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Infrastructure's Role in Sustaining Asia's Growth

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Contents

Abstract

This paper provides a comprehensive overview of the issues, policies, and political economy of infrastructure investment, and a review of empirical literature of the relationship between growth and infrastructure. Empirical estimations using the growth accounting framework for a panel of 123 economies confirm that while infrastructure contributes to growth, the extent of the contribution generally varies according to the level of income of countries. Telecommunications are most important for low-income countries, while transportation and energy are the most relevant for middle-income and high-income economies, respectively. Results pertaining to the Asia and Pacific region reveal infrastructure on telecommunications, roads, and energy generation to have been supportive of growth in the region.

I. Introduction

Asia's high investment rates in recent decades have supported rapid expansion of infrastructure, which in turn has supported the region's rapid growth. How investments in physical infrastructure are planned and financed, how they generate useful services, and how those services are allocated to producers and consumers can be complex. Focusing on infrastructure assets, services, and markets, and the environment in which infrastructure makes its contributions to economic growth and development, helps in analyzing effective infrastructure investment and related policies.

Infrastructure consists of physical assets such as power generation, transmission, and distribution systems, transportation or communications networks, and water and sanitation systems. By some definitions, social, organizational or regulatory institutions can also be considered as infrastructure (often referred to as "soft" infrastructure to differentiate it from "hard" physical infrastructure). This paper focuses primarily on the role of hard (physical) infrastructure in sustaining Asia's growth. Even so, the scope is too broad to permit much more than an overview of relevant issues.

Infrastructure has been widely characterized by theory and empirical studies as a source and facilitator of economic growth. Infrastructure contributes to growth directly through its fiscal stimulus effects and through the services it provides, which can serve as inputs to other economic activities. Indirectly, it contributes to growth through externalities that improve productivity such as facilitating technology dissemination, prolonging the longevity of complementary capital goods, etc. For a region as trade-dependent as Asia, infrastructure that facilitates trade in the region can also lead to cross-country growth spillovers.

While Asian economies in general have grown at unprecedented rates in recent decades, sustained growth is imperative if the 1.8 billion individuals living below $2 a day (in purchasing power parity terms) in the region are to be lifted out of poverty, and if the region's Millennium Development Goal of halving the proportion of the population living below $1 a day by 2015 is to be achieved.[1] At present, the need for greater infrastructure remains substantial (see Table 1).

[1] The $1 a day poverty threshold was recently revised to $ 1.25. The first target is, however, still referred to by its old name for convenience (ADB 2010).

Table 1: Challenges in Access to Infrastructure Services in Asia

Infrastructure	Issues
Energy	0.8 billion in Asia have no access to basic electricity service 1.8 billion still rely on traditional biomass for cooking and heating
Water	1.8 billion lack basic sanitation 600 million lack safe drinking water High climate change risk
Transport	Half of roads are unpaved In some countries 30%–40% of villages are without all-weather road access Tens of millions have no access to affordable and convenient transport services
Urban	505 million slum dwellers in Asia Significant increase of urban poor without access to urban services

Source: Kim (2011).

Moreover, the rest of the world is looking at the Asian region to play an even more important role in shaping the world economy in the aftermath of the recent global financial crisis, which has made economic restructuring inevitable. While this may mean opportunities for high- and upper-middle-income countries in the region to consolidate their economic and social gains, it also implies opportunities for lower-middle and low-income economies to catch up with their higher income counterparts in the region and the rest of the world.

In this context, it is important to understand how infrastructure can help sustain growth in Asian economies. In particular, it would be useful to know the parameters and variables related to infrastructure at different stages of development that policy makers have to consider over the medium and long term to ensure that Asian economies are well positioned to exploit the opportunities that global economic restructuring may offer. This paper intends to contribute to this important discussion through (i) a comprehensive overview of the issues and policies involved in infrastructure investment, postconstruction asset management, and their political economy; (ii) re-examining the empirical findings and underpinnings of the nexus between growth and infrastructure; (iii) an empirical analysis on the kinds of infrastructure that are critical in supporting growth for economies at different stages of development; and (iv) policy recommendations for infrastructure development in the region based on the preceding analyses.

