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Threshold Effects of Institutional Quality in the Infrastructure-Growth Nexus

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Abstract

This study estimates the threshold level of institutional quality that will ensure the efficient use of infrastructure in stimulating growth in Sub-Saharan Africa based on panel data from 41 countries in the region between 1996 and 2015. It employs a dynamic panel threshold regression model which is derived from the New Institutional Economics theory and this is estimated using the first-differenced Generalized Method of Moments estimator. Results reveal that the relationship between infrastructure and growth is non-linear which provides support for the use of a threshold regression model, with institutional quality serving as the threshold variable. In terms of the threshold level, the findings show that the index of institutional quality that will ensure the efficient use of infrastructure in stimulating growth is 0.410. The study also finds that, on average, countries in the region operate below this threshold level, hence their poor growth. The conclusion that is drawn from the analysis is that poor or low institutional quality is one of the factors hampering the growth of countries in the SSA region. A major limitation of the study is that the estimator employed for the threshold analysis is developed for models with single threshold value only and so does not allow for multiple threshold values. Thus, it is recommended that governments in the region need to formulate and implement policies targeted at improving the level of institutional quality in their countries.

Keywords**:** infrastructure, institutions and growth, sub-Saharan Africa, principal components, threshold regression model, first-differenced General Method of Moments

JEL Classification Codes: H540, O430, O550, C380, C240, C130

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1. Introduction

The importance of adequate infrastructure development as a veritable tool for achieving sustainable economic transformation has long been acknowledged. In view of this, quite a number of studies have examined the role of infrastructure development in stimulating growth over the last two and half decades. In spite of this renewed focus on infrastructure development, the growth effect of infrastructure has not been well established in the empirical literature. The empirical literature on the link between institutional quality and the infrastructure-growth nexus can be divided into three strands.

The first strand is made up of studies which assessed the relationship between infrastructure and economic growth. These early studies which were pioneered by Aschauer (1989) find conflicting results on the relationship. Attempts to settle this controversy led to the emergence of another strand of the literature which assessed the mediating effect of institutional quality using a linear approach. This second category of studies argued that investigating the infrastructure-growth nexus without capturing the role of institutional quality will distort the results. However, the evidence provided by these studies has been faulted on the ground that the use of a linear approach is too restrictive. In order to circumvent the limitation of the linear approach, scholars have suggested the use of a non-linear approach. Estache and Fay (2007) as well as Dethier and Moore (2012) argued that non-linearity should be adequately captured when modelling the growth effects of infrastructure since the provision of infrastructure services is mostly through networks.

Efforts at addressing the issue of non-linearity in the empirical literature culminated in the emergence of the third category of studies. This strand of the literature used the non-linear approach known as threshold regression model which is a simple but efficient method in capturing non-linearities in cross section and time series models. More precisely, the studies evaluated the productivity of infrastructure stocks using threshold regression models, in which the threshold variable is defined as either the level of the infrastructure stock actually available or one of its indicators. Although they were able to address the issue of non-linearity, the studies also suffer from a defect. The defect is that they did not give any consideration to the role of institutional quality in their threshold modelling, even though its importance to the infrastructure-growth nexus had been pointed out.

The implication of this is that studies on the threshold effects of institutional quality in the relationship between infrastructure and growth are scarce, particularly in the context of countries in SSA. This study therefore addresses this major gap in the literature by investigating the threshold effects of institutional quality in the infrastructure-growth nexus in the SSA region over the period 1996 to 2015. Its novelty lies in the fact that it is the first study to attempt the estimation of the threshold level of institutional quality that will ensure the efficient use of infrastructure in stimulating growth. It will provide policy makers in the region with estimate of the minimum level of institutional quality that will ensure that their countries derive optimum growth benefits from their infrastructure development efforts. The paper is divided into sections. Following this introductory section, section 2 presents a brief review of the empirical literature, while section 3 discusses the methodology on which the study is based. Section 4 focuses on empirical analysis and interpretation of results while section 5 contains the conclusion and policy implication.

2. Review of Empirical Literature

This section reviews the available empirical evidence on the link among infrastructure, institutional quality and growth. It does so by first looking at the early contributions and then turning to the subsequent studies which have attempted to proffer solutions to the shortcomings identified in the early studies.

