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Institutional Quality, Infrastructure and Economic Growth in Africa

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Abstract

We use a panel data set of 46 African countries over the 2003-2015 period to study the role of institutional quality in infrastructure-led growth. Based on the causal analysis, we show large positive effects of growth for countries with strong institutional quality in comparison to their counterparts with weak institutional quality. This result is not sensitive to the choice of a particular measure of infrastructure or institutional quality. Our results suggest the presence of nonlinearities when estimating infrastructure-led growth and emphasize the importance of complementarities influencing such an estimation.

Keywords

Infrastructure, Economic Growth, Rule of Law, Governance, Africa, Panel Data.

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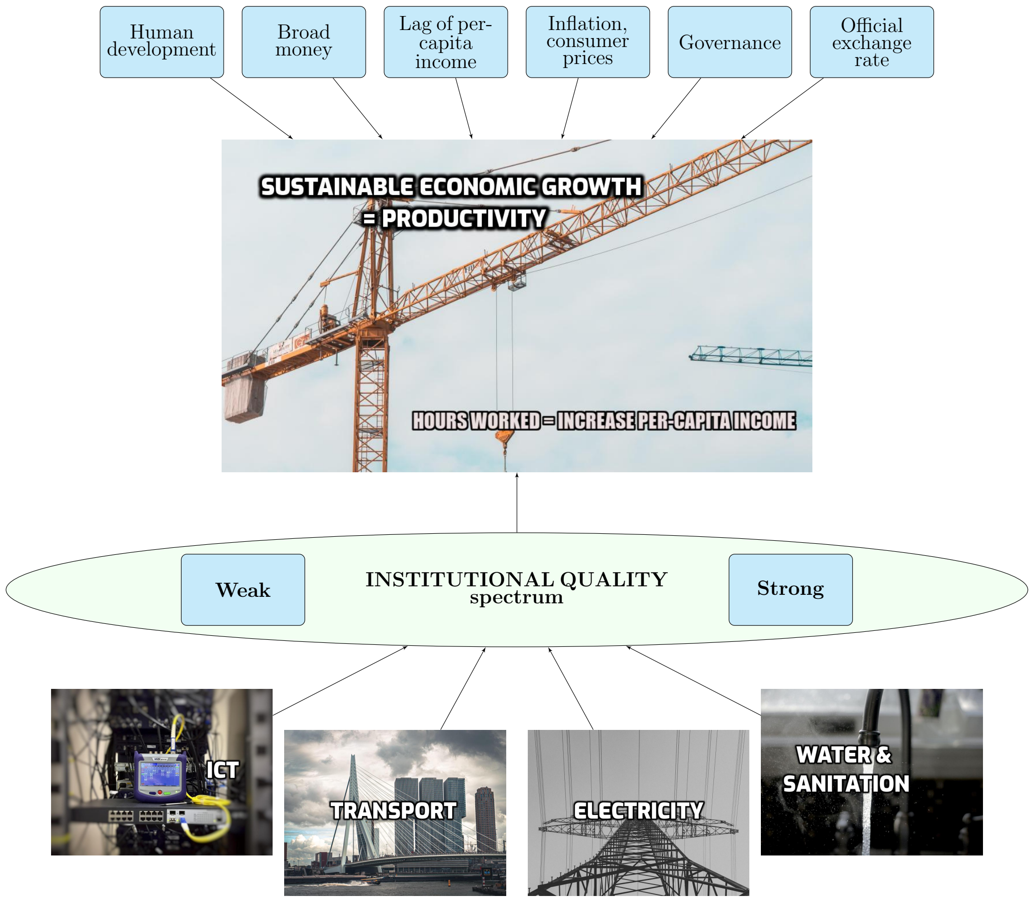

Figure 1. Schematic Diagram of Institution's Impact on Infrastructure-led Economic Growth

Note: We credit the following artists for providing the photographs used in this figure: Guillaume Techer (guillaumeval.techer@gmail.com) for SUSTAINABLE ECONOMIC GROWTH, Ildefonso Polo for ICT, Mika Baumeister (ich@mikabaumeister.de) for TRANSPORT, Jaroslaw Kwoczala for ELECTRICITY, and Imani for WATER & SANITATION.

1 Introduction

Africa faces a huge infrastructure gap. Only about 30% of Africa is connected to the electrical grid (AfDB, 2018; Blimpo and Cosgrove-Davies, 2019), only 50% have access to basic handwashing facilities and less than half of those have access to clean water and sanitation (WHO/UNICEF, 2017), only 10% have access to the internet, and less than a quarter of the road networks are paved (Mayaki, 2014). Consequently, in its 2016 Annual Development Effectiveness Review, the African Development Bank argued in favor of encouraging African policymakers to invest more in infrastructure as a means to propel the continent to a path of sustainable economic growth and development (AfDB, 2016). However, critics still debate whether unilateral increases in infrastructure spending can lead to growth. The reason for this is even though some African nations (e.g., Cameroon, Nigeria, and post-Arab Springs Tunisia) have enjoyed high strides in infrastructure penetration over the years, many of them have experienced only modest or stagnant economic improvements. In this paper, we offer an interpretation of why this is the case and present the circumstances supporting the infrastructure-led growth hypothesis. Specifically, we consider the presence of a missing link that mediates on how infrastructure impacts economic growth and conceptualize that "institutional quality" is that link.

The relationship between infrastructure and economic growth is complex and evolving. Earlier theoretical works presented the notion that infrastructure is a production factor that influences growth directly (e.g., Aschauer, 1993; Gramlich, 1994). Subsequent works supported the premise that infrastructure influences productivity only through spillovers into sectors that require such infrastructure to be productive – i.e., either by lowering transportation costs, improving labor productivity, reducing mortality or through scaling brought about by market expansion (e.g., Barro, 1990; Fedderke and Bogetić, 2009). Alternately, another school of thought that developed argued that infrastructure services only materialize in the presence of the right set of incentives (e.g., Banerjee and Duflo, 2005; Straub, 2011). Proponents of this type of modeling say that imperfect information, adverse selection, and moral hazard problems that plague government-driven public investments can become viable only in the presence of an adequate level of the regulatory framework (Laffont and Tirole, 1993, 2000). Our study falls under the last category, focusing on the role of institutional quality in making infrastructure productive.

A balanced panel of 46 African countries between 2003 and 2015 is selected based on the availability of data on the key study variables and on appropriate confounding factors. Using the rule of law as a proxy of institutional quality, our empirical strategy begins by examining the presence of institutional quality clusters in the data using Hansen' (1999) endogenous threshold regression technique. Taking these threshold points as given, we then use the dynamic generalized methods of moments (GMM) panel estimation (Arellano and Bover, 1995; Blundell and Bond, 1998) to model the infrastructure-growth relationship over the regions identified by the threshold regression. By doing it this way, we can directly draw inferences on whether, if at all, and to what extent the legal state of affairs interferes with the process by which infrastructure drives economic growth. We also permit our approach to be consistent across several dimensions to ensure a wider applicability of our conclusions. To this extent, we test our proposition using an alternate comprehensive measure of governance that captures several aspects of social justice and on various types of infrastructure (information and communication technology, transport, electricity, and water services and sanitation).

