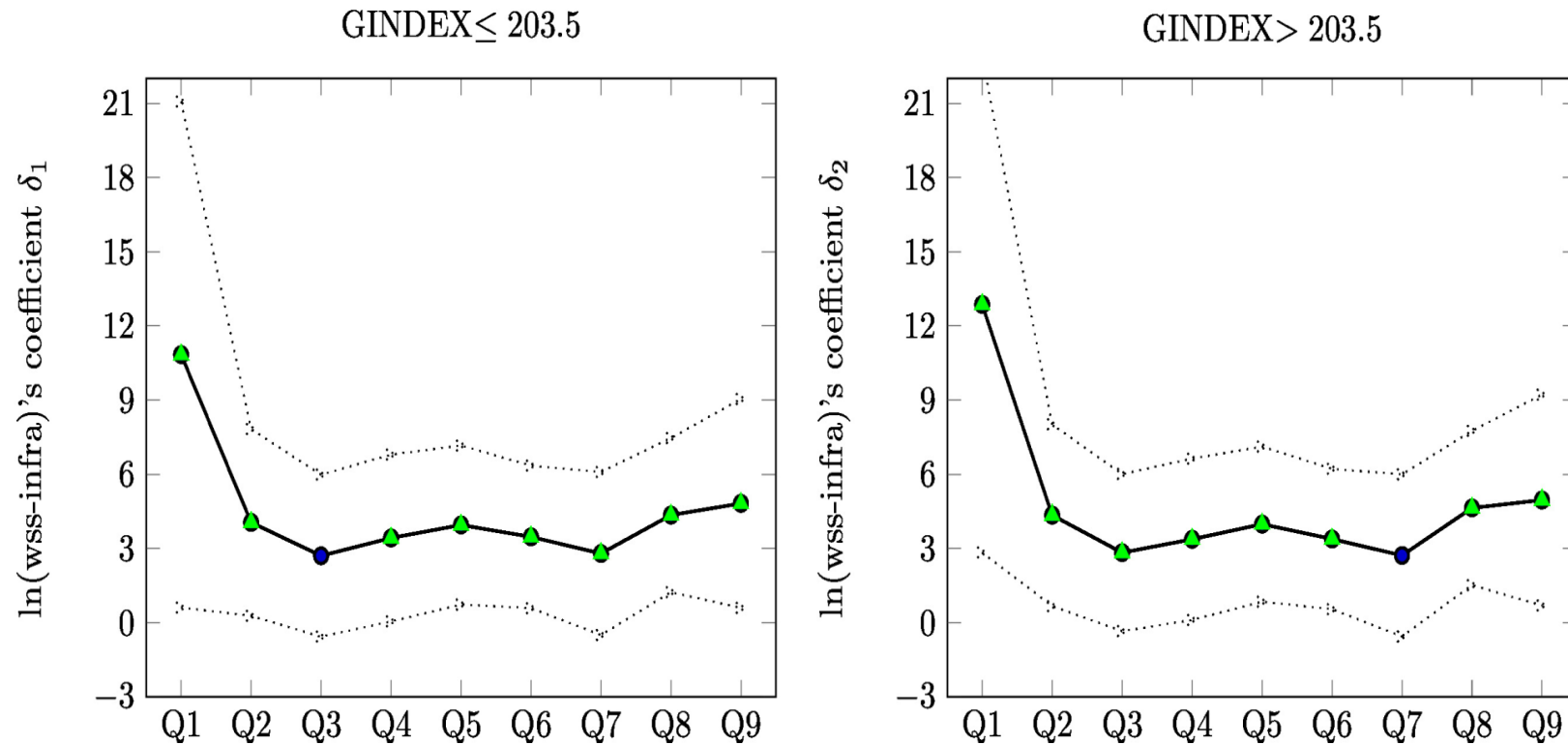
Figure 5 Quantile Regression for Electricity Infrastructure Index by Governance Threshold

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)

- Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Congo, Dem. Rep., Congo, Rep., Cote d'Ivoire, Egypt, Equatorial Guinea, Eswatini, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, South Africa, Sudan, Tanzania, Togo, Tunisia, Uganda, Zambia.