2.1. Infrastructure and Growth

The empirical literature on the nexus between infrastructure and economic growth is quite substantial. Although a majority of the studies report a significant positive effect of infrastructure on output, productivity, or their growth rates (e.g. Batuo, 2015; Boopen, 2006; Cadot, Röller & Stephan, 2006; Calderón & Servén, 2003a; Estache, Speciale & Veredas, 2005; Fedderke & Bogetic, 2009; Siyan, Eremionkhale & Makwe, 2015; Yamano & Ohkawara, 2000; as well as Zhang & Sun, 2019), a few others, such as the ones by Ansar et al. (2016); Canning and Pedroni (2004); Devarajan, Swaroop and Zou (1996); and Ghafoor and Yorucu (2002) find ambiguous, insignificant or even negative effects of infrastructure on growth. Attempts to settle this controversy in the empirical literature led to the emergence of a new strand of literature preoccupied with the need to assess the extent to which institutional quality affect the relationship between the two variables.

2.2. Infrastructure, Institutions and Economic Growth

Although many scholars acknowledge the implications that institutional quality has for the effects of infrastructure on growth, only a few studies have tested the relationship empirically. While some of these studies find that infrastructure has a significantly higher payoff in countries with strong institutional quality than in countries with poor institutional quality (e.g. Badalyan, Herzfeld & Rajcaniova, 2015; Crescenzi, Cataldo & Rodríguez-Pose, 2016; Damijan & Padilla, 2014; Escobal & Ponce, 2011; and Seethepalli, Bramati & Veredas, 2008), others find insignificant effects of the interaction between infrastructure and institutional quality on economic growth particularly in countries where institutional quality is relatively poor (Kodongo & Ojah, 2016; and Okoh & Ebi, 2013). One limitation of these studies is their use of a linear interaction model that is made up of a linear interaction term between infrastructure and institutional quality, which has been faulted on the ground of being too restrictive. For example, Neftci (1984) and Falk (1986) find that, contrary to the assumption of the standard linear framework, several economic time series variables possess non-linear properties. Specifically, non-linearity in the relationship between infrastructure and output is brought about by network effects (Serven, 2010). In this respect, Estache and Fay (2007) as well as Dethier and Moore (2012) explain that the provision of infrastructure services is mostly through networks. The implication of this is that any analysis based on a linear model may lead to biased inferences.

2.3. Threshold Effects in the Productivity of Infrastructure

In order to take care of the issue of non-linearity, a handful of studies, such as Candelon, Colletaz and Hurlin (2013); Deng, Shao, Yang and Zhang (2014); as well as Égert, Kozluk and Sutherland (2009), have attempted to investigate threshold effects in the productivity of infrastructure. Evidence in this strand of the literature reveals that the relationship between output and infrastructure stocks is non-linear, with the productivity of infrastructure exhibiting strong threshold effects. However, one major shortcoming of the studies is that they did not give any consideration to the role of institutional quality in their threshold modelling of the productivity of infrastructure.

3. Methodology

3.1. Theoretical Framework

The theoretical basis for the analysis adopted in this study is the New Institutional Economics (NIE) theory developed by North and Thomas

(1973), Williamson (1985), Matthews (1986), and North (1990). This theory emphasizes the instrumentality of high institutional quality in the growth process. It allows for the relaxation of some of the impracticable assumptions underlying the neo-classical theory which is an alternative theory of the growth effects of infrastructure. These assumptions include full rationality, perfect information as well as zero transaction costs. Unlike the other theories on the infrastructure-growth relationship, NIE recognises the fact that good policies alone are not sufficient to yield sustained growth unless they are backed by adequate institutional quality. Its popularity derives from an expanding argument about the inability of markets alone to ensure economic efficiency. While earlier works on growth take the existence of institutions as given, more recent works showed the flaw in such approach.

In particular, the failure of the neoclassical as well as endogenous growth models to address the growth disparities among countries led some economists into examining other fundamental factors that are necessary in explaining why countries differ in their growth rates and income levels. Towards this end, economists incrementally advanced the notion that, in addition to government policies, high institutional quality is required to bring about higher economic growth. Unlike neoclassical economics, a striking feature of the theory is that the institutional framework is not assumed to be exogenous. Instead, it is clearly treated as an object of research such that the way and manner any given institutional arrangement affect economic behaviour is accorded due consideration (Richter, 2005).