We add to the literature on the role of institutions in economic growth in general (e.g., Banerjee and Duflo, 2005; Lenz et al., 2017; UNCTAD, 2018) and in infrastructure-led economic growth in particular (e.g., Roller and Waverman, 2001; Esfahani and Ramirez, 2003; Canning and Pedroni, 2008; Calderon and Serven, 2010) by providing robust estimates of infrastructure-growth elasticities across institutional quality groups in Africa. Specifically, we show that infrastructure only contributes to growth in countries with strong institutional quality (and with good governance, in general). On the flip side, in countries with weak institutional quality (and with bad governance), infrastructure seems to negatively impact growth brought about by adverse externalities that outweigh the direct benefits of infrastructure investments. The policy implication of our results is striking: most African nations have low infrastructure stock in place (AfDB, 2014, 2018) with many looking forward to increasing their infrastructure-related investments to bolster economic growth (AfDB, 2016, 2019). In these situations, it becomes crucial for policymakers to carry out reforms that ensure that these investments yield higher financial and social returns. Our paper suggests that significant governance improvements are required before infrastructure investments are made to ensure that infrastructure-growth elasticity remains positive and relevant.

The rest of the paper is organized as follows. Section 2 presents a review of selected literature that explains the process by which infrastructure development leads to economic growth. Section 3 describes the empirical methodology, namely the endogenous threshold regression and the dynamic GMM panel estimation, employed in this paper along with a brief overview of the data that accompanies our empirical analyses. Section 4 presents our main findings and discusses robustness checks. Section 5 presents the concluding remarks of the paper.

2 Literature Review

The empirical investigation of the infrastructure-growth relationship can largely be traced back to the series of papers by David Aschauer, where he documents substantial positive elasticities between certain “core” infrastructural investments in streets, highways, airports, mass transit, sewers, and water systems, and economic growth (Aschauer, 1989a, 1989b, 1989c). Since then, a plethora of studies have documented all variations and ranges of elasticities (positive, negative, and zero) utilizing different samples, different periods, and different methodologies.* In this section, we discuss some of the pertinent literature that links infrastructure to economic growth, with a special emphasis on works done on the African continent.

The relationship between infrastructure and growth was long thought to be linear and was modeled as such. With this type of modeling, some scholars have relied on country-based analysis rather than on cross-country analysis to investigate the persistence of infrastructure capital on growth. For example, see Owusu-Manu et al. (2019) for Ghana; Njiru et al. (2020) (2020) for Kenya; Akinbobola and Saibu (2004) and Oyeniran and Onikosi-Alliyu (2016) for Nigeria; and Fedderke et al. (2005, 2006), Kularatne (2006), Fedderke and Bogetić (2009), Kumo (2012), and Gnade et al. (2017) for South Africa.

There is also an additional body of research that investigates the linear infrastructure-growth relationship for a set of sub-Saharan African countries and, largely due to data unavailability, focuses only on singular measures of infrastructure as opposed to one composite measure that captures all aspects of a country’s infrastructure capital stock. Gyimah-Brempong and Karikari (2010), Babatunde (2011), Cleeve and Yiheyis (2014), Batuo (2015), Donou-Adonsou et al. (2016), Haftu (2019), and David and Grobler (2020) document steep increasing returns to telecommunications infrastructure, Njoh (2000) and Boopen (2006) for transportation infrastructure, and Wolde-Rufael (2006) and Akinlo and Apanisile (2014) for electricity infrastructure.

Taking positive infrastructure elasticities as a given, the last set of linear design models compares the extent of infrastructure penetration in the market versus

*See the survey works of Gramlich (1994), Sturm et al. (1998), Romp and de Haan (2007), and Straub (2011).

the quality of infrastructure available for household consumption, based on their propensity to enhance output. This type of investigation is particularly interesting because it is vital for countries facing huge infrastructure deficits to decide where to invest their infrastructure funds. While some argue that the economic gains as a whole is more so from a larger stock of infrastructure than from quality enhancements (Calderon, 2009; Chakamera and Alagidede, 2017), others find the exact opposite (ACBF, 2016). Contrastingly, Calderon and Serven (2010) find that there is strong evidence that infrastructure stocks in telecommunications, electricity, and roads as well as their quality has a positive impact on the long-run economic growth.

Due to the conflicting elasticities reported in infrastructure studies, some authors have challenged the notion that the true relationship between infrastructure and growth is linear. For instance, some argue that the true relationship depends on the initial conditions, which is why infrastructure development has immediate and relatively large impacts on poorer countries than in countries where there is already an established infrastructure network in place (Calderon and Serven, 2014). In the case of transport networks, it is reasonable to expect that economic growth will be stagnant up until some level of road networks are developed. Beyond that level, additional roadways will prompt an immediate increase in economic growth until an optimal level of the network is established, and at such a point, the benefits to building yet another roadway are limited (Li, 2010; Calderon and Serven, 2014).

Another reason for nonlinearity is the presence of network externalities. It is quite possible that with a certain level of infrastructure present in the economy, the direct gains from infrastructure spills over to other sectors like health and education (Serebrisky, 2014). For example, Hjort and Poulsen (2019), using the World Bank Enterprise Survey data on six African countries (Ghana, Kenya, Mauritania, Nigeria, Senegal, and Tanzania), report that the introduction of fast Internet affects employers' relative demand for skilled and unskilled labor, and decreases (un)employment inequality in Africa. While spillovers are possible, there is a lack of consensus on what the level of infrastructure is that leads to these spillovers. Roller and Waverman (2001), using a sample of 21 OECD countries over 20 years, find that the critical mass that dictates spillovers appears to be at a level of telecommunications infrastructure that is near-universal service. Contrastingly, Hurlin (2006), using a balanced panel of developing countries, finds that the network spillovers can occur even at lower and intermediate levels of infrastructure.

Lastly, Banerjee and Duflo (2005) also point out that complementarity as a reason for why we observe a nonlinear relationship between infrastructure and growth. They point to several "non-aggregative" sources including government failures (inadequate regulations, excessive interventions), credit constraints and failing insurance markets, intergenerational constraints, and behavioral issues as reasons why adding infrastructure capital stock may not lead to its corresponding productivity enhancements. For example, Lenz et al. (2017) show that the recent large-scale electricity roll-out in Rwanda had weak impacts on classical poverty indicators because of existing social bottlenecks such as inadequate transport links. In the same way, (UNCTAD, 2018) also shows that the efforts to increase connectivity through transport networks are more likely to influence growth only when those networks are targeted to those regions where industrial activities can be more easily facilitated.

In addition to nonlinearity, one more specific methodological issue that needs to be addressed is the reverse causality between infrastructure and growth. While the direct causation that the country's response to its infrastructural needs, innovations in infrastructural stock, and the level of infrastructural endowments unilaterally triggers its economic growth is widely documented, there is some evidence that growth triggers infrastructure buildup as well (Esfahani and Ramirez, 2003; Canning and Pedroni, 2008; Calderon and Serven, 2010; Straub, 2011). The simple logic behind the reverse causality is this – a country's infrastructure must be paid for and high-income countries can find additional funds to pay for such developments far easier than low-income countries. Therefore, it is important to utilize some sort of instrumental variable approach to correct for the upward simultaneity bias brought about by this reverse causality.

Our postulation in this paper is that the infrastructure-growth nexus is nonlinear. From the literature review presented above, this is an area in the African infrastructure/growth nexus with a gap that needs more analysis. Broadly taking insights from Banerjee and Duflo (2005), we argue that this nonlinearity can primarily arise from the complementarity that infrastructure shares with the quality of institutions in the country. By utilizing an endogenous threshold analysis, we further analyze whether low and high institutional quality offers different complementarity effects on growth.