The next section discusses some key characteristics of infrastructure that make it a special sector in terms of demand (consumption of infrastructure services) and supply (investment). Section III discusses the political economy of infrastructure investment. Section IV reviews the empirical literature on the interaction between infrastructure and growth. Section V describes the empirical methodology of this paper and analyzes the estimation results. Section VI concludes by discussing further challenges and issues in infrastructure investment. It also suggests some policy recommendations for infrastructure development in the region.

II. Key Characteristics of Infrastructure

According to Underhill (2010, 163), infrastructure is "a broad mix of large scale public systems, services, and facilities … necessary for economic activity to function". While it is apparent from this definition that infrastructure can refer to a vast array of large scale structures and attendant services, this paper focuses on the physical infrastructure of telecommunications, energy, and transportation. Infrastructure assets often require large investments and require lengthy construction periods, delaying realization of the potential for cost recovery. Such assets usually cover particular geographic areas with the services they generate and may be natural monopoly providers of their services within those areas.

A. Public Goods Characteristics

Infrastructure investments usually generate externalities, or spillover effects, which can be either positive or negative (or both, depending on who is affected). This may make it difficult to exclude users who are unwilling to pay for the services, to set prices that accurately reflect economic effects, or to collect payments that are proportional to usage. These characteristics mean that infrastructure services are usually at least partly public goods, and the public sector has a role to play. That infrastructure services often benefit the poor, in turn generating positive externalities, strengthens the public sector role.

Externalities and poverty among service consumers make implementation of user fees difficult. The public sector should be substantially involved in most infrastructure sectors, but poor countries face weak revenue-raising capacity and limited access to financial markets, suggesting a domestic dilemma. Network effects and coverage characteristics also make it difficult to delimit an appropriate role for public infrastructure policy.

The scale and long-time horizon typical of infrastructure projects also lead toward public sector involvement. These characteristics raise particular issues in financing infrastructure investments, and the importance of financial market development in supporting infrastructure investment. In particular, bond markets with long-term bonds in local currency ease foreign exchange risk in international financial intermediation. Limited capacity in the public sector budget highlights the importance of crowding in the private sector, which is easier in some infrastructure sectors such as telecommunications, than others. Where pure private sector investment is unlikely, public–private partnerships (PPPs) offer a possible financing modality. Success in PPPs depends on reaching appropriate risk-sharing agreements and reliable institutional structures. Political risk coverage or risk sharing helps to mitigate risks of potential political turmoil to private sector investors over the lengthy horizon.

The large scale and long time horizon also mean that infrastructure projects are usually bulky investments, which are more likely to be undertaken by powerful agents in the local

economy (especially when foreign investment is discouraged). The domestic political or economic power of the investors leads in turn to threats of possible market dominance and/or regulatory capture. Good governance then plays a critical role in providing an adequate level of comfort for private sector investors to participate in infrastructure investment. The complementarity of physical and institutional infrastructure has its own dynamic in the development process, with development of quality institutional infrastructure often playing catch-up to physical infrastructure in the early stages of development.

B. Infrastructure-Industry-Growth Nexus

As a bulky expenditure in the economy, infrastructure is widely recognized to directly contribute to growth as a stimulus spending. This is what Roland-Holst (2006) termed as the Keynesian aspect of infrastructure spending. As a rule of thumb, total investment needs appear to vary from well over 7% of gross domestic product (GDP) in low-income countries to around 3.1 % of GDP in upper-middle income countries (Estache and Fay 2007).

Another direct channel by which infrastructure and its concomitant services contribute to growth comes from its intrinsic property as an intermediate input to nearly if not all forms of economic activity. In the standard production function context, infrastructure is an input that improves general productivity and the productivity of other inputs (Straub 2008). Empirically, the presumed link between infrastructure and growth stems from the idea that cross country disparities in productivity can be explained by differences in the availability and quality of infrastructure.