NIE regards institutions as “soft” infrastructure, i.e., regulatory mechanisms that must be put in place to facilitate the efficient operation and functioning of the “hard” component. In countries with high institutional quality, investments in infrastructure will not only benefit private individuals, but will also create a positive return for society as a whole. In countries with low or poor institutional quality, on the other hand, resources that are meant for infrastructure development will be diverted into rent-seeking activities which are beneficial to private individuals but yield no benefits to the society as a whole. Poor institutional quality will reduce the rate of return to new investment in infrastructure as well as the already existing one. From the NIE perspective, therefore, modelling the growth effects of infrastructure without incorporating the quality of institutions will yield inconsistent results.

3.2. Model Specification

This study investigates the threshold effects of institutional quality in the productivity of infrastructure using the approach developed by Seo and Shin (2016) known as the dynamic Panel Threshold Regression (PTR) model which is based on the first difference (FD) transformation. The advantage of this approach lies in its ability to take care of unobserved individual heterogeneity inherent in a threshold panel analysis like the one carried out in this study. It allows the regressors as well as the threshold variable to be endogenous which makes it more appropriate than the one developed by Hansen (1999) for investigating the relationship among infrastructure, institutional quality and economic growth.

Considering country $i = 1,2,...,N$ at a time $t = 1,2,...,T,$ the threshold model is specified as follows:

$$\begin{aligned} y_{it} &= (\rho_1 y_{it-1} + \delta_{11}k_{it} + \delta_{21}x_{it} + \delta_{31}q_{it})I\{q_{it} \le \lambda\} + \\ &(\rho_2 y_{it-1} + \delta_{12}k_{it} + \delta_{22}x_{it} + \delta_{32}q_{it})I\{q_{it} > \lambda\} + \varepsilon_{it} \end{aligned} \tag{1}$$

where y_{it}, the dependent variable, is economic growth, y_{it-1} is the dependent variable lagged by one period, k_{it} is physical capita, x_{it} is the aggregate index of infrastructure, q_{it} is the aggregate index of institutional quality which also serves as the threshold variable in this study, $I\{.\}$ is an indicator function, λ denotes the threshold parameter or value which divides the observations into two regimes, while $\rho_1, \delta_{11}, \delta_{21}, \delta_{31}$ and $\rho_2, \delta_{12}, \delta_{22}, \delta_{32}$ are the slope parameters associated with the two regimes, respectively. While physical capital is one of the main variables often included in any growth model, the lagged dependent variable is included in this study in order to capture "conditional transitional convergence". The error, ε_{it}, consists of two error components as follows:

$$\varepsilon_{it} = \mu_i + v_{it} \tag{2}$$

where μ_i is an unobserved individual fixed effect and v_{it} is a zero mean idiosyncratic random disturbance.

3.3. Technique of Data Analysis

Equation (1) is estimated using the first-differenced GMM (FD-GMM) estimator following the work of Seo and Shin (2016). The validity or reliability of the findings is based on two tests reported by the estimator. The first test is called the linearity test which confirms the existence or otherwise of non-linearity in the estimation which is captured by threshold effects. The test is based on the null hypothesis of no threshold effects (linearity) and this is rejected if the *p*-value is less than 5% which is the convention according to Fisher (1956) and Bross (1971). The second test is known as the J-test which determines the validity or otherwise of the instruments used. Since both the threshold variable and regressors are allowed to be endogenous, each variable is instrumented with its lagged value. The test is based on the null hypothesis that the instruments are valid and this is not rejected if the *p*-value is greater than 5%.

3.4. Definitions of Variables and Sources of Data

The analysis in this study is based on annual time series data from 41 SSA countries (see Table 1 in the Appendix section for the list of countries). Economic growth is the dependent variable and is measured by natural logarithm of real Gross Domestic Product (GDP) per capita (constant 2010 US$). The natural logarithm of gross capital formation per capita (constant 2010 US$) is employed to measure investment in physical capital. Physical measures of infrastructure rather than monetary ones are used. Of the five sub-sectors that make up infrastructure, the study considered just four as a result of the lack of sufficient data on the fifth one (transport). The four sub-sectors considered are telecommunications (fixed telephone subscriptions and mobile cellular subscriptions), electric power (electric power consumption), clean water (improved water source) and improved sanitation (improved sanitation facilities). All these data are sourced from the World Bank's World Development Indicators (WDI, 2017).

Many of the empirical studies that have examined the productivity of infrastructure have based their analyses on single infrastructure sub-sector despite the fact that they take a broad theoretical perspective of infrastructure (see, for example, Loayza, Fajnzylber & Calderón, 2005). The use of single indicators by these studies is as a result of the high correlation that has been found among measures of various kinds of infrastructure. However, investigating the growth effects of infrastructure using a single infrastructure sub-sector has its own defects. For instance, Calderón, Moral-Benito and Servén (2015) argue that since physical infrastructure is a multi-dimensional concept, none of these individual sub-sectors can, all by itself, proxy infrastructure adequately.