3 Empirical Methods and Data

Empirical Methods

We start our empirical investigation of whether infrastructure-growth nexus is nonlinear using Hansen's (1999) threshold analysis. Specifically, the threshold analysis allows the data to endogenously select regimes not based on the principal causal variable (infrastructure) but based on the measure of institutional quality. By setting the analysis in this way, we can model the complementarity effects of infrastructure and institutional quality on growth effectively. However, we believe the endogeneity between infrastructure and growth may be a concern that also needs to be addressed. Employing a system GMM estimation method proposed by Arellano and Bover (1995) and Blundell and Bond (1998), we correct for such endogeneity in each regime previously identified by the threshold analysis. The formulation of the empirical model is explained in detail below.

Threshold Analysis We estimate the number of thresholds j, their values, and the model coefficients using the following equation:

$$y_{it} = \alpha_i + \nu Y_{it-1} + \eta \Omega_{it} + \sum_{p=0}^{j} \delta_p q_{it} I_{itp} + \beta x_{it} + \epsilon_{it} \tag{1}$$

where y_{it} denotes the economic growth rate of country $i(= 1, \ldots, N)$ at time $t(= 1, \ldots, T)$, Y_{it-1} is the lag of GDP per capita, q_{it} is the infrastructure development proxy for country i at time t, and x_{it} is the vector of other covariates. I_{itp} is the indicator variable for regime $p(= 0, \ldots, j)$ determined by the values of institutional quality $\Omega_{it} \in [\bar{\Omega}_p, \bar{\Omega}_{p+1})$ and δ_p is the coefficient of infrastructure q_{it} in that regime. ν, η, and β are the coefficients for the lag of GDP per capita, institutional quality, and the vector of covariates (mentioned later in Section 3), respectively.

α_i represents country-specific fixed effects and ϵ_{it} represents random model disturbances. $\forall j > 0$, we can ascertain that threshold exists and the regime indicator variable that defines each regime p can be written as,

$$I_{itp} = \begin{cases} 1, & \bar{\Omega}_p < \Omega_{it} \leq \bar{\Omega}_{p+1} \\ 0, & \text{otherwise.} \end{cases} \tag{2}$$

where the boundary conditions at the end, $\bar{\Omega}_0 = 0$ and $\bar{\Omega}_{j+1} = \infty$. When $j = 1$, equation (1) reduces to a single threshold model with a threshold level of $\bar{\Omega}_1$ and can be written as the following equation:

$$y_{it} = \alpha_i + \nu Y_{it-1} + \eta\Omega_{it} + \delta_0 q_{it} I_{it0} + \delta_1 q_{it} I_{it1} + \beta x_{it} + \epsilon_{it} \tag{3}$$

where I_{it0} is one for all values of institutional quality in the regime $p = 0$, i.e., when $\Omega_{it} \in [0, \bar{\Omega}_1)$, and zero otherwise. In the same way, I_{it1} is one for all values of institutional quality in the regime $p = 1$, i.e., when $\Omega_{it} \in [\bar{\Omega}_1, \infty)$, and zero otherwise.[†] Finally, when $j = 0$, equation (1) reduces to a linear panel model.

The validity of the threshold models is tested sequentially. First, the single threshold model ($j = 1$) is compared with the linear panel model ($j = 0$) to check whether the single threshold model is valid. If the model is valid and a single threshold is present, then the double threshold model ($j = 2$) is compared with the single threshold model ($j = 1$) to check for the validity of the double threshold model. If a double threshold exists, we then check for the validity of the triple threshold model; and so on. In our analysis, we estimate up to three thresholds and test model validity using the STATA command XTHREG developed by Wang (2015).

System GMM Estimation Method The primary methodological issue of concern is the bidirectional relationship between infrastructure and growth. In this paper, we use the system GMM estimation procedure described in Arellano and Bover (1995) and Blundell and Bond (1998) to correct for this type of causality. System GMM builds on a system of two equations - an *original equation* that is expressed in levels form and a *transformed equation* that is expressed in the first-differences form, both of which use higher-order lagged values as instruments. This type of estimation is a considerable improvement over the difference GMM (Arellano and Bond, 1991), which only uses the transformed equation in its estimation, to eliminate the fixed effects.

In our case, the original equation is described as follows:

$$Y_{it} - Y_{it-1} = \alpha_i + \nu Y_{it-1} + \sum_{p=1}^{j} \gamma_p I_{itp} + \lambda q_{it} + \sum_{p=1}^{j} \delta_p I_{itp} q_{it} + \beta x_{it} + \mu_{it} \tag{4}$$

where the dependent variable $Y_{it} - Y_{it-1}$ is the logarithmic difference of GDP per-capita at time t and $t-1$, I_{itp} and $I_{itp}q_{it}$ are the indicator variable of regime p

[†]Put simply, I_{it0} and I_{it1} are equal to one for institutional quality values that are less than (or equal to) and greater than the threshold cutoff point of $\bar{\Omega}_1$.

(as identified by the threshold analysis) and its interaction with the infrastructure variable q_{it}, respectively. mu_{it} is the error term. Equation (4) can be rewritten as,

$$Y_{it} = \alpha_i + (1+\nu)Y_{it-1} + \sum_{p=1}^{j} \gamma_p I_{itp} + \lambda q_{it} + \sum_{p=1}^{j} \delta_p I_{itp} q_{it} + \beta x_{it} + \mu_{it}. \tag{5}$$

The transformed equation is written as,

$$\begin{aligned} Y_{it} - Y_{it-1} = (1+\nu)\Delta Y_{it-1} + & \sum_{p=1}^{j} \gamma_p \Delta I_{itp} + \lambda \Delta q_{it} \\ & + \sum_{p=1}^{j} \delta_p \Delta (I_{itp} q_{it}) + \beta \Delta x_{it} + \Delta \mu_{it}. \end{aligned} \tag{6}$$

For the single threshold case ($j = 1$), equations (4) and (6) can be re-written as

$$Y_{it} - Y_{it-1} = \alpha_i + \nu Y_{it-1} + \gamma_p I_{it1} + \lambda q_{it} + \delta I_{it1} q_{it} + \beta x_{it} + \mu_{it} \tag{7}$$

and

$$\begin{aligned} Y_{it} - Y_{it-1} = (1+\nu)\Delta Y_{it-1} + & \gamma \Delta I_{it1} + \lambda \Delta q_{it} \\ & + \delta \Delta (I_{it1} q_{it}) + \beta \Delta x_{it} + \Delta \mu_{it}. \end{aligned} \tag{8}$$

Both equations (7) and (8) are estimated simultaneously using the STATA command XTABOND2 developed by Roodman (2009a). The difference variables in the transformed equation are instrumented by higher-order lagged variables in levels and level variables in the original equation are instrumented by higher-order lagged differences. Following Roodman (2009b), the number of lagged instruments used in our estimation is restricted to three lags. The test of instrument validity proposed by Arellano and Bover (1995) is done in two stages. First, a modified version of the Arellano–Bond test is used to test whether the first-differenced residuals have a second-order serial correlation. If the test provides evidence that there is no second-order serial correlation, then the GMM estimator is consistent. Second, the Hansen J-test and Difference-in-Hansen test report the overidentification and instrument validity statistics that are required for system GMM, respectively. If we fail to reject the null hypothesis, the instruments are valid.

Data

Our sample on 46 African countries between the years 2003 and 2015 is primarily assimilated from three sources: the African Development Bank's 2018 African Infrastructure Development Index, the World Bank's World Development Index, and the World Bank's World Governance Index. The construction of our sample was determined solely based on data availability on principal study variables and the need for a balanced panel for analyses. The final sample has 598 country-year observations. Appendix 1 lists the sample of countries used in our paper.

