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The Joint Impact of Infrastructure and Institutions on Economic Growth

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Abstract

This paper examines the joint impact of infrastructure capital and institutional quality on economic growth using a large panel data set covering 120 countries and spanning the years $1980-2015$. The empirical strategy involves estimating a simple growth model where, in addition to standard controls, infrastructure, institutional quality and their interaction are included as explanatory variables. Potential endogeneity concerns are addressed by means of GMM estimators that utilize internal instruments. We find that the interaction terms between infrastructure capital and institutional quality have a positive and significant impact on economic growth. These results are robust to a variety of alternative specifications and institutional quality measures. Hence, our results suggest that maximizing returns from infrastructure development requires improving the quality of institutions.

Keywords: infrastructure; institutions; growth; dynamic panel
JEL classification: H54, F20

1. Introduction

Physical infrastructure assets such as roads, electrical grid, telecommunication networks, water supply, and waste disposal provide services that are central to the functioning of modern economies (Palei, 2015). Beyond being one of the most essential inputs in the process of economic growth, the supply of efficient public infrastructure improves the quality of life and is critical for national security (Baldwin and Dixon, 2008). Owing to sustained economic development, population pressure and rapid advances in science and technology in the past century, infrastructure capital has become increasingly diverse and broad. Hence, improving the quality and quantity of infrastructure capital as a vital factor of production has become an integral part of sustainable development policies.

A large body of theoretical literature has studied the contributions of infrastructure capital to aggregate output, productivity and welfare. Often, the literature discusses these contributions in terms of the growth effects of productive government spending models (see, for instance, Barro, 1990; Glomm and Ravikumar, 1997; Ghosh and Roy, 2004). Moreover, since the seminal work of Aschauer (1989), there has been a growing interest in empirically investigating the link between infrastructure capital and economic growth (see, e.g., Canning and Pedroni, 1999; Bougheas et al., 2000; Röller and Waverman, 2001; Calderón and Servén, 2004; Calderón et al., 2015). Despite using a variety of datasets and empirical methodologies, most of these empirical studies document a generally positive correlation and long-run effect of physical infrastructure on aggregate output and productivity (Munnell et al., 1990; Fernald, 1999; Calderón and Servén, 2004; Fedderke et al., 2006; Torrisi, 2010).

Similar to infrastructure capital, institutional quality as a determinant of economic performance has also received increasing attention in the empirical growth literature in the past three decades (see, among others, North, 1991; Coase, 1992; Ostrom et al., 1993; Rodrik, 2003). Studies generally provide convincing evidence that differences in institutional quality are one of the deepest determinants of the differences in economic development among countries (Rodrik et al., 2004; Acemoglu et al., 2005; Acemoglu et al., 2008; Lee and Kim, 2009; Valeriani et al., 2011; Acemoglu and Robinson, 2013; Law et al., 2013). In particular, the protection of civil and property rights, economic and political freedom, law and order, bureaucratic quality and low levels of corruption have been shown to be associated with higher rates of economic growth (Bénassy-Quéré et al., 2007).

While large bodies of empirical literature have examined the separate roles of infrastructure capital and institutional quality in economic development, existing cross-country studies pay surprisingly little attention to the complementarities between infrastructural and institutional capability in their effects on economic growth. The few exceptions to this generalization include Esfahani and Ramırez (2003), Maiorano and Stern (2007) and Andonova and Diaz-Serrano (2009). Using a cross-country study and a structural model of infrastructure, Esfahani and Ramırez (2003) document the crucial role of generic institutional capabilities that lend credibility and effectiveness to governments in enabling high infrastructure returns. However, these authors have employed pure cross-sectional regressions that are known to suffer from endogeneity biases. Maiorano and Stern (2007) find a positive effect of regulatory institutions on mobile telecommunication infrastructure and on the levels of per capita GDP. Despite using narrow measures of infrastructure capital and institutional quality, the study by Maiorano and Stern (2007) suggests a potentially positive joint impact of infrastructure and institutions on economic growth. A similar study by Andonova and Diaz-Serrano (2009) shows that while political institutions are essential to the development of telecommunications infrastructure, their effect is limited, as mobile technologies are less dependent on political constraints. Conversely, bad institutions are often considered to be behind weak economic performances of infrastructural projects, particularly in the developing economies (Aron, 2000; Chang, 2011). Among other indicators, a lower quality of infrastructure across a range of economies is associated with corruption (Tanzi and Davoodi, 1998; Dal Bó and Rossi, 2007; Gillanders, 2014; Corrado and Rossetti, 2018). Besides, when governments are weak to implement infrastructural investments, or when they apply excessive interventions, potential gains from infrastructure investments might be suppressed or appropriated (Straub, 2011).

The present study aims to reassess the role of infrastructure capital in economic growth under varying degrees of institutional quality.[1] In this context, while infrastructure capital is considered as a physical core, institutional quality can be viewed as a soft component in shaping growth patterns.[2] Hence, the first contribution of this paper is to revisit the joint impact of infrastructure capital and institutional quality using a new dataset that consists of several alternative measures

[1]In this paper we consider the basic physical capital stocks, using electric power generation and telecommunication subscriptions as proxies for infrastructure assets.

[2]In our model, infrastructure capital is taken as a crucial treatment variable, while institutional quality is a moderator.

for both variables. We employ a balanced dataset of 120 countries spanning the period 1980–2015.

The second contribution of this paper concerns the estimation methodology. Empirical growth models often include lagged dependent variables as a covariate to control for the convergence effect. This creates an endogeneity problem, as the lagged dependent variable will be–by construction–correlated with the unobserved country-specific effects (Caselli et al., 1996). Earlier studies on institutions and infrastructure, such as Esfahani and Ramırez (2003) and Law et al. (2013), use cross-sectional regressions and apply an instrumental variable approach to address the endogeneity problem. However, implementing an instrumental variables estimation approach is often challenging as it is difficult to find a reliable instrumental variable for infrastructure capital and institutional quality (Lee and Kim, 2009). Our second contribution is thus to provide more reliable results addressing this endogeneity problem by means of the system Generalised Method of Moments (system-GMM) estimator (Arellano and Bover (1995); Blundell and Bond (1998); Bond et al. (2001)). This estimator is well suited to account for the potential endogeneity of not only the lagged dependent variable, but also of other explanatory variables.

As a third contribution, this paper improves upon extant studies on the joint effects of infrastructure and institutions, such as Esfahani and Ramırez (2003), Maiorano and Stern (2007) and Andonova and Diaz-Serrano (2009), by employing a large spectrum of institutional quality indicators, including democracy, autocracy, executive constraints, and bureaucratic quality, government stability, control over corruption, and the rule of law. These indicators capture three different dimensions of political institutions: political stability, administrative quality and democratic accountability. Accordingly, this study helps to understand if the effects of infrastructure capital on economic growth vary with respect to different institutional aspects. This allows us to check, for instance, whether promoting democracy is more important than controlling corruption in enhancing the productivity of infrastructural projects.

Our results show that that infrastructure capital is positively and significantly correlated with economic growth in countries with higher institutional qualities, and vice versa. In particular, infrastructure capital affects economic growth positively and significantly in the presence of considerably better institutional frameworks such as democracy, law and order, control of corruption, bureaucratic qualities and government stability. On the contrary, weaker institutional setups, such as autocracy, diminish the growth impacts of infrastructure capital. Our results are robust to the use of various alternative specifications and estimation methods. These results suggest that improving the quality of institutions is essential to reap the full economic benefits of infrastructural investments.

The rest of the paper is organized as follows. Section 2 introduces the empirical specification of our model. Section 3 describes our data in detail. Section 4 provides the results and Section 5 contains the conclusion. Finally, the Appendices contain supplementary material.

2. Empirical Model Specification

To examine the role of infrastructure capital on economic growth under varying degrees of institutional quality (henceforth we use the word 'institutions' and 'institutional quality' alternatively), we employ theoretical models that link economic growth with rent-seeking models. Specifically, our model builds up on the endogenous growth model of Barro (1990), which incorporates infrastructure capital as one factor of production. At this point, it is noteworthy that infrastructural investments are highly vulnerable to substantial bribes and rent-seeking activities (Shleifer and Vishny, 1993).

Hence, weak institutional setups may lead to lower quality of infrastructural investments and hence slow the rate of economic growth (Knack and Keefer, 1995; Mauro, 1997). That is, institutional quality is expected to have a direct effect on growth because it affects the efficiency of infrastructural investments. This view is echoed by, among others, Chong and Gradstein (2007), who argue that weak institutions divert resources from productive to unproductive sectors and encourage rent-seeking behaviors.