From the demand side, the nexus between firm productivity and infrastructure can perhaps be substantiated by firm experience as captured by the World Bank Enterprise Surveys (World Bank 2010a) where firms identified electricity and transportation as significant constraints to doing business (East Asia 24% and 16.4%; East Europe and Central Asia 35.1% and 19%; Latin America and Caribbean 39% and 19%; Middle East and North Africa 42.9% and 21.5%; OECD 6.1% and 7.4%).[2] From the supply side, investment climate surveys and empirical evidence also reveal that infrastructure is one of the major determinants in attracting investments to an economy, thereby promoting growth (Estache and Fay 2007, Nabar and Syed 2011).

The facilitating properties of infrastructure also reduce cost and distribution margins in an economy thus promoting market integration, domestic and international trade, and enhancing comparative advantage.

Finally, infrastructure contributes to growth through indirect channels. Agénor and Moreno-Dodson (2006) explained that infrastructure can extend the longevity of private

[2] First figures refer to electricity and second figures refer to transportation in each region.

capital through mitigation of wear and tear; reducing adjustment costs by making possible quick responses to economic opportunities; and improving access to health and education services by providing means to use these social services. The first two improvements make efficiency gains possible, while the last is important not only because of its social benefits but also because education and health are ways by which human capital improvement is achieved, which in turn accounts for total factor productivity (TFP) improvements in growth models. Finally, Estache and Fay (2007) add that reliability and access to infrastructure also promote technology adoption by firms.

Moreover, a study by Roberts and Deichmann (2009) points to evidence that infrastructure capital enables an economy to benefit substantially from growth spillovers of neighboring economies. These effects were shown to be particularly relevant and substantial for landlocked countries.

While the focus is on positive interactions between infrastructure and growth, there are also cases when infrastructure can dampen growth and/or exacerbate income inequality in an economy. First, the spatial character of infrastructure services means that the geographical location of infrastructure assets affects the access to those services. Second, their public investment aspect also means that they compete with other essential investments such as those on health and education, which may or may not be more important than infrastructure in certain income levels. Third, the opportunity costs associated with infrastructure investment may also be substantial, especially when they are provided over their growth-maximizing levels (Canning and Pedroni 2004). Finally, infrastructure investment may lead to crowding out of other investment activities if its manner of financing is unsustainable, such as through increases in distortionary taxes (Agenor and Moreno-Dodson 2006). It is therefore important for policy makers to realize that different infrastructure sectors have different characteristics and interact with different industries in different ways. The complexities of these relationships limit the efficacy of public planning for infrastructure and contribute to the dynamics of structural transformation and comparative advantage, with alternative environmental impacts. They also influence the spatial development of the host economy with far-reaching consequences.

C. Infrastructure in Asia and the Pacific

The infrastructure performance of Asian and Pacific economies varies widely. Table 2 shows that on the one hand, high-income economies in the region like Hong Kong, China; Japan; the Republic of Korea; Singapore; and Taipei,China have infrastructure ranked as among the best in the world, while there are also countries in the region like Afghanistan, Bhutan, and Nepal that have infrastructures found among the poorest globally.

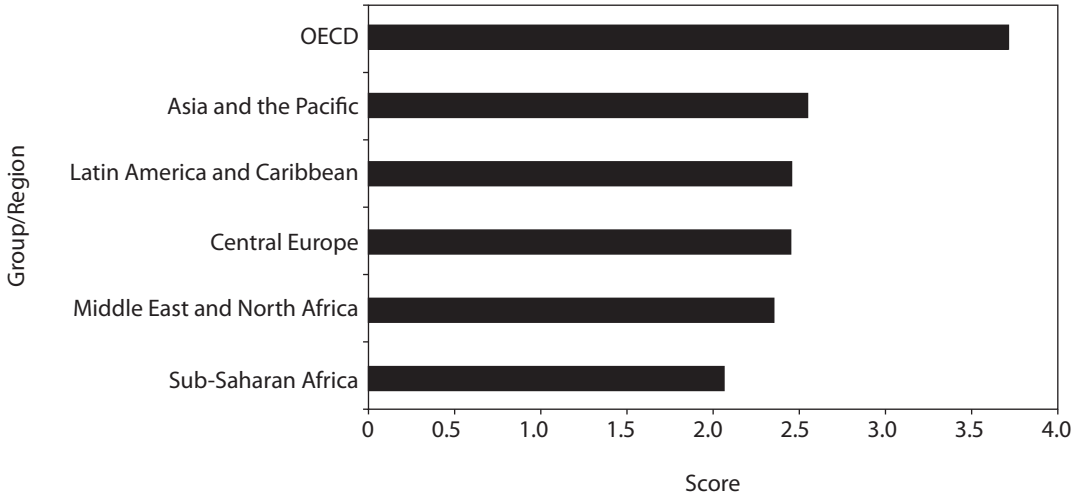
On a regional and economic group basis, the World Bank's Logistics Performance Index (LPI) ranks infrastructure in the Asia and Pacific region right next to those of the Organisation for Economic Co-operation and Development (OECD) countries (see Figure 1). However, the average scores between the two groups (3.71 and 2.55) reveal that there is a considerable gap to fill if the region is to achieve an infrastructure level comparable to that of the OECD. An even larger gap is to be filled in some Asian and Pacific economies if the infrastructure levels of Singapore, the highest scorer, is a good indication of the ideal levels and quality of infrastructure in an economy.