As noted earlier, the dependent variable y_{it} is the per-capita GDP growth rate (PCIG). The main variable of interest is infrastructure development (q_{it}). The individual proxies that we use to capture infrastructure development include the overall infrastructure composite index (INFRA) provided by the African Development Bank and its components - Information and communication technology index (ICT), Transport index (TSP), Electricity index (ELEC), and Water Supply and Sanitation index (WSS). The ICT index includes phone subscriptions per capita (including fixed lines and mobile subscriptions), the number of internet users per capita, fixed broadband subscribers per capita, and the share of international internet bandwidth. The TSP index includes the network of roads as well as the prevalence of paved roads. The ELEC index includes the total electricity produced and imported in millions of kilowatt-hours per hour and per inhabitant. Lastly, the WSS index includes the population share with access to water sources and sanitation facilities. In a sense, these indices broadly capture access to infrastructure and to some extent the quality of infrastructure as well. For instance, while the road network signals access to TSP infrastructure on a per-capita basis, the overall prevalence of paved roads in a country signifies the quality of TSP infrastructure in that country.

The list of covariates used in our analysis is motivated by standard economic theory (e.g., see Barro, 2003; Ndoricimpa, 2017): one-period lag of per capita income (PCIL), semi-log inflation (INFLA), mean years of schooling (MYSCH), the official exchange rate (XRATE), broad money (MONEY), gross fixed capital formation (GFCF), and finally, rule of law (LAW) as a measure of institutional quality Ω_{it}.[‡] Also, we compute INFLA by the inflation augmentation process as described in Ibarra and Trupkin (2016), given as follows:

[‡]We repeat our analyses with governance index (GINDEX) as a measure of institutional quality, which produces qualitatively similar results to those that are presented in this paper.

$$\text{SLINFLA} = \begin{cases} \text{INFLA}_{it} - 1, & \text{INFLA}_{it} \leq 1 \\ ln(\text{INFLA}_{it}), & \text{INFLA}_{it} > 1. \end{cases} \tag{9}$$

where INFLA_{it} denotes the inflation rate for country i at time t. The covariates are represented as natural logarithmic variants and as a share of GDP wherever applicable. Finally, to facilitate a logarithmic transformation, we also standardize the values of the LAW variable between 1 to 100.[§] Table 1 describes the variables and presents summary statistics for key study variables.

Table 1. Variable Description and Summary Statistics.

Variable	Description	Mean	Std	Min	Max
PCIG	GDP per capita growth rate (%)	2.425	7.222	−62.378	121.780
PCIL	GDP per capita - one lag	2,442.255	3,229.198	194.873	20,512.941
INFRA	Africa Infrastructure Development Index	19.050	15.744	0.369	85.621
ICT	ICT Index	3.595	7.852	0.000	66.085
TSP	Transport Index	10.465	11.831	0.915	58.756
ELEC	Electricity Index	9.140	17.352	0.010	96.241
WSS	WSS Index	49.656	21.173	6.044	99.014
SLINFLA	Semi-log Inflation	1.310	2.005	−31.856	4.587
MYSCH	Mean years of schooling	4.689	2.003	1.200	10.200
XRATE	Official exchange rate	552.369	1,015.863	0.867	7,485.517
MONEY	Broad money (% of GDP)	37.962	37.089	3.161	289.361
GFCF	Gross fixed capital formation (% of GDP)	23.108	8.529	5.885	60.018
L	Rule of law.	−0.071	1.013	−2.606	1.906
LAW	Rule of law (standardized). The raw values of this measure, L_i, ranges between -2.6 and +1.9 for our sample. We transform these values into an index that ranges from +1 to +100 using the following formula: $\frac{L_i - L_a}{L_b - L_a}$, where L_a and L_b are the minimum and maximum values taken by this variable.	56.186	22.451	1.000	100.000

4 Results

Unit root and Cointegration tests

We start by examining certain properties of key variables used in our data. Table 2 reports the statistic for Choi's (2001) tests for unit-roots in panel datasets. The null hypothesis is that all panels contain unit roots and the alternate hypothesis is that at least one panel exhibits stationarity. Most processes are insignificant both at levels and log-levels. Almost all the processes are significant at differences and log-differences. Put simply, the processes that govern our data are stationary at I(1).

[§]The standardization procedure that we employ is similar to those used in other works (e.g., see Sahni et al., 2020).

Table 2. Panel unit root tests.

	PCI		INFRA		ICT		TSP		ELEC		WSS		LAW	
	level	diff	level	diff	level	diff	level	diff	level	diff	level	diff	level	diff
P	42.88	123.40^b	88.87	196.33^a	23.99	177.90^a	339.76^a	695.55^a	43.19	145.52^a	33.84	115.97^b	120.22^b	214.38^a
Z	4.39	-3.26^a	2.27	-4.51^a	5.34	1.25	-4.39^a	-17.28^a	6.70	-0.87	8.21	2.85	1.89	-5.86^a
L*	4.20	-3.21^a	1.55	-5.29^a	5.74	-0.30	-9.66^a	-28.54^a	7.21	-1.46^c	8.72	2.78	1.06	-6.59^a
Pm	-3.62	2.31^b	-0.23	7.69^a	-5.01	6.33^a	18.27^a	44.49^a	-3.60	3.95^a	-4.29	1.77^b	2.08^b	9.02^a
	PCI		**INFRA**		**ICT**		**TSP**		**ELEC**		**WSS**		**LAW**	
	log-level	log-diff	log-level	log-diff	log-level	log-diff	log-level	log-diff	log-level	log-diff	log-level	log-diff	log-level	log-diff
P	108.90	177.84^a	250.64^a	249.96^a	245.14^a	392.94^a	448.88^a	622.92^a	87.32	224.10^a	50.53	117.72^b	99.12	163.04^a
Z	0.51	-4.05^a	-4.67^a	-6.22^a	-4.64^a	-9.31^a	-5.50^a	-15.34^a	2.66	-5.41^a	5.92	1.67	3.13	-4.32^a
L*	0.21	-4.61^a	-7.41^a	-7.92^a	-6.83^a	-14.28^a	-13.59^a	-24.74^a	2.21	-6.59^a	6.23	1.76	2.69	-4.62^a
Pm	1.25	6.33^a	11.70^a	11.64^a	11.29^a	22.19^a	26.31^a	39.14^a	-0.34	9.74^a	-3.06	1.90^b	0.52	5.24^a

Note: The augmented Dickey-Fuller test with lag 1 is reported in this table. ^{a} $p < 0.01$, ^{b} $p < 0.05$, and ^{c} $p < 0.10$.

Table 3 reports the results of the cointegration tests. We contrast the same null hypothesis that there is no cointegration with two different alternate hypotheses: (H_{a1}) some (but, necessarily not all) panels are cointegrated, and (H_{a2}) all panels are cointegrated. Our results indicate that, in both cases, we can reject the null hypothesis and consequently conclude that our study variables are cointegrated.

Table 3. Panel cointegration tests.

	Variance ratios				
between D.log(PCI) & ...	log(INFRA)	log(ICT)	log(TSP)	log(ELEC)	log(WSS)
H_0: All panels are not cointegrated. H_{a1}: Some panels are cointegrated	-3.13^{***}	-3.52^{***}	-2.72^{***}	-2.87^{***}	-4.64^{***}
H_0: All panels are not cointegrated. H_{a2}: All panels are cointegrated.	-6.50^{***}	-6.49^{***}	-6.20^{***}	-6.58^{***}	-6.47^{***}

Note: *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.10$.