Our empirical model is derived from Canning and Pedroni (2008), who, following Barro (1990), incorporate stochastic disturbance terms over time. Such an approach allows us to estimate the role of infrastructure capital in a reduced form growth model using panel data estimation techniques. Specifically, our theoretical model describes the long-run growth rate of output per capita as a function of infrastructure capital and institutions.[3] Formally, our model, after a logarithmic transformation, is written as

$$\dot{y_{it}} = \alpha + \theta G_{it} + \gamma I_{it} + \sigma I_{it} * G_{it}, \tag{1}$$

where $\dot{y_{it}}$ denotes the GDP per capita growth rate for country i at time period t, I_{it} represents an indicator of institutional quality, G_{it} stands for infrastructural capital, and $I_{it} * G_{it}$ is the interaction term between institutions and infrastructure.

Our empirical model follows from (1) and looks as follows:

$$\dot{y}_{it} = \alpha + \theta G_{it} + \gamma I_{it} + \sigma I_{it} * G_{it} + \lambda Z_{it} + \epsilon_{it}, \tag{2}$$

where Z_{it} is a vector of control variables and ϵ_{it} is the error term. In this model the marginal effect (ME) of G_{it} on $\dot{y}_{it}$ is given by:

$$ME(G_{it} \mid I_{it}) = \frac{\partial \dot{y}_{it}}{\partial G_{it}} = \theta + \sigma I_{it} \tag{3}$$

In (3) unless σ is zero, the marginal effect of G_{it} is conditional on the value of I_{it}. Since we have a symmetric interactive model specification in (2), the marginal effect of I_{it} on $\dot{y}_{it}$ is also conditional on G_{it}, i.e.,

$$ME(I_{it} \mid G_{it}) = \frac{\partial \dot{y}_{it}}{\partial I_{it}} = \gamma + \sigma G_{it}. \tag{4}$$

Thus, the coefficient of the interaction term, σ, indicates both the slope of the relationship between $ME(G_{it} \mid I_{it})$ and I_{it}, and the slope of the relationship between $ME(I_{it} \mid G_{it})$ and G_{it} (Berry et al., 2012). Therefore, we propose the following hypothesis:

$\mathbf{H_{Infrastructure|Institutions}}$: The marginal effect of infrastructure capital on economic growth is expected to be positive in the presence of a high level of institutional quality, and this positive effect is expected to get more strength as the institutional quality improves. Similarly, the marginal effect of institutional quality is expected to be positive at any non-zero level of infrastructure capital and the effect gets stronger as infrastructure capital increases.

[3] Appendix A provides a detailed theoretical discussion of the model.

2.1. Dynamic panel data estimation approach

The empirical growth literature on the effects of infrastructure capital and institutional quality on economic growth has heavily relied on pure cross-sectional estimation methods (see, e.g., Esfahani and Ramırez, 2003; Glaeser et al., 2004; and, Rodrik et al., 2004). Nonetheless, the pure cross-sectional estimations often suffer from endogeneity bias, which arises by construction from the correlation between unobserved country-specific effects and the lagged dependent variable (Caselli et al., 1996). Furthermore, reverse causality from determinants of growth, such as infrastructure capital and institutional quality, to economic growth could be another source of endogeneity and could bias estimation results. To overcome these endogeneity concerns, an instrumental variable approach could be employed. Nevertheless, it is often difficult to find reliable instruments, which can be associated with the explanatory variable, but not with the error term.

In the empirical growth literature, the General Method of Moments (GMM)-based dynamic panel data estimators suggested by Arellano and Bond (1991); Arellano and Bover (1995); and Blundell and Bond (1998) are widely used to overcome the aforementioned econometric challenges in pure cross-sectional growth regressions. It is noteworthy that these estimators address unobserved country heterogeneity, omitted variable bias, and potential endogeneity that could arise from reverse-causality, by removing country-specific effects through first-differencing and employing lagged values as internal instruments (Arellano and Bover, 1995; Blundell and Bond, 1998).

In this study, we employ the system-GMM estimator (Arellano and Bover, 1995; Blundell and Bond, 1998) to examine the effects of infrastructure capital and institutional quality on aggregate output. We employ a panel data set of 120 countries over the period 1980 − 2014, with data averaged over five-years periods to overcome business cycle effects. Our baseline model is a multiplicative interaction model, which is derived from (2):

$$\dot{y}_{it} = \alpha + \beta \dot{y}_{it-1} + \theta INFR_{it} + \gamma INST_{it} + \sigma INST^{*}_{it} INFR_{it} + \lambda Z_{it} + \mu_i + \upsilon_{it} \tag{5}$$

where y_{it-1} is log GDP per capita of the previous five-year period and μ_i denotes the unobserved country-specific fixed effect. In (5) the interaction term allows the marginal effect of infrastructure capital on economic growth to vary with different degrees of institutional quality.

Unlike the difference-GMM (Arellano and Bond, 1991), which employs equations in first differences, the system-GMM estimator uses a system of two equations: one in first differences and the other in levels. The variables in levels in the latter are instrumented with their first differences, and these additional instruments reduce small sample biases and imprecision associated with the difference-GMM estimator (Arellano and Bover, 1995; Blundell and Bond, 1998; Roodman, 2006).

To test if our model is correctly specified, we apply two tests, namely the overidentification test, and the test for deeper lag serial correlation of the residuals in the differenced equation. Under the null hypothesis of instrument validity, the Sargan/Hansen tests for over-identifying restrictions are asymptotically distributed as a Chi-squared random variable with degrees of freedom equal to the number of instruments less the number of parameters. The autocorrelation determines tests the presence of autocorrelation of order three in the residuals in first differences, which is equivalent to testing autocorrelation of order two in the residuals in levels.

3. Data Description

Our goal in this paper is to estimate the effect of infrastructure capital, institutional quality and their interaction on aggregate economic growth worldwide. To this end we employ a balanced panel dataset that covers 120 countries during the period $1980 - 2015$. The list of the sample countries covered by the study is provided in Table 8. The variables used in the model and the source of data are briefly discussed below while summary statistics are documented in 1.

The dependent variable is the growth rate of aggregate output of a country. Aggregate output is measured by gross domestic product (GDP) per capita in constant 2010 US dollars. The data are obtained from the World Bank Development Indicators database (World-Bank, 2017).

One of the main challenges in the research on infrastructure and growth is obtaining quality national-level data on infrastructure capital. Sector-specific physical infrastructure data on investment or capital stock volumes are available only for a handful of high-income economies, and usually for just a few years. Hence, due to the incomplete nature of the data for other sectors of infrastructural investments, such as road networks, airports, and irrigation, we focus on telephone and power production infrastructure.

Accordingly, we use fixed telephone subscriptions per 100 people and the aggregate electric power generation kwh per capita as proxies for infrastructure capital investment. As a particular merit of these indicators, telephone networks and electric power generation are major contentious issues in the political economy of infrastructure development in many countries, and their productivity could be strongly influenced by the quality of prevailing institutions (Esfahani and Ramırez, 2003).

Fixed telephone subscriptions refer to the sum of an active number of analog fixed telephone lines, voice-over-IP (VoIP) subscriptions, fixed wireless local loop (WLL) subscriptions, ISDN voice-channel equivalents and fixed public payphones. Alternatively we use the telephone data from the Cross-National Time-Series Data Archive (CNTS) (Banks, 2011), which consolidates fixed line and cellular telephones.

Our electric power generation data comes from the U.S.-Energy-Information-Administration (2017), which provides access to a wide range of global energy and climate statistics. The dataset provides electricity generation by energy sources such as oil, nuclear, hydroelectric, gas, coal, and others. For this study, we use the aggregated data from all sources in kilowatt hour (kwh) for each country, divided by the total population of the country.

To measure institutional quality, we rely on two primary sources. First, we use the political institution indicators from the Polity IV Project dataset (Marshall and Jaggers, 2002). Second, we employ the political risk index of the International Country Risk Guide (ICRG) dataset, which provides survey-based data on the rule of law, control of corruption, bureaucratic quality, and government stability (Howell, 2011). A brief description of the individual institutional quality indicators used in the current study is provided below:

- **Polity2**: This is a combination of institutionalized democracy and institutionalized autocracy. The Polity2 score, which is derived from the Polity IV Dataset (Marshall and Jaggers, 2002), is computed by subtracting the autocracy score from the democracy score. The resulting unified Polity2 scale ranges from +10 (strongly democratic) to -10 (strongly autocratic).

- **Constraints on executive**: This refers to the extent of institutionalized constraints on the decision-making powers of chief executives, whether individuals or collectives, where any "accountability group may impose such limitations." This variable, which is also from the Polity IV Dataset, ranges from one to seven, wherein the larger the value, the larger the degree of constraints on the executive.