Table 2: Infrastructure Scores Based on the Logistics Performance Index

Rank	Economy	Infrastructure	Rank	Economy	Infrastructure
4	Singapore	4.22	104	Azerbaijan	2.23
5	Japan	4.19	109	Georgia	2.17
13	Hong Kong, China	4.00	111	Maldives	2.16
22	Taipei,China	3.62	114	Cambodia	2.12
23	Korea, Rep. of	3.62	118	Kyrgyz Republic	2.09
27	China, People's Rep. of	3.54	120	Pakistan	2.08
28	Malaysia	3.50	128	Tajikistan	2.00
36	Thailand	3.16	132	Lao PDR	1.95
47	India	2.91	133	Mongolia	1.94
57	Kazakhstan	2.66	134	Myanmar	1.92
64	Philippines	2.57	135	Papua New Guinea	1.91
66	Viet Nam	2.56	138	Sri Lanka	1.88
69	Indonesia	2.54	139	Afghanistan	1.87
72	Bangladesh	2.49	141	Bhutan	1.83
92	Armenia	2.32	143	Nepal	1.80

Note: Scores go from 1 to 5, with 1 as the lowest score and 5 as the maximum score.
Source: Logistics Performance Index (World Bank 2010b).

Figure 1: Average Infrastructure Score by Region



Note: Japan, the Republic of Korea, and Mexico were not included as OECD in the computation.
Source: Computed by the authors based on the Logistics Performance Index (World Bank 2010b).

The World Economic Forum's Global Competitiveness Report (GCR) also provides scores for an economy's infrastructure based on the responses of firms to its Executive Opinion Survey. Table 3 provides resulting scores which indicate the quality and sufficiency of roads, rail, ports and electricity for Asian economies included in the survey, and the average number of mobile and fixed phone line subscriptions per 100 persons. Once again, it is apparent that the high income economies in the region dominate in the scores for these essential forms of infrastructure.

Table 3: Infrastructure Scores of Asian Economies based on the GCR

Economy	GCR Scores				Phones per 100 Persons*
	Road	Rail	Ports	Electricity	
Hong Kong, China	6.5	6.7	6.8	6.9	116.7
Singapore	6.6	5.8	6.8	6.7	89.8
Japan	5.6	6.6	5.2	6.8	62.7
Korea, Rep. of	5.8	5.7	5.5	6.3	69.6
Taipei,China	5.8	5.7	5.4	6.2	90.0
Malaysia	5.7	4.7	5.6	5.7	63.1
Brunei Darussalam	5.3	N.A.	4.5	5.2	63.5
Thailand	5.1	3.0	5.0	5.7	66.5
China, People's Rep. of	4.3	4.3	4.3	5.3	39.4
Sri Lanka	4.2	3.6	4.9	4.6	43.3
Georgia	3.9	3.6	4	5.1	40.6
Azerbaijan	3.8	3.9	4.2	4.1	51.8
India	3.8	4.6	3.9	3.1	23.5
Kazakhstan	2.4	4.0	3.3	4.1	60.0
Indonesia	3.5	3.0	3.6	3.6	42.0
Pakistan	3.8	3.1	4	2.1	29.6
Armenia	3.4	2.2	2.9	4.4	52.7
Viet Nam	2.7	2.9	3.6	3.6	67.8
Cambodia	3.8	1.6	3.9	3.1	19.1
Tajikistan	3.0	3.2	1.9	2.6	37.4
Philippines	2.8	1.7	2.8	3.4	42.8
Mongolia	1.7	2.5	3.3	3.1	45.7
Bangladesh	3.0	2.5	3.4	1.6	16.0
Kyrgyz Republic	2.7	2.8	1.4	2.3	45.5
Timor-Leste	2.2	N.A.	2.5	1.6	5.2
Nepal	2.3	1.2	2.9	1.2	14.4