On the other hand, adding all the individual infrastructure indicators into the analysis in order to capture the multi-dimensionality of infrastructure also comes with some empirical difficulties. One of such difficulties, according to Calderón, Moral-Benito and Servén (2015), is that it could give rise to an over-parameterized specification which will distort the estimate of the output contribution of each infrastructure indicator. In order to overcome this dilemma, this study uses the Principal Component Analysis (PCA) which transforms the different dimensions or sub-sectors of infrastructure into a single index referred to as the aggregate index of infrastructure. The different dimensions of infrastructure are expressed in logarithmic form before the transformation.

To measure institutional quality, this study used the World Bank's Worldwide Governance Indicators (WGI), 2017. The WGI have lately become one of the most commonly used indicators of institutional quality in empirical studies undertaken by academicians as well as policymakers. The choice of this measure is informed by the fact that it is computed from several data sources, and therefore, any bias or error that may arise in the process of computing the data is likely to be minimal relative to other sources of data (Borrmann, Busse & Neuhaus, 2006). The WGI dataset summarizes six dimensions of institutional quality, namely, control of corruption, government effectiveness, political stability and absence of violence, regulatory quality, rule of law, and voice and accountability. For the purpose of analysis, however, the study used the PCA to transform the six dimensions into a single index which is expressed in logarithmic form and this is referred to as the aggregate index of institutional quality.

4. Empirical Analysis and Interpretation of Results

4.1. Descriptive Statistics

Before proceeding to the econometric analysis, this study examined the descriptive statistics of the variables used for analysis. The findings are reported in Table 2.

The results show that the average GDP per capita is US$2,229.69, while the average initial GDP per capita is US$2,175.89. These statistics indicate that, on average, SSA countries fall within the lower middle-income category by the World Bank standard (countries within the income bracket of US$1,026–US$4,035 are classified as lower middle-income).

Table 2: Descriptive Statistics

Variable	Obs.	Mean	Standard Deviation	Minimum	Maximum
GDP Per Capita	820	2229.69	3159.99	186.66	20333.94
Initial GDP Per Capita	820	2175.89	3104.31	170.58	20333.94
Physical per Capita	820	797.95	1720.86	3.12	17012.38
Index of Infrastructure	820	-0.32	1.52	-5.76	2.83
Index of Institutional Quality	820	0.39	0.12	0.15	0.67

Sources: Author's computations based on WDI and WGI of the World Bank (2017).

The mean value of the index of infrastructure is -0.32 and this corresponds to poor infrastructure according to the categorization of infrastructure index by Akanbi (2015). The index of institutional quality recorded a mean value of about 0.39, suggesting low institutional quality across the region on average (on a scale of 0 to 1).

4.2. Threshold Results

Results of the dynamic threshold regression are reported in Table 3. The results reveal that the index of institutional quality that will ensure a significantly high payoff to infrastructure in terms of growth (threshold level) is 0.410, with the estimated threshold level splitting the observations into two regimes. The first regime contains the observations below the threshold value and represents low institutional quality. About 61% of observations fall into this regime. The other regime contains the observations above the threshold value and represents high institutional quality. The implication of the estimated threshold is that countries in SSA need to improve their overall index of institutional quality to 0.410 (on a scale of 0-1 index, with higher index implying better quality) for them to optimize the potentials of infrastructure in stimulating economic growth. This value is higher than the mean value of 0.387 obtained for the region from the descriptive statistics, which confirms the argument that, on average, countries in SSA are operating below the threshold level.

The coefficient of lagged GDP per capita is positive below and above the threshold value, with the magnitude of the latter larger than the former. Physical capital has a positive sign in the low and high regimes, with the magnitudes being 0.251 and 0.535, respectively. The coefficient of institutional quality is negative in the low regime, while it is positive in the high regime. This implies that an inverse relationship exists between institutional quality and growth at low levels of institutional quality (that is, below the threshold level). Hence, low institutional quality retards growth, while high institutional quality promotes it.