- **Institutionalized democracy**: This measure covers three aspects: (*i*) the presence of institutions and procedures through which citizens can express effective preferences about alternative policies and leaders; (*ii*) the existence of institutionalized constraints on the exercise of power by the executive; and (*iii*) the guarantee of civil liberties to all citizens in their daily lives and acts of political participation. This variable, which is drawn from the Polity IV Dataset, ranges from zero to ten, wherein the larger the value, the larger the degree of institutionalized democracy.

- **Institutionalized autocracy**: This measure defines the presence of a distinctive set of political characteristics including: (*i*) the competitiveness of political participation; (*ii*) the regulation of political participation; (*iii*) the openness and competitiveness of executive recruitment; and (*iv*) constraints on the chief executive. This variable, which is also taken from the Polity IV Dataset, ranges from zero to ten, wherein the larger the value, the larger the degree of institutionalized autocracy.

- **Bureaucracy quality**: This index is a shock absorber that tends to minimize revisions of policy when governments change. Therefore, many points are given to countries where the bureaucracy has the strength and expertise to govern without drastic changes in policy or interruptions in government services. In these low-risk countries, the bureaucracy tends to be somewhat autonomous from political pressure and to have an established mechanism for recruitment and training. The related data comes from the International Country Risk Guide (Howell, 2011).

- **Rule of law**: This index, which is taken from the International Country Risk Guide (Howell, 2011), measures the strength and impartiality of the legal system. It ranges from zero to six, wherein the larger the value, the lower the risk.

- **Control of corruption**: This index (which comes from the International Country Risk Guide (Howell, 2011) measures potential corruption in the form of excessive patronage, nepotism, job reservations, "scratching each other's back", secret party funding, and suspiciously close ties between politics and infrastructure capital. It ranges from zero to six, wherein the larger the value, the lower the control of corruption.[4]

- **Government stability**: This indicator is meant to assess both of the government's ability to carry out its declared program(s), and its ability to stay in office. We use data from the International Country Risk Guide (Howell, 2011). The risk rating assigned is the sum of three sub-components: government unity, legislative strength, and popular support. Each of these items ranges from zero to four, wherein the larger the value, the lower the risk.

In line with the empirical growth literature (see, for instance, Mankiw et al., 1992; Barro and Lee, 1996; Sala-i Martin, 1997; Nawaz, 2015), we use a vector of control variables including human

[4]The largest risk of corruption is that at some point it will become so overweening (or some major scandal will be suddenly revealed) as to provoke a popular backlash, resulting in a fall or overthrow of the government, a major reorganization or restructuring of the country's political institutions, or, at worst, a breakdown in law and order, rendering the country ungovernable. Contract repudiation indicates the risk of a modification in a contract taking the form of repudiation, postponement, or scaling down due to budget cutbacks, indigenization pressure, a change in government, or a change in government's economic and social policies.

capital, trade openness, macroeconomic stability and growth rate of population in the estimated equations. The data for all these control variables, except the educational attainment, are obtained from the World Development Indicators (World-Bank, 2017). The data on educational attainment are drawn from Barro and Lee (2013).

Educational attainment is measured using average years of schooling of males and females above 25 years of age. Annual population growth rate for year t is the exponential rate of growth of midyear population from year $t-1$ to t, expressed as a percentage. The trade openness of the sample countries is computed as the sum of imports and exports of goods and services as a percentage of GDP.

Table 1: Summary statistics of variables used in estimation

VARIABLES	Number of observation	Mean	Standard deviation	Minimum	Maximum
Log of GDP per capita	4,356	8.240	1.568	4.880	11.63
Log of all telephone per capita	4,356	10.08	2.162	4.248	15.31
Log of trade openness	4,356	22.26	3.047	2.797	28.56
Log of population growth rate	4,356	1.204	0.647	-2.522	2.766
Log of financial development	4,212	3.326	1.071	-1.514	7.688
Log of telephone subscriptions	4,356	1.479	1.945	-5.096	4.314
Log of electric kwh production per capita	4,248	7.426	2.325	0.527	21.59
Log of years of secondary education	824	1.226	0.651	0.029	2.629
Log of years of tertiary education	824	0.280	0.309	0	1.330
Democracy	4,032	5.210	4.053	0	10
Autocracy	4,032	2.185	3.049	0	10
Polity2	4,032	3.035	6.807	-10	10
Executive constraints	4,032	4.652	2.272	0	7
Government stability	3,636	7.388	2.246	1	12
Control of corruption	3,635	3.194	1.485	0	11
Rule of law	3,635	3.618	1.571	0	6
Bureaucratic quality	3,636	2.266	1.233	0	4
Polity2 X telephone	4,032	12.17	16.85	-28.41	43.14
Democracy X telephone	4,032	12.50	15.72	-30.58	43.14
Autocracy X telephone	4,032	0.348	6.131	-27.96	28.41
Executive constraint X telephone	4,032	9.287	11.44	-25.48	30.20
Control of Corruption X telephone	3,635	6.600	8.456	-15.27	39.15
Rule of law X telephone	3,635	7.562	9.307	-12.22	25.89
Bureaucratic quality X telephone	3,636	5.226	6.239	-10.69	17.26
Government stability X telephone	3,636	12.84	15.66	-45.87	46.70
Polity2 X electric	3,924	28.68	54.83	-135.2	119.9
Democracy X electric	3,924	42.86	37.30	0	119.9
Autocracy X electric	3,924	14.24	22.53	0	135.2
Executive constraint X electric	3,924	36.89	22.84	0	104.6
Corruption X electric	3,599	25.58	16.24	0	100.8
Rule of law X electric	3,599	28.93	17.45	0	71.94
Bureaucratic quality X electric	3,600	18.69	12.80	0	47.96
Government stability X electric	3,600	56.54	23.16	3.88	119.20

4. Results

In this section we discuss estimation results of empirical growth models, where infrastructure, institutional quality and the interaction of the two are our variables of interest. In particular, we first run Ordinary Least Squares (OLS) regressions to explore the relationship between economic growth and its determinants. Furthermore, we use the fixed-effect (FE) model in order to exploit the panel dimension of the data and tackle the cross-sectional heterogeneity. To overcome the endogeneity problems associated with the dynamic nature of growth models, we use the system-GMM estimator (Arellano and Bond, 1991; Blundell and Bond, 1998).

4.1. *Pooled OLS and Fixed Effect Estimations*

Table 2 presents pooled OLS estimation results using annual economic growth as a dependent variable and infrastructure and institutional quality and their interactions as covariates of interest. In each column, we include time dummies to account for time-effects. In all the specifications, interaction terms between infrastructure and institutions are included. In particular, while Columns (1), (2) and (3) consist of the interaction between fixed telephone subscriptions per 100 people (hereinafter telephone) and Polity2, Columns (4), (5) and (6) include the interaction terms between electric power generation in kwh per capita (hereinafter electricity) and Polity2. In Columns (2) and (5), we control for population growth rate. In Column (3) and (6), we add more growth determinants that are standard in the growth literature.

Table 2: OLS Estimation

	Telephone			Electricity		
Column VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Log of Telephone	6.872***	7.163***	0.939**			
	[0.0939]	[0.105]	[0.360]			
Polity2	-0.293***	-0.290***	-0.0638**	-2.145***	-1.986***	-0.918***
	[0.0248]	[0.0247]	[0.0247]	[0.121]	[0.123]	[0.0737]
Polity2 X Telephone	0.223***	0.247***	0.0414**			
	[0.0103]	[0.0103]	[0.0194]			
Polity2 X Electric				0.369***	0.336***	0.150***
				[0.0173]	[0.0177]	[0.0108]
Log of Electric				4.068***	3.875***	1.335***
				[0.175]	[0.186]	[0.108]
Log of trade openness			2.649***			1.839***
			[0.431]			[0.0960]
Log of financial development			0.457*			2.274***
			[0.232]			[0.147]
Log of population growth rate		2.100***	0.0595		-2.607***	-0.0594
		[0.224]	[0.179]		[0.422]	[0.235]
Constant	74.18***	70.97***	21.20**	48.70***	53.83***	12.32***
	[0.578]	[0.665]	[9.122]	[1.399]	[1.749]	[1.866]
Observations	3,996	3,996	3,564	3,924	3,924	3,492
R-squared	0.848	0.852	0.722	0.704	0.711	0.863
Year	Yes	Yes	Yes	Yes	Yes	Yes

Notes: This table documents the pooled OLS regressions results. All specifications consist of GDP per capita growth as a dependent variable and it is regressed on time fixed effects, telephone, Polity2, the interaction between Polity2 and telephone, the ratio total credit to the private sector to GDP (financial development), trade openness, population growth rate, electricity, and the interaction between Polity2 and electricity. All the explanatory variables, except Polity2, are used in natural logarithmic forms. Standard errors in parenthesis are heteroskedasticity robust. Significance at the 1%, 5% and 10% levels is indicated by ***, **, and *, respectively.