*Data is as of 2008.
GCR = Global Competitiveness Report.
Note: For road, rail, ports and electricity, scoring is from 1 to 7, with 1 as the lowest score and 7 as the highest.
Source: Calculated by the authors based on the GCR 2010–2011 (Schwab 2010).

Upon reviewing the figures presented in the table, one is prompted to ask whether the high incomes of some of the economies in the region were in a significant way caused by investing in the right types and appropriate levels of infrastructure.

III. Political Economy of Infrastructure

The characteristics of infrastructure described above make the political economy of infrastructure investment difficult, with political considerations often outweighing economic ones. The large scale and large cost of most infrastructure projects means that the political stakes associated with their success or failure are high. Similarly, their long-term nature—with much time taken to negotiate, implement, and build, while public interest typically has a much shorter time horizon—means that the potential political gains are likely to be front-loaded. Meanwhile, costs are more likely to rise in the distant future, when current incumbents may have left office. In addition, the fact that a politician typically gets more media attention for equal spending on new infrastructure as compared to maintenance of existing assets skews the balance of interest against maintenance.

The public goods nature of many infrastructure projects, along with their potential local monopoly characteristics, also ensures their attention and involvement in political debates. The largely local nature of their benefits raises the potential for difference of interests between central and local authorities. In this context, a country's system of fiscal decentralization or revenue sharing can have a strong influence, and unfortunately fiscal systems of perverse incentives are not rare.

The potential monopoly gains and the importance of infrastructure services as inputs to other production or sales processes (including transportation) similarly raises the stakes for private sector enterprises to influence the design and investment process. The strategic importance to public well-being of some infrastructure services (notably transportation, water, and power) makes them easy targets for suppressing prices below market levels. Price suppression may be politically popular, but it encourages overconsumption and waste by consumers and discourages suppliers from providing expanded services.

Concerns about strategic importance (including for communications) may also be used to limit foreign investment. Conversely, some foreign investors may be able to exert undue influence through their much greater size and more developed human resources, particularly in smaller and poorer economies. Poorly developed local bond markets may give foreign investors with easier access to international markets an advantage over local investors in financing infrastructure projects.

When some or all of these factors come together in designing and implementing a public–private partnership for a large, high-stakes project, there is tremendous temptation for one or more participants to try to resort to side or informal payments to influence the negotiation process. Good governance becomes critical in maintaining efficiency of investment. A policy environment that aims to be conducive to infrastructure investment will have policies that are long-term (to match the investment horizon), certain (to mitigate risks for investors), and transparent (to promote competition where feasible).

IV. Review of Empirical Evidence on Infrastructure's Contribution to Growth

A. Growth Accounting Framework

The predominant approach to the empirical study of the relationship between growth and infrastructure has been through the growth accounting framework. Infrastructure is normally included as a factor of production together with noninfrastructure capital, labor, and human capital. A pioneer of this approach is Aschauer (1989) who arguably spurred the widespread and controversial interest now given to the subject because of his findings that the contribution to growth and productivity of public expenditures (as a proxy for infrastructure's contribution) can be much higher than those from private investment (Egert et al. 2009). However his findings were later disputed because of their failure to deal with important estimation issues arising from the model.

First, public expenditures were observed to be poor proxies for infrastructure. Expenditure figures tend to overestimate infrastructure capital because of inefficiencies and rent seeking. Moreover, broad public capital can be different from public expenditure on infrastructure because of the heavy involvement of some government bodies in noninfrastructure commercial and industrial activities. Calderon et al. (2011) point out that using expenditure figures as a proxy for infrastructure also ignores the increasing private participation in infrastructure investment and management. Many studies following Aschauer have continued to use public expenditures as proxies, but the assembly of data sets on infrastructure stocks later on led to the predominant use of the latter in more recent empirical studies.