Threshold analysis

Next, we proceed to conduct our threshold estimation to sequentially check for the existence of the rule of law (LAW) thresholds in our sample. We begin by checking for the presence of a single threshold. In this case, the null hypothesis affirms that the LAW threshold does not exist and the alternate hypothesis affirms the presence of a single LAW threshold. The threshold levels with their 95% confidence interval estimated over 1000 replications are provided in Table 4.

We find that the F-statistic is significant at one percent level indicating the presence of a single threshold in all infrastructure specifications, except in the case

Table 4. Estimation of models with unitary threshold.

Threshold variable	Infrastructure variable	Threshold level	Threshold estimator (level = 95): Threshold	Lower	Upper	Threshold effect test (bootstrap = 1000): Fstat	Crit10	Crit5	Crit1
LAW	INFRA	Single	3.451	3.442	3.468	58.230***	18.068	21.560	34.219
LAW	ICT	Single	4.451	4.348	4.454	13.460	17.550	23.300	37.579
LAW	TSP	Single	3.451	3.442	3.468	58.230***	18.068	21.560	34.219
LAW	ELEC	Single	3.451	3.442	3.468	84.320***	19.108	24.073	36.508
LAW	WSS	Single	3.451	3.442	3.468	35.750***	17.275	20.121	29.734

Note: *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.10$.

of ICT. We also find that the single threshold estimate (95% confidence interval) occurs at log-level of 3.45 (3.44 - 3.47) of LAW, which translates to -1.18 (minus 1.20 - minus 1.16) in raw values. Note that the range of values for LAW, in raw terms (represented as L), is between -2.60 and $+1.91$. See Table 1.

To test the presence of additional higher-order thresholds, we repeat the analysis with the number of thresholds equal to three. The results are reported in Table A2. We find that while the F-statistics for single thresholds are significant at one percent level (coinciding with the results presented in Table 4), the F-statistics for double and triple thresholds are insignificant, indicating the absence of thresholds of any higher order. Therefore, we empirically confirm that only a single threshold exists that demarcates the sample into two rule of law regimes - a weak rule of law regime ($-2.60 <$ L ≤ -1.18) and a strong rule of law regime ($-1.18 <$ L $\leq$ 1.91).

The model that we estimate to come up with the single threshold can be expressed as

$$\begin{aligned} \text{PCIG}_{it} = \alpha_i + &\delta_0 ln(q_{it}).I(ln(\text{LAW}_{it}) \leq \bar{\Omega}_1) + \delta_1 ln(q_{it}).I(ln(\text{LAW}_{it}) > \bar{\Omega}_1) \\ &+ \nu ln(\text{PCI}_{it-1}) + \eta ln(\text{LAW}_{it}) + \beta_1 ln(\text{MYSCH}_{it}) \\ &+ \beta_2 ln(\text{XRATE}_{it}) + \beta_3 ln(\text{SLINFLA}_{it}) \\ &+ \beta_4 ln(\text{MONEY}_{it}) + \beta_5 ln(\text{GFCF}_{it}) + \epsilon_{it} \end{aligned} \tag{10}$$

where q represents the array of infrastructure measures (INFRA, TSP, ELEC, and WSS) for which meaningful threshold estimates exist (see Table 4). The parameter $\bar{\Omega}_1$ is the threshold value for the rule of law that is endogenously produced by the model, and δ_0 and δ_1 are the elasticities of infrastructure on growth for weak rule of law regime and strong rule of law regime, respectively. Table 5 gives the result.

Table 5. Single threshold panel regressions: Using LAW as the threshold.

	Infrastructure variables (InfraVars)							
	(1) INFRA		(2) TSP		(3) ELEC		(4) WSS	
	β	se	β	se	β	se	β	se
log(PCIL)	-0.312^{***}	(0.028)	-0.285^{***}	(0.027)	-0.298^{***}	(0.027)	-0.296^{***}	(0.028)
SLINFLA	-0.001	(0.001)	-0.001	(0.002)	-0.001	(0.001)	-0.001	(0.002)
log(MYSCH)	0.064	(0.041)	0.154^{***}	(0.036)	0.140^{***}	(0.036)	0.106^{***}	(0.038)
log(XRATE)	0.025	(0.016)	0.038^{**}	(0.016)	0.042^{***}	(0.016)	0.031^{*}	(0.016)
log(MONEY)	-0.025^{**}	(0.010)	-0.023^{**}	(0.011)	-0.016	(0.010)	-0.024^{**}	(0.011)
log(GFCF)	0.025^{**}	(0.012)	0.026^{**}	(0.012)	0.027^{**}	(0.012)	0.021^{*}	(0.012)
log(LAW)	-0.004	(0.022)	0.016	(0.022)	0.010	(0.022)	0.007	(0.023)
log(InfraVars)								
log(LAW) $< \bar{\Omega}_1$	0.024	(0.017)	-0.037^{*}	(0.021)	-0.043^{***}	(0.011)	0.073^{**}	(0.029)
log(LAW) $\geq \bar{\Omega}_1$	0.068^{***}	(0.016)	0.012	(0.021)	0.017^{*}	(0.009)	0.101^{***}	(0.028)
Constant	1.916^{***}	(0.195)	1.597^{***}	(0.184)	1.699^{***}	(0.183)	1.474^{***}	(0.185)
F	25.560^{***}		22.920^{***}		26.520^{***}		22.340^{***}	
N	598		598		598		598	

Note: InfraVars represents infrastructure variables - INFRA, TSP, ELEC, and WSS in columns (1), (2), (3), and (4), respectively. $\bar{\Omega}_1$ represents the threshold value that demarcates the sample into regimes. Standard errors (se) in parentheses. *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.10$.

For brevity, we only elaborate on the coefficients of infrastructure. First, we note that $\delta_0 \neq \delta_1$ in all models, confirming our hypothesis that the infrastructure-growth relationship is nonlinear. Second, we also broadly note that $\delta_0 < \delta_1$ in all models, indicating that countries with strong rule of law have higher elasticities than countries with weak rule of law. In column (1), δ_0 is insignificant, and δ_1 is positive ($+0.068$) and significant. That is, while the association is nonexistent when rule of law is weak, a one percent increase in overall infrastructure INFRA is associated with a 0.068% increase in growth rate when rule of law is strong. In column (2), δ_0 is negative (-0.037) and significant, and δ_1 is insignificant. That is, while a one percent increase in transport infrastructure TSP is associated with a 0.037% decline in growth rate when rule of law is weak, any such association is nonexistent when rule of law is strong. In column (3), δ_0 is negative (-0.043) and δ_1 is positive ($+0.017$), both being statistically significant. That is, a one percent increase in electricity infrastructure ELEC is associated with a 0.043% decline (0.017% increase) in growth rate when rule of law is weak (strong). Finally, in column (4), both δ_0 ($+0.073$) and δ_1 ($+0.101$) are positive and significant. That is, a percentage increase in water and sanitation infrastructure WSS is associated with a 0.073% increase in growth rate when rule of law is weak, the same percentage increase is associated with a 0.101% increase in growth rate when rule of law is strong. Thus, the results of this analysis, though conducted without causal corrections, provide a basis for studying the infrastructure-growth relationship across rule of law regimes.