The results show that the interaction terms have the expected positive sign throughout the specifications. These results are consistent with our hypothesis that the marginal productivity of infrastructure capital in the economy tends to be larger with better institutional quality. However, these results should be taken with caveats as OLS in pooled regressions neither addresses individual heterogeneity nor solves the endogeneity of explanatory variables.

Figure 1 and 2 plot the marginal effect of infrastructure capital on economic growth across the observed ranges of Polity2 based on the estimates of Column (3) and (6) of Table 2, respectively. They show that the correlation between infrastructure capital and economic growth is positive and statistically significant at the 95% confidence interval across all levels of institutional quality. The converse result that the marginal effect of institutional quality (Polity2) on economic growth depends positively on telephone and electricity is shown by Figures 3 and 4 in Appendix B.

To avoid the possibility of modeling business cycle fluctuations, we now exploit the time variation of the sample by splitting our 35 years of data into 7 non-overlapping 5-year periods. Table 3, which is structured similarly to Table 2, presents results for panel fixed-effect regressions, and it includes the lag of GDP per capita as explonatory variable. Using five-year averages of annual economic growth as the dependent variable, we examine the effects of infrastructure and institutions by means of the within estimator. As control variables, Table 3 additionally includes average years of secondary education in Columns (2) and (5), and tertiary education in Columns (3) and

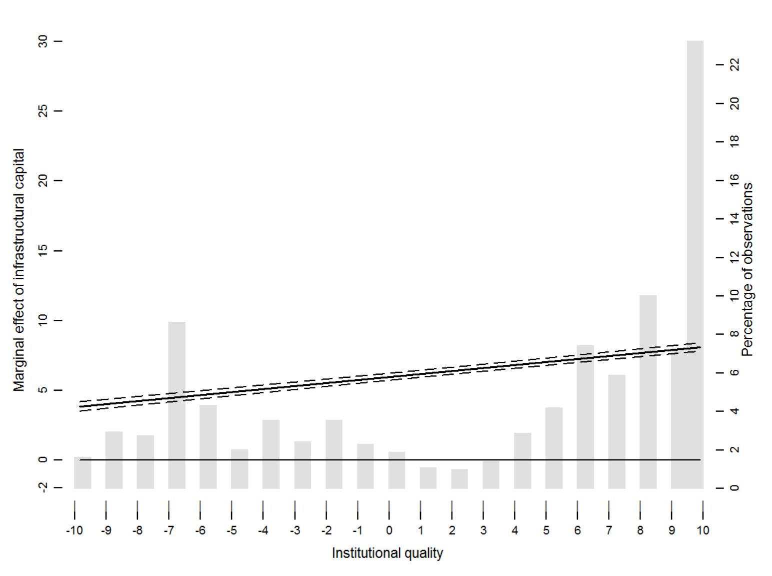

Figure 1: The effect of Polity2 on the marginal effects of telephone infrastructure on economic growth. The graph is is derived from the OLS regression results documented in Column 3 of Table 2.

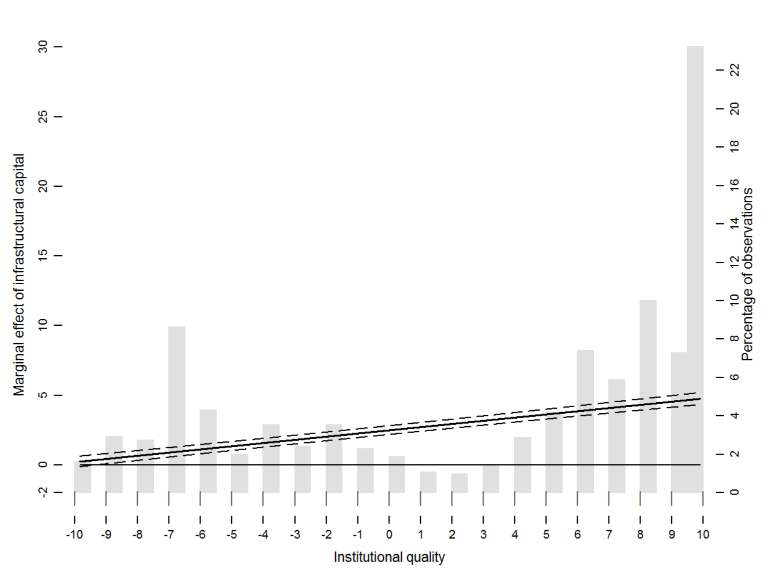

Figure 2: The effect of Polity2 on the marginal effects of electric power infrastructure on economic growth. The graph is derived from the OLS regression results documented in Column 6 of Table 2.

(6), respectively. Throughout the specifications, the results indicate that the coefficients on the interaction between infrastructure and institutions are positive and statistically significant, at least at the 10% significance level.

In Table 3, the effects of education on growth are not statistically significant and are negative in some cases. These results may be explained by noting that institutions and education are strongly correlated (see, for instance, Glaeser et al., 2004 and Bhattacharyya, 2009). One can argue that a high correlation between the two predictors may induce multicollinearity, making it difficult to disentangle separate effects. This result might also be interpreted from the point of view of heterogeneity (Flachaire et al. (2014)), since education and institutions could have different effects on growth for different groups of countries. Nevertheless, there are some cases where average years of tertiary education is positive and highly significant.

In general, in Table 3 we find results that provide strong support for the hypothesis that infrastructure capital is positively correlated with economic growth given high-quality political institutions. Nonetheless, results should be seen with some degree of caveats as the fixed effect estimator suffers from endogeneity problems that arise from the correlation between the lagged dependent variable and the country-specific fixed effects.

Table 3: Panel fixed effects estimation results

	Telephone			Electricity		
Column	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES						
Log of GDP per capita_t-1	-0.492***	-0.548***	-0.663***	-0.500***	-0.536***	-0.659***
	[0.0474]	[0.0551]	[0.0346]	[0.0422]	[0.0508]	[0.0418]
Log of Telephone	1.263***	1.470***	0.960***			
	[0.390]	[0.410]	[0.289]			
Polity2	-0.0555*	-0.0323	-0.0331	-0.223***	-0.176**	-0.186***
	[0.0322]	[0.0313]	[0.0233]	[0.0806]	[0.0761]	[0.0603]
Polity2 X Telephone	0.0493**	0.0385*	0.0316*			
	[0.0210]	[0.0205]	[0.0166]			
Polity2 X Electric				0.0302**	0.0248**	0.0258**
				[0.0124]	[0.0117]	[0.0100]
Log of Electric				1.508***	1.578***	0.778**
				[0.454]	[0.456]	[0.303]
Log of average years of secondary education	-0.139			0.278		
	[0.742]			[0.846]		
Log of average years of tertiary education		4.018***	2.045**		2.710**	1.174
		[1.111]	[0.983]		[1.176]	[0.995]
Log of trade openness			2.289***			2.519***
			[0.348]			[0.386]
Log of financial development			0.454**			0.433**
			[0.185]			[0.213]
Log of population growth rate			0.223			0.00344
			[0.189]			[0.221]
Constant	39.98***	42.36***	-2.488	30.83***	32.62***	-11.83
	[3.787]	[4.208]	[8.113]	[4.031]	[4.661]	[9.516]
Observations	693	693	679	679	679	665
R-squared	0.507	0.531	0.695	0.482	0.493	0.682
Number of countries	99	99	97	97	97	95
Year	Yes	Yes	Yes	Yes	Yes	Yes

Notes: This table reports results of a set of panel regressions aimed at estimating the effects of infrastructure and institutions on economic growth. All specifications consist of 5-year non-overlapping GDP per capita growth as a dependent variable and growth determinants as covariates. Results are obtained by employing the within (fixed effects) panel data estimator. All regressors, except Polity2 and time dummies, are used in natural logarithmic forms. Standard errors in parenthesis are heteroskedasticity robust. Significance at the 1%, 5% and 10% levels is indicated by ***, **, and *, respectively.