Second, in a study dealing with subjects across time, one has to deal with the time series properties of the data. Numerous studies have found that many of the variables included in infrastructure-augmented growth models tend to exhibit nonstationarity in their levels, which may lead to spurious regressions if simply ignored. This is particularly true for variables such as GDP per capita (Egert et al. 2009).

Third, aside from the stationarity, one also has to deal with issues of heterogeneity of the subjects in a cross country and panel analysis. The issue may be particularly severe when members of a panel are diverse (Hurlin 2006) as is the case in our study.

Fourth, in an analysis that attempts to examine the effect of different types of infrastructure on growth, it is important to deal with multicollinearity among the infrastructure variables. Indeed, Calderon and Servén (2005) find a correlation of 0.94 between telephone density and power generating capacity and a 0.6 correlation between roads and power generating capacity.

Fifth, endogeneity is an aspect of infrastructure–growth analysis that should be examined. Infrastructure can contribute to growth but infrastructure stocks may also be increasing because more prosperous economies (those growing faster) have a tendency to increase investments in infrastructure (Hurlin 2006).

While there are many empirical works on the subject, few are comprehensive enough to deal with the all the complications arising from the nature of the investigation. Seethepalli et al. (2008) employed a panel of East Asian economies but did not confront the heterogeneity of the subjects in the study, reasoning that the issue is less relevant because of the short number of observations.

Straub and Terada-Hagiwara (2010), on the other hand, conducted three types of empirical analyses. Their cross section analysis of 102 countries collapsed the data set through averaging over the period.[3] While averaging is an accepted smoothing technique and regularly applied in growth accounting framework-based studies, the scale of averaging involved in this exercise is such that it can at best only give tentative indications of the relationship between infrastructure and growth. The second set of the Straub–Hagiwara analyses attempted to capture the growth externalities arising from infrastructure investment by performing individual time series regressions for 14 developing countries in Asia, employing total factor productivity (TFP) as dependent variable, and infrastructure stocks as control variables. However, this procedure did not adequately take into account the time series properties of the data. Finally, the third set of analyses involved a panel approach using the same methodology as the second set of analysis.

Canning and Pedroni (2004) dealt adequately with the time series properties, and heterogeneity and endogeneity issues of the data in their panel of countries but examined only the direction of the net impact of infrastructure on growth, not its extent.

Hurlin (2006) focused his investigation in OECD countries on the network aspect of infrastructure through a panel threshold regression framework. The premise of his specification is that the network characteristic of infrastructure implies nonlinearity in the contribution of these structures, depending on the extent of “completeness” of the network. The paper addressed the methodological issues through assumptions that: (i) reverse causation is a consequence of threshold effects; (ii) the nonstationarity of the data series implies that the true data generating model is a threshold model; and (iii) cross-country heterogeneity is a consequence of threshold effects (Hurlin 2006). The validity of these assumptions, however, still needs to be verified empirically.

Calderón et al. (2011) employed the pooled mean group (PMG) estimation technique in their study covering 88 countries. This method allows for short-term parameter heterogeneity while imposing long-run homogeneity by assuming that the presence of a

[3] The period covered by the analyses varied according to data availability of infrastructure variables.

single cointegrating vector among the variables implies a common long-run production function for the countries. Some however are skeptical of the validity of imposing a single long-run production function across a very diverse set of countries (Straub and Terada-Hagiwara 2010).

Fernald (1999) used industry-level analyses emphasizing the network and geographic location aspects of infrastructure to examine how road building in the US impacted on the productivity of 29 industries. His findings indicate that road building in the US prior to 1973 did improve productivity of US industries, albeit benefiting vehicle-intensive industries disproportionately. Post-1973, when the road network had already been completed, the findings do not indicate any abnormal rate of return from road construction (Fernald 1999).

Overall, the majority of growth accounting-based frameworks have found empirical support for a positive link between infrastructure and growth (Straub 2008). All the studies mentioned in the preceding paragraphs find positive and significant contributions of infrastructure to growth. In particular, telecommunications infrastructure is consistently found to be a significant growth factor.