System GMM estimation

We correct for the reverse causality problem discussed in Section 2 using the system GMM estimation method. As a benchmark case, we first estimate the growth model without the threshold variable. The results are presented in Table A3. We find that all infrastructure elasticities on growth are insignificant, except for ICT. Now, to incorporate the rule of law threshold into the modeling, we include the regime indicator variable I_{it1} (i.e., a dichotomous variable that equals one for strong rule of law, zero otherwise) and its interaction with infrastructure $I_{it1}q_{it}$. We classify the lag of the natural logarithm of per capita income, infrastructure, and the interaction term as endogenous. Following Roodman (2009b), we limit the lag length of instruments in the system GMM estimation to three. The model that we estimate can be written as,

$$\begin{aligned} ln(\text{PCI}_{it}) - ln(\text{PCI}_{it-1}) = \alpha_i &+ \nu ln(\text{PCI}_{it-1}) + \gamma I_{it1} + \lambda ln(q_{it}) + \delta I_{it1} ln(q_{it}) \\ &+ \beta_1 ln(\text{MYSCH}_{it}) + \beta_2 ln(\text{XRATE}_{it}) \\ &+ \beta_3 ln(\text{SLINFLA}_{it}) + \beta_4 ln(\text{MONEY}_{it}) \\ &+ \beta_5 ln(\text{GFCF}_{it}) + \mu_{it}. \end{aligned} \tag{11}$$

Table 6 presents the result of this analysis. Before interpreting this result, we perform certain diagnostic tests to ensure that the estimates are consistent. Like any dynamic model, the system GMM estimation must meet two requirements to find support for estimate consistency: (a) the error terms must not be serially correlated, and (b) the model must be correctly specified. For (a), we perform the Arellano-Bond-type first- and second-order autocorrelation tests, and for (b), we conduct the Hansen tests for overidentification and the difference-in-Hansen tests for exclusion restrictions. All test statistics for (a) and (b) are insignificant, which invariably demonstrates the absence of autocorrelation in errors, the validity of overidentification restrictions, and the validity of the instruments in our model specifications.

The growth elasticity of infrastructure for the weak rule of law regime is captured by the coefficient of q_{it} (i.e., λ) and for the strong rule of law regime is captured by summing up the coefficients of q_{it} and $I_{it1}q_{it}$ (i.e., $\lambda + \delta$). In other words, ceteris paribus, δ captures the growth differential that arises from being

Table 6. System GMM estimation.

	Infrastructure variables (InfraVars)							
	(1) INFRA		(2) TSP		(3) ELEC		(4) WSS	
	β	se	β	se	β	se	β	se
log(InfraVars)	-0.093^{***}	(0.019)	-0.024	(0.015)	-0.064^{***}	(0.017)	0.001	(0.073)
I_1	-0.259^{***}	(0.077)	-0.079	(0.056)	-0.073	(0.052)	-0.086	(0.317)
log(InfraVars) $\times$ I_1	0.102^{***}	(0.030)	0.058^{**}	(0.028)	0.066^{***}	(0.016)	0.041	(0.086)
log(PCIL)	-0.005	(0.009)	-0.024	(0.019)	0.002	(0.011)	-0.016	(0.015)
SLINFLA	-0.000	(0.001)	-0.001	(0.001)	-0.000	(0.001)	-0.000	(0.001)
log(MYSCH)	0.012	(0.012)	0.016	(0.025)	0.010	(0.023)	0.013	(0.020)
log(XRATE)	-0.007^{*}	(0.004)	-0.008^{**}	(0.003)	-0.007^{*}	(0.004)	-0.010^{**}	(0.004)
log(MONEY)	-0.021	(0.022)	-0.040^{*}	(0.022)	-0.016	(0.013)	-0.040^{*}	(0.021)
log(GFCF)	0.030	(0.018)	0.046^{**}	(0.020)	0.020	(0.019)	0.045^{**}	(0.020)
Constant	0.297^{***}	(0.093)	0.225^{*}	(0.130)	0.104	(0.069)	0.097	(0.314)
Arellano-Bond test								
· AR(1): Z-value	-1.230		-1.230		-1.250		-1.210	
· AR(2): Z-value	0.770		0.770		0.710		0.880	
Hansen test (χ^2)	42.490		40.620		36.820		39.470	
Difference-in-Hansen test (χ^2)	28.680		28.970		31.260		27.850	
N	552		552		552		552	

Note: InfraVars represents infrastructure variables - INFRA, TSP, ELEC, and WSS in columns (1), (2), (3), and (4), respectively. I_1 is the indicator variable for strong rule of law regimes (i.e., $I_1 = 1$ if log(LAW)> 3.45, zero otherwise). Standard errors (se) in parentheses. *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.10$.

in countries with a strong rule of law culture vis-á-vis countries with weak rule of law. The numerical estimates from Table 6 are as follows. In column (1), λ is negative (-0.093) and significant, and δ is positive ($+0.102$) and significant. This implies that, with a percentage increase in overall infrastructure INFRA, countries with weak rule of law experience a 0.093% growth penalty, and a 0.102% growth differential is noted in countries with strong rule of law over their weak rule of law counterparts. That is, there is a net positive growth of 0.009% in countries with a strong rule of law. In column (2), λ is insignificant and δ is positive ($+0.058$) and significant. This implies that while a percentage increase in transport infrastructure TSP results in no change in the growth of countries having weak rule of law, it results in a 0.058% growth differential in countries with strong rule of law. In column (3), λ is negative (-0.064) and significant, and δ is positive ($+0.066$) and significant. That is, with a percentage increase in electricity infrastructure ELEC, we observe a 0.064% growth penalty in countries with weak rule of law and a 0.066% growth differential (net positive growth by 0.002%) in countries with strong rule of law. In column (4), λ and δ are both insignificant, which implies that contrasting with other infrastructure measures, changes in water and sanitation infrastructure WSS result in no discernable changes in growth, irrespective of the level of rule of law.

There are a few lessons learned from the causal analysis presented above. First, even the endogeneity-corrected estimates confirm our premise that the infrastructure-growth relationship is nonlinear. Second, we can state with certainty that rule of law plays an important role in studying the infrastructure-growth relationship. More precisely, we show that countries with weak rule of law experience steeper growth penalties (see models with INFRA and ELEC), whereas there are economically and statistically significant positive growth differentials linked with countries with strong rule of law (see models with INFRA, TSP and ELEC). Finally, WSS, which showed a differential impact on growth in our threshold analysis, lost its efficacy in explaining growth in both rule of law regimes after correcting for endogeneity. The key takeaway from this analysis is that, even after allowing causal interpretations, we can comprehensively conclude that while infrastructure development has a detrimental impact on growth in countries with weaker rule of law, countries with stronger rule of law enjoy significant positive effects on growth.

Robustness tests

To test the assertion that our results are solely driven by the choice of the institutional quality measure (the rule of law), we repeat the analysis presented thus far (Tables 2 through 6), using a more encompassing measure of a country's governance GINDEX. This measure is a standardized aggregate of several variables: the political regime authority spectrum index (commonly referred to as POLITY2) and the six governance dimensions (voice and accountability, political stability, government effectiveness, regulatory quality, rule of law, and corruption control) compiled by Kaufmann et al. (2010). The results are, for the most part, qualitatively similar and are presented in Tables A4 through A9.

5 Concluding remarks

This paper provides evidence on how institutional quality affects the infrastructure-growth relationship. By using rule of law as a proxy of institutional quality in a sample of 46 African countries between 2003 and 2015, we show that there are significant gains to growth from infrastructure development in countries that have strong rule of law, but, such gains are lower and sometimes negative in countries that have weak rule of law. This is the main result of our paper. We further show that the aforementioned result empirically stands even after controlling for potential reverse causality that may have influenced our baseline result.