4.2. ***System-GMM estimation results***

Table 4: System-GMM estimation results

	Telephone			Electricity		
Column VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Log of GDP per capita_t-1	-0.138***	-0.146***	-0.152***	-0.016	-0.014	-0.106***
	(0.033)	(0.032)	(0.026)	(0.023)	(0.029)	(0.023)
Log of Telephone	0.705***	0.780***	0.542***			
	(0.210)	(0.212)	(0.160)			
Polity2	-0.026	-0.023	-0.025	0.003	-0.075	-0.173***
	(0.034)	(0.031)	(0.025)	(0.076)	(0.059)	(0.063)
Polity2 x Telephone	0.049***	0.054***	0.053***			
	(0.014)	(0.014)	(0.013)			
Polity2 X Electric				0.011	0.021**	0.033***
				(0.011)	(0.009)	(0.010)
Log of Electric				0.093	0.126*	0.185**
				(0.077)	(0.075)	(0.074)
Log of average years of secondary education	0.571			-0.094		
	(0.503)			(0.373)		
Log of average years of tertiary education		0.925	-0.228		-1.391	-0.508
		(0.716)	(0.698)		(1.055)	(0.725)
Log of trade openness			0.363***			0.377***
			(0.133)			(0.118)
Log of financial development			0.753***			0.799***
			(0.176)			(0.212)
Log of population growth rate			0.741***			0.586**
			(0.245)			(0.270)
Constant	9.574***	10.420***	0.158	0.806	0.621	-4.195**
	(2.105)	(2.309)	(2.615)	(1.274)	(1.641)	(1.836)
Observations	693	693	679	679	679	665
Number of countries	99	99	97	97	97	95
period dummy	Yes	Yes	Yes	Yes	Yes	Yes
Hansen Test (stat.)	0.131	0.135	0.740	0.169	0.183	0.845
Test AR(3) (z-stat.)	0.461	0.464	0.759	0.409	0.333	0.642

Notes: Results are obtained by employing the system-GMM estimator for dynamic panel data models. Standard errors in parenthesis are the Windmeijer robust standard errors. Significance at the 1%, 5% and 10% levels is indicated by ***, **, and *, respectively. For further notes, see Table 3.

Table 4 depicts results obtained by using the system-GMM dynamic panel data estimator, which addresses the problems of endogenous explanatory variables and time-invariant omitted variables. This estimator combines moment conditions for the model in first differences with moment conditions for the model in levels. The table depicts results for two infrastructure capital indicators: telephone (columns (1), (2) and (3)) and electricity (columns (4), (5) and (6)). For all specifications, institutional quality is proxied by Polity2. Our main variable of interest is the coefficient on the interaction term between infrastructure and institutions, which turns out to be positive and statistically significant in most of the specifications. The results confirm the presence of a positive and statistically significant correlation between infrastructure development and economic growth in the presence of democratic political regimes. The main difference between the fixed-effects results in Table 3 and the system-GMM results in Table 4 is that the effect of average years of tertiary education is not statistically significant in the system-GMM estimation while it was significant in one of the specifications in Table 3, generally depicting a weak relationship between education and economic growth. Likewise, Acemoglu et al. (2005) found that education measured by average years of schooling has no explanatory power for institutions when country fixed effects are included in the analysis.

In all of our specifications in Table 4, we use the two-step GMM procedure and employ the so-called Windmeijer finite sample corrections on the standard errors (Windmeijer, 2005). As we are able to reject autocorrelation of order two, but not one, we use the second and third lags of the variables in levels as instruments for the equation in first differences. Hence, nowhere among the regressions did the overidentification and AR(2) test statistics show any evidence of poor instrument choice or bad specification of the model at the 95% confidence level.

In summary, estimation results imply that both infrastructure capital and institutional quality are important for economic growth even after taking into account possible omitted variables and endogeneity problems using GMM-based panel data estimators. Moreover, while it is a common practice to consider the impacts of the two factors on economic growth separately (e.g., Acemoglu et al., 2005; Flachaire et al., 2014; Calderón et al., 2015), our use of interaction terms yields interesting results which confirm that the infrastructure and institutions are complementary to each other in their effects on economic growth.

4.3. ***Robustness checks***

This section shows that our results are robust to using a variety of alternative institutional quality measures and distinct indicators of infrastructure capital.

4.3.1. ***Alternative institutional quality indicators***

Acknowledging the potential limitations of relying on Polity2 as the only measure of the quality of political institutions, we consider two groups of alternative institutional quality indicators. The first group consists of three indicators that are taken from the Polity IV Project dataset while the second group includes four indicators from the Country Risk Guide (ICRG) dataset. Following Docquier et al. (2016), we can classify these two datasets into de jure and de facto measures of institutional quality. Accordingly, the "Polity2", "democracy", "autocracy" and "constraints on executive" are constructed based on expert coding of legal documents and can therefore be interpreted more as de jure measures. On the other hand, the "bureaucratic quality", "rule of law", "control of corruption", and "government stability" indices are based largely on subjective analysis and can therefore be seen as de facto measures of institutional quality.

Table 5 documents system-GMM based results using three (de jure) measures of the quality of political institutions, which are taken from the Polity IV Project dataset. These alternative measures of political institutions are constraints on the executive (the extent of which the decision-making powers of chief executives), institutional democracy and institutional autocracy. In Columns (1) and (4) of Table 5, we report results on the interaction between executive constraints and telephone and electricity, respectively. The results indicate that infrastructure capital investment is positively and highly correlated with economic growth, and the correlation becomes stronger in the presence of executive accountability and political stability. As already discussed, the Polity2 score as a parameter is constructed by subtracting the institutionalized autocracy score of a country from its institutionalized democracy score to generate an aggregate measure of democracy that runs from -10 to 10.[5] In order to see the robustness of the results obtained using Polity2, we now decompose

[5]The Polity2 variable seemingly provides the political regime in events of "interregnum" and "transition".

Table 5: System-GMM estimation results with more de jure institutional quality indicators

	Telephone			Electricity		
Column	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Executives	Democracy	Autocracy	Executives	Democracy	Autocracy
Log of GDP per capita_t-1	-0.148***	-0.159***	-0.132***	-0.111***	-0.130***	-0.099***
	(0.027)	(0.030)	(0.023)	(0.024)	(0.024)	(0.023)
Log of Telephone	-0.001	0.352*	0.730***			
	(0.216)	(0.198)	(0.161)			
Executives Con.	0.004			-0.454**		
	(0.078)			(0.201)		
Executives Con. X Telephone	0.149***					
	(0.036)					
Democracy		-0.035			-0.364***	
		(0.043)			(0.110)	
Democracy X Telephone		0.093***				
		(0.020)				
Autocracy			0.049			0.246*
			(0.048)			(0.139)
Autocracy X Telephone			-0.099***			
			(0.026)			
Log of Electric				-0.251*	0.036	0.283**
				(0.138)	(0.079)	(0.131)
Executives Con. X Electric				0.096***		
				(0.031)		
Democracy X Electric					0.067***	
					(0.017)	
Autocracy X Electric						-0.045**
						(0.019)
Log of average years of tertiary education	-0.391	-0.556	-0.017	-0.486	-0.423	-0.230
	(0.718)	(0.766)	(0.625)	(0.746)	(0.738)	(0.745)
Log of trade openness	0.357***	0.344***	0.370***	0.446***	0.445***	0.355***
	(0.121)	(0.126)	(0.135)	(0.148)	(0.143)	(0.107)
Log of financial development	0.726***	0.703***	0.747***	0.734***	0.754***	0.856***
	(0.194)	(0.189)	(0.182)	(0.192)	(0.211)	(0.171)
Log of population growth rate	0.765***	0.844***	0.519***	0.534**	0.632**	0.280
	(0.259)	(0.258)	(0.195)	(0.257)	(0.268)	(0.197)
Constant	0.094	1.298	-1.004	-2.947	-3.199*	-4.320**
	(2.545)	(2.548)	(2.538)	(2.057)	(1.887)	(1.792)
Observations	679	679	679	665	665	665
Period dummy	Yes	Yes	Yes	Yes	Yes	Yes
Hansen Test (stat.)	0.795	0.828	0.781	0.887	0.931	0.918
Test AR(3) (z-stat.)	0.738	0.784	0.659	0.643	0.702	0.491

Notes: Results are obtained by employing the system-GMM estimator for dynamic panel data models. Standard errors in parenthesis are the Windmeijer robust standard errors. Significance at the 1%, 5% and 10% levels is indicated by ***, **, and *, respectively. For further notes, see Table 3.

Polity2 into democracy and autocracy. In Columns (2) and (5) of Table 5 we consider the interaction between telephone and institutionalized democracy, and electricity and institutionalized democracy, respectively. The results confirm that infrastructure capital investment has a positive and robust effect on economic growth and the effect increases as the democracy score improves. On the other hand, as results on Columns (3) and (6) of Table 5 show, infrastructure capital positively affects economic growth, but the effect gets weaker as governments become more autocratic. Therefore the results using disaggregated de jure institutional quality measures (Table 5) are qualitatively similar to the baseline results obtained by using the comprehensive Polity2 measure (Table 4).