B. Cost Function Approach

Aside from the growth accounting framework, the other mainstream approach to examining the infrastructure–growth nexus is through a cost function framework, which assumes that a firm maximizes profit given the price of its product and a cost function that takes infrastructure into account (Egert et al. 2009).

Using this approach, Iimi (2008) employed a business environment survey and estimated substantial cost savings from improved electricity, water supply, and telecommunications for firms in selected European and Central Asian countries, contributing to economic growth. Demetriades and Mamuneas (2000) found positive contributions of public infrastructure capital to the supply of products in an economy and its demand for inputs of production.

Aside from the two general frameworks mentioned above, there remain a number of imaginative yet pragmatic ways to study the growth–infrastructure nexus. Straub (2008) has pointed out the importance of studying the spatial characteristics of infrastructure and incorporating advances in the field of economics of agglomeration to make empirical literature more relevant and informative to policy makers. Hulten (1996) stressed that the effectiveness with which infrastructure is used or maintained can be more important than green infrastructure investments. Agenor and Moreno-Dodson (2006) provide a survey of empirical studies of how infrastructure contributes to growth through indirect channels such as labor productivity improvements, reduced adjustment cots, extended durability of other capital, and improved access to education and health services. Calderón and Servén (2005) also explored the links between infrastructure and income distribution.

V. An Empirical Approach to Infrastructure and Stages of Growth

A. Theoretical Framework

This paper adopts a Cobb-Douglas infrastructure-augmented aggregate production function as a starting point for the analysis.

$$Y = AK^{\alpha}H^{\beta}Z^{\gamma}L^{1-\alpha-\beta-\gamma} \quad (1)$$

Y is output, *K* is (physical) capital stock, H is human capital stock, *Z* is infrastructure stock, *L* is labor, and *A* denotes total factor productivity. As is common in the literature, constant returns to scale is assumed.

Expressing the variables in per worker terms and taking their logs gives the estimation function described by equation (2).[4]

$$y_{it=}\mu_i \quad \alpha k_{it} + \beta h_{it} + \gamma z_{it} + \varepsilon_{it} \quad (2)$$

Parameters α, β, and γ denote the elasticities with respect to output and ε is a disturbance term. μ_t captures the time invariant fixed effects of TFP in the economy. The lower case variables *y, k,* and *z* represent the per worker and log values of the variables in equation (1). *h* is the average years of schooling of the working population and is not expressed in log values in accordance with the specification adopted by Barro and Lee (2010). The subscript *it* denotes the panel nature of the data set, where *i* denotes individual economies and *t* denotes time.

Infrastructure appears twice in the function above: once lumped together with other capital and then once again by itself. γ therefore cannot be directly interpreted as the elasticity of infrastructure. Instead, it merely represents the extent to which the output contribution of infrastructure capital surpasses or falls below the output contribution of total capital (Calderon and Serven 2005). It can be interpreted as the impact of redirecting resources invested in other types of capital to investments in infrastructure (Canning and Bennathan 2000). On the other hand, insignificant coefficients imply that infrastructure has the same return as that associated with other capital (Estache and Fay 2007). The implication is that the elasticity associated with infrastructure depends on its ratio to capital stocks (Hurlin 2006).

[4] Representing the aggregate relationship in per worker terms implies ignoring scale effects that may be important in estimating the effects between growth and infrastructure. Such an approach, however, allows for a simple way to account for reverse causation, which has been a major challenge to the integrity of aggregate production functions (Canning and Bennathan 2000).

B. Data

This study covers 123 economies from 1971 to 2005.[5] While data pertaining to output, capital, and labor are complete, data on infrastructure has gaps. The panel is therefore unbalanced. This problem of data gaps was mitigated by collapsing the data into intervals of 5-year averages.

The proxy variables used for the paper's estimation, including their sources, are detailed below. Like other recent studies on growth and infrastructure, we used stocks rather than flows to mitigate the problem of reverse causation. We also avoided using public expenditures as a proxy for infrastructure for reasons already explained earlier.