We perform several robustness checks to find additional support for our paper. First, to investigate what types of infrastructure development exhibit sensitivity to rule of law, we repeat our analyses with the component measures of infrastructure development that are widely discussed in the literature, namely information and communication technology (ICT), transport (TSP), electricity (ELEC), and water services and sanitation (WSS). We show that while all types of infrastructure unilaterally affect growth per se, only the latter three types (TSP, ELEC, and WSS) exhibit asymmetrical effects on economic growth in both extremes of rule of law. Second, to dispel the notion that rule of law as a proxy for institutional quality is too restrictive, we repeat our analyses using an equally-weighted index of several country governance parameters: political regime status, voice and accountability, political stability, government effectiveness, regulatory quality, rule of law, and corruption control, and find similar results.

The implications of our results are far-reaching. Why would infrastructural investments hinder economic growth in countries with weaker governance? It is quite possible that while infrastructure has a sizable positive effect (both direct and spillover) on economic growth in countries with strong governance, their weak governance counterparts may possess structural frictions that prevent any such infrastructure spillovers. These frictions may sometimes be large enough to erase all of the direct gains to growth, resulting in negative growth elasticities to infrastructure. Guasch et al. (2005) and Sahni and Paul (2019) have noted a few of these frictions in their works. Using a sample of 307 water and transport projects in five Latin American countries between 1989 and 2000, Guasch et al. (2005) show that the returns to infrastructure are severely diminished by certain opportunistic players that use the lax regulatory framework to expropriate funds from infrastructure projects after sunk investments have been made. Along similar lines, Sahni and Paul (2019) document that, in countries with rampant corruption, the water administration institutions are rarely independent of political pressure and are sometimes forced to authorize infrastructure projects in protected lands, leading to significant ecological costs that accumulate over many years. Therefore, it is safe to say that rule of law (and governance in general) is a vital yardstick to assess whether investments must be made in infrastructure projects and whether such projects turn out to be successful. Next, why is ICT's effect on growth immune from the governance-based scrutiny? One possibility is that this result is purely data-driven. We do not have an apriori reason to believe that this is the case, especially when our preliminary summaries show that the variable ICT is well-behaved with no apparent outliers (see Table 1). However, another intriguing possibility for this result may stem from the fact that ICT investments are inherently different from all the other infrastructure investments – they are predominantly private-funded and foreign-financed (Williams et al., 2011; ICA,

2016) and, therefore, can be expected to have sensible procedural scrutiny and credible auditing systems in place.[¶] Taken together, the level of rule of law may quite possibly be irrelevant in the analysis of the ICT-growth relationship due to the absence of structural frictions that commonly plague other infrastructural investments. Future research may evaluate further the efficacy of the suppositions made here in data.

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Appendix

Table A1. List of countries.

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

Table A2. Estimation of models with triple thresholds.

			Threshold effect test (bootstrap = 1000):			
Threshold variable	Infrastructure variable	Threshold level	F-statistic	Critical value at 10%	Critical value at 5%	Critical value at 1%
LAW	INFRA	Single	64.090***	17.779	20.504	30.890
		Double	9.810	15.913	19.574	31.221
		Triple	5.990	15.050	19.019	26.650
LAW	ICT	Single	13.460	17.745	22.711	35.498
		Double	5.880	15.706	20.606	31.642
		Triple	4.140	15.844	20.325	30.857
LAW	TSP	Single	58.230***	16.981	21.502	31.731
		Double	9.020	15.915	19.836	35.700
		Triple	2.830	18.906	27.485	59.353
LAW	ELEC	Single	84.320***	18.968	23.398	33.111
		Double	15.510	16.269	20.677	29.765
		Triple	3.970	20.261	24.502	37.142
LAW	WSS	Single	35.750***	16.922	20.402	27.589
		Double	−20.230	16.229	20.316	27.542
		Triple	3.530	16.657	22.539	63.319

Note: $^{***}\ p < 0.01$, $^{**}\ p < 0.05$, and $^{*}\ p < 0.10$.

Table A3. Estimation of models with triple thresholds.

	Infrastructure variables (InfraVars)									
	(1) INFRA		(2) ICT		(3) TSP		(4) ELEC		(5) WSS	
	β	se	β	se	β	se	β	se	β	se
log(InfraVars)	−0.008	(0.014)	−0.003**	(0.001)	0.013	(0.010)	0.001	(0.005)	0.058	(0.042)
log(LAW)	−0.003	(0.011)	−0.007	(0.009)	−0.006	(0.012)	−0.005	(0.009)	−0.011	(0.012)
log(PCIL)	−0.020	(0.017)	−0.028***	(0.010)	−0.018	(0.017)	−0.018	(0.017)	−0.042	(0.025)
slinfla	−0.001	(0.001)	−0.001	(0.001)	−0.001	(0.001)	−0.001	(0.001)	−0.001	(0.001)
log(MYSCH)	0.025	(0.017)	0.034**	(0.016)	0.009	(0.021)	0.015	(0.022)	0.018	(0.018)
log(XRATE)	−0.008**	(0.003)	−0.007***	(0.003)	−0.007***	(0.002)	−0.007***	(0.003)	−0.010**	(0.004)
log(MONEY)	−0.026	(0.022)	−0.023	(0.018)	−0.038**	(0.018)	−0.030*	(0.017)	−0.040	(0.025)
log(GFCF)	0.038**	(0.019)	0.046***	(0.018)	0.043**	(0.019)	0.039**	(0.018)	0.061**	(0.026)
Constant	0.169	(0.161)	0.167	(0.129)	0.163	(0.160)	0.166	(0.156)	0.112	(0.119)
Arellano-Bond test										
· AR(1): Z-value	−1.120		−1.110		−1.120		−1.120		−1.120	
· AR(2): Z-value	0.800		0.790		0.790		0.800		0.770	
Hansen test (χ^2)	40.530		38.040		37.180		36.780		38.800	
Difference-in-Hansen test (χ^2)	30.170		30.100		29.830		30.560		30.540	
N	552		552		552		552		552	

Note: InfraVars represents infrastructure variables - INFRA, ICT, TSP, ELEC, and WSS in columns (1), (2), (3), (4), and (5), respectively. Standard errors (se) in parentheses. $^{***}\ p < 0.01$, $^{**}\ p < 0.05$, and $^{*}\ p < 0.10$.

Table A4. Summary statistics of GINDEX and its components.

Variable	Description	Mean	Std	Min	Max
V	Voice accountability	−0.568	0.729	−2.000	1.191
VOICE	Voice accountability (standardized)	48.514	21.329	6.611	100.000
P	Political stability	−0.015	1.087	−3.315	1.943
POLSTAB	Political stability (standardized)	62.511	20.579	1.000	99.585
G	Government effectiveness	−0.064	0.983	−2.446	1.990
GOVEFF	Government effectiveness (standardized)	53.695	22.147	1.000	100.000
R	Regulatory quality	−0.103	1.053	−2.645	1.867
REGQ	Regulatory quality (standardized)	56.090	23.242	1.000	99.560
C	Corruption control	−0.010	0.961	−1.869	2.160
CORRUPT	Corruption control (standardized)	46.147	23.851	1.000	100.000
PTY	Political regime index	1.926	5.297	−9.000	10.000
POLITY2	Political regime index (standardized)	57.529	27.833	1.000	100.000
GINDEX	Governance index $(VOICE + POLSTAB + GOVEFF + REGQ + CORRUPT + LAW + POLITY2)$	380.671	118.600	135.604	663.718

Table A5. Estimation of models with unitary threshold (GINDEX).