We next turn to other alternative (de facto) measures of institutional quality given in the International Country Risk Guide (ICRG) dataset. Table 6 reports results for a similar set of estimations as in Table 4, but with bureaucratic quality, the rule of law, government stability and control of corruption as institutional quality indicators. In most of the specifications of Table 6, the results on the interaction between infrastructure capital and institutional quality are statistically significant with the expected signs. The four measures of political institutions all exhibit the same pattern, with good political institutions enhancing the effect of infrastructure capital on economic growth.

To sum up, our robustness analysis by means of alternative and disaggregated measures of political institutions indicates that political institutions play a crucial role in determining the effect of infrastructure capital on aggregate output.

4.3.2. ***Telephone subscription including cellular***

Our next robustness check involves employing an alternative measure of the telephone infrastructure. Following the emergence of the information and communication technology (ICT), cellular phones have become more popular since the 1990s. In the baseline analysis, we used the fixed line telephone as a proxy for infrastructure capital. Table 7 estimates the effect of institutions and infrastructure on economic growth by using the total number of telephone subscriptions per capita (both cellular and none-cellular) as a proxy for infrastructure capital. The data for the total number of telephone subscriptions per capita are drawn from the Cross-National Time-Series Data Archive (CNTS) dataset. Results documented in Table 7 show that, except for Columns (3) and (8), the interaction terms between infrastructure and institutions have statistically significant effects with the expected signs. Therefore, these results confirm the robustness of our baseline results to using more a comprehensive telephone infrastructure indicator.

5. Conclusion

The current study revisits the ongoing debate on the determinants of long-run economic growth with a specific focus on the roles of infrastructure capital and political institutions. Our hypothesis is that the marginal effect of the infrastructure capital on economic growth depends on the quality of existing political institutions, i.e., the better the institutional quality, the larger the productivity of infrastructure, and vice versa. In order to address potential econometric concerns with respect to endogeneity, **heterogeneity** and reverse causality, we verify our hypothesis not only by means of the fixed-effects estimations, but also by using system-GMM dynamic panel data estimations.

Our results show that there is a positive correlation between infrastructure capital and economic growth in countries with good institutional quality. On the other hand, the results indicate that the productivity of the infrastructure capital is no longer positively associated with economic growth in countries where a highly autocratic regime is in power. These results are robust to the use of different specifications and estimators, and they are consistent with a variety of alternative indicators of infrastructure (electric power generation and telecommunication subscriptions) and political institutions (democracy, autocracy, executive constraint, bureaucratic quality, the rule of law, and government stability).

Our results confirm that the effect of infrastructure capital on aggregate output depends on the quality of political institutions prevailing in a country. These results are in line with two potential explanations. First, political institutions (even in the absence of a significant direct effect Flachaire et al., 2014) are a central element in the growth process since they determine the marginal effect of standard growth determinants such as investment on the physical capital (infrastructure

Table 6: System-GMM estimation results with more de facto institution quality indicators

	Telephone				Electricity			
Column	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	Bureaucratic.Q	Rule of law	Government.S	C.Corruption	Bureaucratic.Q	Rule of law	Government.S	C.Corruption
Log of GDP per capita_t-1	-0.178***	-0.167***	-0.138***	-0.175***	-0.150***	-0.152***	-0.163***	-0.166***
	(0.033)	(0.032)	(0.023)	(0.030)	(0.028)	(0.035)	(0.032)	(0.029)
Log of Telephone	0.385**	0.293	0.071	0.123				
	(0.188)	(0.200)	(0.220)	(0.242)				
Bureaucratic Quality	-0.390**				-1.067*			
	(0.175)				(0.581)			
Bureaucratic Q. X Telephone	0.247***							
	(0.083)							
Rule of Law		-0.091				-0.882*		
		(0.137)				(0.462)		
Rule of Law X Telephone		0.155***						
		(0.054)						
Government stability			-0.066				-0.038	
			(0.081)				(0.174)	
Government S. X Telephone			0.044*					
			(0.024)					
Control of Corruption				-0.231				-0.903
				(0.235)				(0.586)
Corruption X Telephone				0.198***				
				(0.074)				
Log of Electric					0.206	-0.028	0.432	0.140
					(0.296)	(0.264)	(0.275)	(0.332)
Bureaucratic Q. X Electric					0.127			
					(0.087)			
Rule of Law X Electric						0.146**		
						(0.060)		
Government S. X Electric							0.010	
							(0.023)	
Corruption X Electric								0.140**
								(0.068)
Log of average years of tertiary education	0.692	1.190	1.020	0.688	1.099	0.382	1.287*	0.520
	(0.715)	(1.029)	(0.708)	(0.853)	(0.830)	(1.033)	(0.719)	(0.916)
Log of trade openness	0.268***	0.264**	0.362***	0.347***	0.386***	0.314***	0.371***	0.467***
	(0.096)	(0.102)	(0.116)	(0.121)	(0.119)	(0.091)	(0.110)	(0.164)
Log of financial development	0.765***	0.599***	0.771***	0.873***	0.818***	0.827***	0.811***	0.797**
	(0.199)	(0.214)	(0.213)	(0.224)	(0.252)	(0.228)	(0.221)	(0.339)
Log of population growth rate	0.463*	0.579**	0.063	0.548*	0.046	0.227	-0.118	0.357
	(0.256)	(0.231)	(0.202)	(0.282)	(0.291)	(0.215)	(0.216)	(0.304)
Constant	4.674*	3.883	0.536	2.530	-0.283	2.336	-0.787	-1.167
	(2.710)	(2.552)	(2.288)	(2.616)	(2.572)	(2.367)	(2.312)	(3.043)
Observations	637	637	637	637	630	630	630	630
Number of Id	91	91	91	91	90	90	90	90
Period	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Hansen Test (stat.)	0.918	0.880	0.962	0.892	0.933	0.892	0.987	0.946
Test AR(3) (z-stat.)	0.604	0.621	0.369	0.234	0.956	0.996	0.666	0.420

Notes: Results are obtained by employing the two-step system-GMM estimator for dynamic panel data models. Standard errors in parenthesis are the Windmeijer robust standard errors. Significance at the 1%, 5% and 10% levels is indicated by ***, **, and *, respectively. For further notes, see Table 3.

Table 7: System-GMM Analysis with All Telephone Per Capita

Column VARIABLES	(1) Polity 2	(2) Executive	(3) Democracy	(4) Autocracy	(5) Rule of Law	(6) Bureaucratic Q.	(7) C.Corruption	(8) Government S.
Log of GDP per capita_t-1	-0.109***	-0.131***	-0.121***	-0.101***	-0.123***	-0.138***	-0.149***	-0.126***
	(0.020)	(0.023)	(0.022)	(0.018)	(0.022)	(0.028)	(0.029)	(0.028)
Polity2 X all Telephone	0.015**							
	(0.007)							
Polity2	-0.138*							
	(0.079)							
Log of all Telephone per capita	0.260**	0.067	0.204*	0.313***	0.113	0.200	0.085	0.214
	(0.105)	(0.116)	(0.112)	(0.116)	(0.146)	(0.141)	(0.191)	(0.173)
Executive X all telephone		0.057**						
		(0.022)						
Executive		-0.509**						
		(0.254)						
Democracy X all telephone			0.024					
			(0.015)					
Democracy			-0.203					
			(0.172)					
Autocracy X all telephone				-0.027*				
				(0.015)				
Autocracy				0.242				
				(0.156)				
Rule of law all telephone					0.067			
					(0.046)			
Rule of Law					-0.598			
					(0.490)			
Bureaucratic Q. X all telephone						0.138**		
						(0.066)		
Bureaucratic Quality						-1.477**		
						(0.663)		
C.Corruption X all telephone							0.099*	
							(0.059)	
Control of corruption							-0.927	
							(0.642)	
Government Stability X all telephone								0.025
								(0.026)
Government Stability								-0.421
								(0.296)
Log of average years of tertiary education	-0.033	0.170	0.075	-0.026	0.448	0.290	0.402	0.524
	(0.516)	(0.576)	(0.598)	(0.465)	(0.574)	(0.656)	(0.685)	(0.768)
Log of trade openness	0.347***	0.396***	0.365**	0.313***	0.317***	0.351**	0.402***	0.299***
	(0.130)	(0.151)	(0.161)	(0.106)	(0.116)	(0.137)	(0.125)	(0.094)
Log of financial development	0.922***	0.935***	0.929***	0.957***	0.893***	1.038***	1.102***	1.081***
	(0.213)	(0.190)	(0.214)	(0.176)	(0.199)	(0.229)	(0.228)	(0.218)
Log of population growth rate	0.168	0.064	0.127	0.158	0.153	0.116	0.212	0.032
	(0.169)	(0.203)	(0.195)	(0.160)	(0.199)	(0.209)	(0.225)	(0.223)
Constant	-4.184**	-1.751	-3.508	-4.760**	-1.416	-2.031	-1.195	-0.786
	(1.917)	(2.066)	(2.512)	(1.934)	(2.404)	(2.378)	(2.729)	(2.828)
Observations	679	679	679	679	637	637	637	637
Number of Id	97	97	97	97	91	91	91	91
Period	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Hansen Test (stat.)	0.985	0.991	0.987	0.990	0.994	0.995	0.899	0.965
Test AR(3) (z-stat.)	0.417	0.374	0.473	0.448	0.998	0.961	0.423	0.806