Table 3: Threshold Results

Regressor\Threshold Variable	**Index of Institutional Quality**
Lower regime	
Lagged real GDP per capita	0.122 (0.001)
Physical capital	0.251 (0.143)
Infrastructure	0.175 (0.565)
Institutional quality	-0.030 (0.112)
Upper regime	
Lagged real GDP per capita	0.306 (0.001)
Physical capital	0.535 (0.186)
Infrastructure	0.394 (0.773)
Institutional quality	0.050 (0.237)
Threshold	0.410 (0.039)
Upper regime (%)	38.7
Linearity (*p*-value)	0.00
p-value of J-test statistic	0.091

Note: Standard errors are reported in parenthesis.
Source*: Author's* computation.

In the case of infrastructure, its coefficient is positive in both regimes with the magnitude being greater in the high regime. Specifically, infrastructure records a coefficient of 0.175 for countries below the threshold level. This implies that every 1% increase in infrastructure promotes growth by about 0.18% below the threshold level. On the other hand, the magnitude is 0.394 for countries in the high regime. This indicates that every 1% increase in infrastructure promotes growth by about 0.39% above the threshold level. The inference from all this is that SSA countries which are able to attain the threshold level of institutional quality gain about 0.22% more in terms of economic growth (0.394% minus 0.175%) than those that are not able to do so, for every 1% increase in infrastructure. Hence, infrastructure has a significantly higher payoff in countries with high institutional quality than in countries with low institutional quality.

The validity or reliability of these findings is assessed using the results of the linearity test and J-test reported at the bottom of Table 3. The study finds that the *p*-value of the linearity test is 0.00, providing strong evidence against the null of linearity and in support of non-linearity in the infrastructure-growth nexus as captured by threshold effects of institutional quality. The results of the J-test show a *p*-value of 0.091, implying that the null of valid instruments is not rejected. Hence, the estimation results are valid.

Thus, this study provides additional insight into the relationship among infrastructure, institutions and economic growth. Specifically, it generates the threshold level of institutional quality that enhances the efficient use of infrastructure in stimulating growth.

5. Conclusion and Policy Implication

This study estimates the threshold level of institutional quality that will ensure the efficient use of infrastructure in stimulating growth. For this purpose, a dynamic panel threshold regression model is derived and estimated using the first-differenced Generalized Method of Moments estimator for 41 SSA countries for the period from 1996 to 2015.

As far as the nature of the relationship between infrastructure and growth is concerned, the analysis reveals evidence in support of the existence of non-linearity in the infrastructure-growth nexus as captured by threshold effects of institutional quality. With regard to the threshold level, the findings show that the index of institutional quality that will ensure the efficient use of infrastructure in stimulating growth is 0.410. The study also finds that, on average, countries in the region operate below this threshold level, hence their poor growth. The analysis is significant in that it provides policy makers in the region with estimate of the minimum level of institutional quality that will ensure that their countries derive optimum growth benefits from their infrastructure development efforts.

From a policy point of view, results show that strategies aimed at massive infrastructure development must be complemented by measures to improve institutional quality in countries of the region. This requires pursuing good governance through a more stable socio-economic and political environment, corrupt-free society, an effective public service, good regulatory environment, and a transparent leadership structure.

In conclusion, results show that high institutional quality is a prerequisite for infrastructure to have substantial positive effects on growth. Poor or low institutional quality is thus one of the factors hampering the growth of countries in the SSA region. Hence, the challenge of providing adequate institutional quality cannot be expunged from the other challenges confronting the region.

Lack of sufficient data restricted the focus of this study to four out of the five sectors of infrastructure, leaving out transport. Although the indicators used are representatives of the infrastructure sector, including transport may have important implications for the relationship of interest. Also, the first-differenced GMM (FD-GMM) estimator employed for the threshold analysis was developed for models with single threshold value only and so does not allow for multiple threshold values.

Thus, it would be fascinating if future research in this area can include data on transport infrastructure. Also, developing estimation algorithms for models with multiple threshold values similar to the FD-GMM estimator will be an interesting area of further research.

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Appendix
List of Countries

Table 1: Countries included in the study sample

Angola	Chad
Kenya	Mozambique
Sudan	Comoros
Benin	Namibia
Lesotho	Congo Republic
Swaziland	Niger
Botswana	Cote d'Ivoire
Madagascar	Nigeria
Tanzania	Equatorial
Burkina Faso	Guinea
Malawi	Rwanda
Togo	Eritrea
Burundi	Sao Tome and Principe
Mali	Ethiopia
Uganda	Senegal
Cape Verde	Gabon
Mauritania	Seychelles
Zambia Cameroon	The Gambia
Mauritius	Sierra Leone
Zimbabwe	Ghana
South Africa	

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