			Threshold estimator (level = 95):			Threshold effect test (bootstrap = 1000):			
Threshold variable	Infrastructure variable	Threshold level	Threshold	Lower	Upper	Fstat	Crit10	Crit5	Crit1
GINDEX	INFRA	Single	5.296	5.272	5.297	25.550**	18.442	23.781	43.599
GINDEX	ICT	Single	5.311	5.254	5.316	10.360	18.178	23.990	35.125
GINDEX	TSP	Single	5.316	5.292	5.325	39.870**	18.852	22.633	43.798
GINDEX	ELEC	Single	5.296	5.272	5.297	29.300**	18.809	26.811	68.971
GINDEX	WSS	Single	5.296	5.272	5.297	14.180	18.389	23.549	38.515

Note: *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.10$.

Table A6. Single threshold panel regressions: Using GINDEX as threshold.

	Infrastructure variables (InfraVars)					
	(1) INFRA		(2) TSP		(3) ELEC	
	β	*se*	β	*se*	β	*se*
log(PCIL)	−0.316***	(0.028)	−0.289***	(0.026)	−0.303***	(0.027)
SLINFLA	−0.002	(0.001)	−0.001	(0.001)	−0.001	(0.002)
log(MYSCH)	0.087**	(0.040)	0.161***	(0.035)	0.150***	(0.036)
log(XRATE)	0.021	(0.016)	0.030*	(0.016)	0.035**	(0.016)
log(MONEY)	−0.032***	(0.010)	−0.029***	(0.011)	−0.030***	(0.010)
log(GFCF)	0.025**	(0.012)	0.028**	(0.012)	0.025**	(0.012)
log(GINDEX)	0.169***	(0.048)	0.166***	(0.047)	0.201***	(0.046)
log(InfraVars)						
log(GINDEX) $< \overline{\Omega}_1$	0.027	(0.018)	−0.040*	(0.022)	−0.017	(0.011)
log(GINDEX) $\geq \overline{\Omega}_1$	0.056***	(0.016)	0.003	(0.020)	0.013	(0.009)
Constant	0.960***	(0.301)	0.761***	(0.293)	0.659**	(0.289)
F	26.180***		25.650***		34.580***	
N	598		598		598	

Note: InfraVars represents infrastructure variables - INFRA, TSP, and ELEC in columns (1), (2), and (3), respectively. $\bar{\Omega}_1$ represents the threshold value that demarcates the sample into regimes. Standard errors (se) in parentheses. *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.10$.

Table A7. Estimation of models with triple thresholds (GINDEX).

Threshold variable	Infrastructure variable	Threshold level	Threshold effect test (bootstrap = 1000): F-statistic	Critical value at 10%	Critical value at 5%	Critical value at 1%
GINDEX	INFRA	Single	25.550*	21.431	27.072	43.108
		Double	−14.750	25.665	36.043	59.259
		Triple	7.490	26.301	35.006	81.099
GINDEX	ICT	Single	10.360	18.535	24.241	36.732
		Double	−3.030	15.344	18.890	29.745
		Triple	5.670	14.260	19.314	31.959
GINDEX	TSP	Single	39.870**	17.520	23.811	45.786
		Double	3.490	20.432	30.294	47.412
		Triple	8.340	27.910	34.649	138.743
GINDEX	ELEC	Single	29.300**	18.165	25.397	70.473
		Double	−20.660	22.476	35.383	76.974
		Triple	3.560	16.185	24.004	90.812
GINDEX	WSS	Single	14.180	18.203	23.283	39.616
		Double	1.230	23.214	28.423	44.506
		Triple	9.570	31.051	37.207	59.411

Note: *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.10$.

Table A8. System GMM estimation: Using GINDEX as the regime variable.

	Infrastructure variables (InfraVars)					
	(1) INFRA		(2) TSP		(3) ELEC	
	β	se	β	se	β	se
log(InfraVars)	−0.141***	(0.031)	−0.034	(0.028)	−0.055**	(0.022)
I_1	−0.469**	(0.184)	−0.143	(0.134)	−0.148	(0.107)
log(InfraVars) × I_1	0.156***	(0.056)	0.090*	(0.052)	0.079**	(0.038)
log(PCIL)	−0.035	(0.022)	−0.015	(0.032)	−0.033	(0.036)
slinfla	−0.001	(0.001)	−0.001	(0.002)	−0.001	(0.002)
log(MYSCH)	0.028*	(0.016)	−0.011	(0.027)	−0.012	(0.022)
log(XRATE)	−0.010**	(0.005)	−0.006	(0.004)	−0.007*	(0.004)
log(MONEY)	−0.025	(0.024)	−0.054**	(0.027)	−0.030*	(0.018)
log(GFCF)	0.048**	(0.023)	0.052*	(0.029)	0.044*	(0.024)
Constant	0.644**	(0.284)	0.241	(0.269)	0.407	(0.340)
Arellano-Bond test						
· AR(1): Z-value	−1.200		−1.240		−1.230	
· AR(2): Z-value	0.910		0.960		0.940	
Hansen test (χ^2)	40.030		41.880		39.170	
Difference-in-Hansen test (χ^2)	27.040		34.370		29.050	
N	552		552		552	

Note: InfraVars represents infrastructure variables - INFRA, TSP, and ELEC in columns (1), (2), and (3), respectively. I_1 is the indicator variable for strong governance index regime (i.e., $I_1 = 1$ if log(GINDEX)> 5.296 in columns (1) and (3), $I_1 = 1$ if log(GINDEX)$>$ 5.316 in column (2), and zero otherwise). Standard errors (se) in parentheses. *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.10$.

Table A9. System GMM estimation: with no regimes (GINDEX).

	Infrastructure variables (InfraVars)									
	(1) INFRA		(2) ICT		(3) TSP		(4) ELEC		(5) WSS	
	β	se	β	se	β	se	β	se	β	se
log(InfraVars)	−0.016	(0.015)	−0.002	(0.002)	0.019	(0.018)	−0.001	(0.008)	0.047	(0.037)
log(GINDEX)	0.057*	(0.033)	0.098	(0.071)	0.100	(0.076)	0.105	(0.072)	0.022	(0.043)
log(PCIL)	0.007	(0.012)	0.020	(0.030)	0.028	(0.026)	0.028	(0.027)	−0.016	(0.013)
slinfla	−0.000	(0.001)	0.000	(0.001)	0.000	(0.001)	0.000	(0.001)	−0.000	(0.001)
log(MYSCH)	0.005	(0.014)	−0.015	(0.032)	−0.040	(0.032)	−0.027	(0.026)	−0.004	(0.013)
log(XRATE)	−0.008**	(0.003)	−0.009**	(0.004)	−0.008*	(0.004)	−0.009*	(0.005)	−0.009**	(0.004)
log(MONEY)	−0.031	(0.025)	−0.041	(0.030)	−0.057	(0.037)	−0.046*	(0.027)	−0.043	(0.028)
log(GFCF)	0.028	(0.018)	0.028	(0.021)	0.029	(0.020)	0.024	(0.021)	0.047**	(0.020)
Constant	−0.270	(0.203)	−0.590	(0.460)	−0.609	(0.492)	−0.638	(0.466)	−0.127	(0.267)
Arellano-Bond test										
· AR(1): Z-value	−1.100		−1.080		−1.090		−1.080		−1.100	
· AR(2): Z-value	0.800		0.770		0.770		0.780		0.770	
Hansen test (χ^2)	38.280		40.160		42.280		38.330		37.980	
Difference-in-Hansen test (χ^2)	28.720		33.660		27.940		30.010		29.520	
N	552		552		552		552		552	

Note: InfraVars represents infrastructure variables - INFRA, ICT, TSP, ELEC, and WSS in columns (1), (2), (3), (4), and (5), respectively. Standard errors (se) in parentheses. *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.10$.