Notes: Results are obtained by employing the two-step system-GMM estimator for dynamic panel data models. Standard errors in parenthesis are the Windmeijer robust standard errors. Significance at the 1%, 5% and 10% levels is indicated by ***, **, and *, respectively. For further notes, see Table 3.

capital, in our case). More precisely, countries with democratic institutional frameworks (binding legislature) have a higher level of economic growth and investment, whereas authoritarian regimes (nonbinding legislatures) adversely affect economic growth (Wright, 2008). Second, regulations are important mechanisms to increase the productivity of public investments as inefficiency is pervasive in public-owned investments. Dal Bó and Rossi (2007) and Corrado and Rossetti (2018) show that a higher level of corruption is significantly associated with a lower degree of efficiency in using infrastructure capital. Moreover, when countries have a weaker commitment power and regulatory capacity, potential returns from infrastructure might be lower due to weak contract enforcement, expropriation, and opportunistic renegotiations (Straub, 2011).

Finally, it is noteworthy that the current study has the following limitations. First, both the theoretical model and the empirical estimation do not address the issue of infrastructure quality. Second, the study does not distinguish between private and public ownership of the infrastructure capital. Third, due to lack of sufficiently large panel data available for other infrastructure sectors, such as transportation, water, and irrigation, we only use the telephone subscriptions and electric power generation as proxies for infrastructure capital. Addressing these limitations is left for future research.

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Appendices

A. Theoretical Framework

Our theoretical model builds up on the endogenous growth model of Barro (1990), which incorporates infrastructure capital as one factor of production. Besides, following Canning and Pedroni (2008), we specify a Cobb-Douglas type production function and apply the model to panel data as

$$Y_{it} = A_{it}.K_{it}^{\alpha}.G_{it}^{\beta}.L_{it}^{1-\alpha-\beta} \tag{6}$$

where the countries and time periods are indexed by i and t, respectively. Aggregate output Y is produced by employing (non-infrastructure) aggregate capital stock K, infrastructure capital stock G, aggregate hours worked by the labor force L, and total factor of productivity A. For simplicity, it is assumed that infrastructure capital is a fixed fraction τ_{it} of total savings s. It can be shown that there is a growth and welfare-maximizing level of investment in the infrastructure capital τ^* (Canning and Pedroni, 2008; Straub, 2011). Note that, without shocks in infrastructure capital, given by $\tau^* = \beta \mid \alpha + \beta$ (Barro, 1990).

Furthermore, Canning and Pedroni (2008) show that the proportion of investment going to infrastructure is $\tau_{it} = \bar{\tau} + \mu_{it}$ where μ_{it} is a zero mean stationary series. Accordingly, in the endogenous growth model, a positive shock to the infrastructure capital will increase income per capita when $\bar{\tau} < \tau^*$ and income per capita will decrease when $\bar{\tau} > \tau^*$.[6] The marginal cost of the increased infrastructure capital is the diversion of resources from other productive sectors, while the marginal benefit is the gain in the long-run income (Straub, 2011).

However, Aron (2000) argues that in growth models, the presence of threshold levels of certain inputs such as infrastructure must be in place before production is feasible. Hence, the constant returns to scale assumption may not be satisfied. Thus, the effect of infrastructure capital on output can be dependent on country-specific institutional variables. To capture this notion, we redefine the production function specified in (6) by including rent-seeking activities that act as a distortion in the production process. Our new production function model is adapted from Nawaz et al. (2014), and given as

$$Y_{it} = (1 - \eta_{it})A_{it}.K_{it}^{\alpha}.G_{it}^{\beta}.L_{it}^{1-\alpha-\beta} \tag{7}$$

where $\eta_{it} \in [0, \hat{\eta}], \hat{\eta} \ll 1$ denotes rent-seeking behavior.

In our model, institutional quality is captured by rent-seeking as a proxy. Formally, $\hat{\eta}$ is the point at which rent-seeking is the highest (institutional quality is the lowest).

We consider that each firm uses all its capacity to appropriate as much rent as possible, which is dependent on the total amount of rent and the quality of institutions. When $r_{it} = 0$, it indicates the presence of high institutional quality, thereby an agent extracts less rent. On the contrary, when $r_{it} = 1$, institutional quality hits its lowest level, and hence, the marginal utility of rent-seeking reaches its maximum (Nawaz et al., 2014). Thus, the level of r_{it} determines the marginal productivity of infrastructural investment.

[6] Canning and Pedroni (2008) complement the model by describing the evolution of the technical progress, A_{it}, the share of investment going to infrastructure, τ, and the size of the workforce, L_{it}.

In contrast, good institutional quality improves the efficiency of infrastructure capital as resources are prevented from being wasted in rent-seeking activities, so they lead to higher economic growth. Furthermore, to predict the long-run growth patterns, it is important to test the consumption and investment decisions made by individual agents. In doing so, we assume that a representative agent is facing an infinite planning horizon and maximizing utility subject to a dynamic budget constraint. As a result, the agent seeks to maximize inter-temporal utility, which is defined as

$$U_{it} = \int_0^\infty e^{-\rho t} \frac{C_{it}^{1-\sigma} - 1}{1-\sigma} dt, \tag{8}$$

where C_{it} denotes consumption per capita, and we assume that $0 < \sigma < 1$. This implies that the elasticity of marginal utility equals the constant $-\sigma$. Moreover, $e^{-\rho t}$ represents the time preference rate, where $\rho > 0$ is a time discount factor. By assuming that other elements of the production function are constant in (7) for simplification, the dynamic budget constraint of infrastructure in per capita terms is subject to:

$$\dot{G_{it}} = \frac{dG}{dt} = (1-\eta_{it})A_{it}.K_{it}^{\alpha}.G_{it}^{\beta}.L_{it}^{1-\alpha-\beta} - C_{it} \tag{9}$$

where a dot over a variable denotes a time derivative. It is assumed that the infrastructure capital stock is $G_{(0)} = 1$ at the initial period. The terminal condition is given as $lim_{t\to\infty} G\lambda e^{-\rho t} = 0$, which indicates that the infrastructure capital stock left over at the end of the planning horizon is zero. In (9) we can observe that increases in the infrastructure capital stock (where $\tau < \tau*$) are equals to the total saving, which in turn, is equals to the difference between output and consumption. Hence, in this case the individual agent chooses optimal consumption $[C_{it} : t \geqslant 0]$ and investment path to determine the level of infrastructure capital stock $[G_{it} : t \geqslant 1]$. To find this optimal allocation of resources by the individual agent, Nawaz et al. (2014) suggest to apply Hamiltonian function, which is given by

$$H = e^{-\rho t} \frac{C_{it}^{1-\sigma} - 1}{1-\sigma} + \lambda[(1-\eta_{it})A_{it}.K_{it}^{\alpha}.G_{it}^{\beta}.L_{it}^{1-\alpha-\beta} - C_{it}] \tag{10}$$

In (10), the expression within the square brackets is equal to $\dot{G}$ and λ is the Lagrange multiplier representing the present value of the shadow price of income. Differentiation of the Lagrange function with respect to C_{it} and G_{it} yields the first order conditions

$$\frac{\partial H}{\partial C_{it}} = 0 \Rightarrow e^{-\rho t} \frac{C_{it}^{-\sigma}}{1-\sigma} - \lambda = 0 \tag{11}$$

and

$$\frac{\partial H}{\partial G_{it}} = -\dot{\lambda} \Rightarrow \lambda(1-\rho_{it})A_{it}.K_{it}^{\alpha}.\beta G_{it}^{\beta-1}.L_{it}^{1-\alpha-\beta} = -\dot{\lambda}. \tag{12}$$

From (11) and (12) and fixing the infrastructure capital stock $G(0) = 0$, the transversality condition equals $lim_{t\to\infty} G_{it}\lambda e^{-\rho t} = 0$. Using the budget constraint in (9), the growth rate of per capita consumption, which is the same as the growth rate of output and infrastructure capital, is given as follows:

$$\frac{\dot{y}_{it}}{yit} = \frac{\dot{C}_{it}}{C_{it}} = \frac{1}{\sigma}[(1-\eta_{it})A_{it}.K_{it}^{\alpha}.\beta G_{it}^{\beta-1}.L_{it}^{1-\alpha-\beta} - \rho] \tag{13}$$

and

$$\frac{\dot{y}_{it}}{yit} = \frac{\dot{C}_{it}}{C_{it}} = \frac{(1-\eta_{it})}{\sigma}(A_{it}.K_{it}^{\alpha}.\beta G_{it}^{\beta-1}.L_{it}^{1-\alpha-\beta})\frac{-\rho}{\sigma}. \tag{14}$$

The outcome in (13) indicates that as institutional quality improves, rent-seeking activities decrease. In our context, this implies that high institutional quality enhances the productivity of infrastructure capital. Finally, differentiating (14) with respect to rent-seeking activities obtains

$$\eta_{it} = \frac{\frac{\partial \dot{y}_{it}}{y_{it}}}{\partial \eta_{it}} = \frac{-(A_{it}.K_{it}^{\alpha}.\beta G_{it}^{\beta-1}.L_{it}^{1-\alpha-\beta})}{\sigma^2} > 0, \tag{15}$$

which shows that, as η_{it} increases, economic growth decreases if $\sigma > 0$.

After a logarithmic transformation, the model (14) is written as

$$\dot{y_{it}} = \alpha + \theta G_{it} + \gamma I_{it} + \sigma I_{it} * G_{it}, \tag{16}$$

where $\dot{y_{it}}$ denotes the GDP per capita growth rate for country i at time period t, I_{it} represents an indicator of institutional quality, G_{it} stands for infrastructure capital, and $I_{it} * G_{it}$ is the interaction term between institutions and infrastructure.

Finally, it is noteworthy that the theoretical model discussed above indicates that the higher η_{it}, the lower the economic growth will be due to less productivity of the infrastructure capital and vice versa. The validation of the statement therefore specifies that when $\eta_{it} = 0$ (in the case of strong institutions) the economic growth is with $\frac{1}{\sigma}[A_{it}.K_{it}^{\alpha}.\beta G_{it}^{\beta-1}.L_{it}^{1-\alpha-\beta} - \rho]$ higher than the economic growth under weak institutions $0 < \eta_{it} < \hat{\eta}$, which is given by $\frac{1}{\sigma}[(1-\eta_{it})A_{it}.K_{it}^{\alpha}.\beta G_{it}^{\beta-1} L_{it}^{1-\alpha-\beta} - \rho]$.

B. Marginal Effect Figures

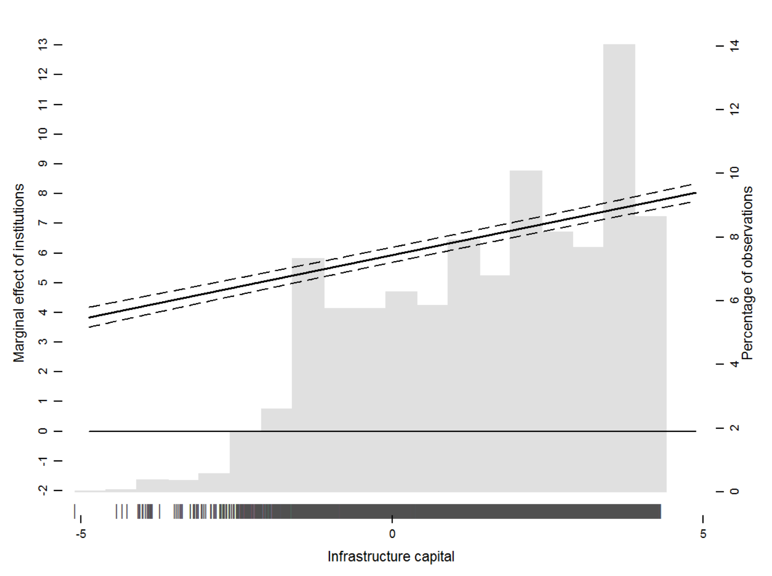

Figure 3: The effect of telephone infrastructure on the marginal effects of Polity2 on economic growth. The graph is derived from the OLS regression results documented in in Column 3 of Table 2.

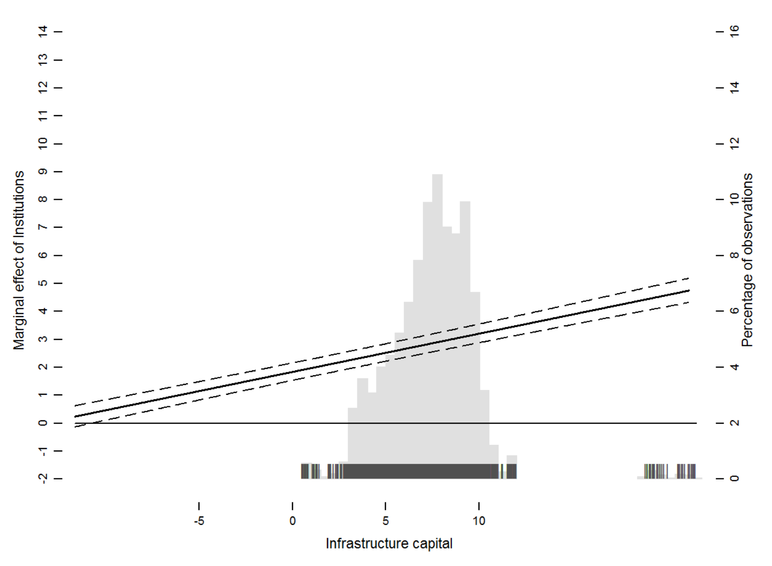

Figure 4: The effect of electric power infrastructure on the marginal effects of Polity2 on economic growth. The graph is derived from the OLS regression results documented in Column 6 of Table 2.

Table 8: List of countries

Code	Country	Code	Country	Code	Country	Code	Country
1	Albania	31	Cyprus	61	Jordan	91	Philippines
2	Algeria	32	Denmark	62	Kenya	92	Portugal
3	Angola	33	Dominica	63	Korea, Rep.	93	Rwanda
4	Argentina	34	Dominican Republic	64	Lesotho	94	Samoa
5	Australia	35	Ecuador	65	Luxembourg	95	Saudi Arabia
6	Austria	36	Egypt, Arab Rep.	66	Madagascar	96	Senegal
7	Bangladesh	37	El Salvador	67	Malawi	67	Seychelles
8	Barbados	38	Ethiopia	68	Malaysia	98	Sierra Leone
9	Belgium	39	Fiji	69	Mali	99	Singapore
10	Belize	40	Finland	70	Malta	100	South Africa
11	Benin	41	France	71	Mauritania	101	Spain
12	Bolivia	42	Gabon	72	Mauritius	102	St. Lucia
13	Botswana	43	Gambia, The	73	Mexico	103	Sudan
14	Brazil	44	Germany	74	Mongolia	104	Suriname
15	Bulgaria	45	Ghana	75	Morocco	105	Swaziland
16	Burkina Faso	46	Greece	76	Mozambique	106	Sweden
17	Burundi	47	Grenada	77	Namibia	107	Switzerland
18	Cabo Verde	48	Guatemala	78	Nepal	108	Tanzania
19	Cameroon	49	Guinea-Bissau	79	Netherlands	109	Thailand
20	Canada	50	Guyana	80	New Zealand	100	Togo
21	Central African Republic	51	Honduras	81	Nicaragua	111	Tunisia
22	Chad	52	Iceland	82	Niger	112	Turkey
23	Chile	53	India	83	Nigeria	113	Uganda
24	China	54	Indonesia	84	Norway	104	United Kingdom
25	Colombia	55	Iran, Islamic Rep.	85	Oman	115	United States
26	Comoros	56	Ireland	86	Pakistan	116	Uruguay
27	Congo, Dem. Rep.	57	Israel	87	Panama	117	Vanuatu
28	Congo, Rep.	58	Italy	88	Papua New Guinea	118	Venezuela, RB
29	Costa Rica	59	Jamaica	89	Paraguay	119	Zambia
30	Cote d'Ivoire	60	Japan	90	Peru	120	Zimbabwe