1. **Dependent Variable:** The dependent variable in the model is real GDP per worker sourced from Heston, Summers, and Aten's (2009) Penn World Tables (PWT).

2. **Infrastructure Variables**[6]: The data on the number of workers used to derive the per worker variables was sourced from the World Development Indicators (WDI).[7]

   (i) Telecommunications

   All telecommunications data were sourced from the World Databank.

   (a) Internet: number of internet users.
   (b) Mobile phones: number of mobile cellular subscriptions
   (c) Phone main lines: number of fixed phone lines connected to the public switched telephone network

   (ii) Transportation

   All transport infrastructure data were sourced from the World Databank and were complemented with data from the International Road Federation (IRF).

   (a) Air freight: volume of freight carried on each flight stage measured in metric tons times kilometers traveled

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5 The complete list of countries and details on infrastructure stock data availability is in Appendix 1. While the list of economies includes what some may consider fragile or unstable states, estimations without such economies did not yield significantly different results.

6 Infrastructure data for Taipei,China were sourced from the Directorate General of Budget, Accounting and Statistics.

7 The WDI series was started in 1980. Imputations using the size of the population aged 15–65 less the average difference between this number and the number of labor force for years where data are available were utilized to derive the labor figures from 1971 to 1979. The demographic data was also sourced from the WDI.

(b) Air carriers: domestic and international takeoffs of air carriers registered in the country
(c) Rail network: total rail route in kilometers[8]
(d) Rail goods: volume of goods transported by railway, measured in metric tons times kilometers traveled
(e) Road networks: total road network in kilometers, which includes motorways, highways, and main or national roads, secondary or regional roads, and all other roads in a country[9]

(iii) Energy

All energy infrastructure data were sourced from the World Databank.

(a) Electricity consumption: electricity production net of transmission, distribution and transformation losses, measured in kilowatt hour (KWh)
(b) Electricity production: electricity production in KWh
(c) Energy production or generation: production of forms of primary energy and combustible renewables and waste, all converted into oil equivalents measured in kilo tons of oil equivalent (Ktoe)
(d) Energy consumption: use of primary energy before transformation to other end-use fuels in Ktoe; includes energy imports and stock changes

3. Other Control Variables

(i) Capital stock

There are no direct data pertaining to capital stock. They were derived using the perpetual inventory method. A uniform depreciation rate was assumed to be 0.07 while the initial capital stock was derived using the approach of Bernanke and Gurkaynak (2001), which used the 10-year forward average growth rate of output to approximate an economy's steady state growth rate. The investment and real GDP values used for the computation were sourced from PWT 6.3.

[8] One must however note that only 62% of the economies included in the study have data on rail. Rail is simply nonexistent in some economies, especially those that have small land areas.

[9] The series on road data had many gaps. There were also cases where suspected changes in the definition of roads in a particular country (sources of IRF data) led to drastic increases or decreases in road statistics, which are highly unrealistic. Such observations are of limited instances and data like these were removed from the series. In cases where the data of percentage of paved roads and kilometers of road networks in the IRF matches those of the WDI, the values for the kilometers of roads were imputed from the existing values.

(ii) Human capital stock

The average years of schooling of an economy's population aged 15 and above from Barro and Lee (2010).

C. Methodology

Two models were employed to estimate the effects of infrastructure on growth. Model (1) employs ordinary least squares (OLS), while model (2) employs instrumental variables through two stage least squares (2SLS). Model (2) is employed to take into account possible endogeneity in the model, which cannot be completely addressed by simply using stocks rather than flow values. Indeed, Hausman specification tests confirm simultaneity between the log values of different infrastructure stocks and GDP. Instrumental variables (IV) were therefore employed by using the lag of the explanatory variables as instruments except for education, which uses parental education as instrument.[10]

Fixed effects (FE) were used in both models (1) and (2) to account for the unobserved heterogeneity of the economies. This allows the model to account for varying definitions of similarly-termed variables across economies to the extent that they are time-invariant. The same principle applies to institutional qualities such as governance and regulatory environment. Furthermore, a Hausman test strongly rejects a random specification in favor of fixed effects.

Finally, infrastructure variables were introduced into the estimation separately to avoid multicollinearity. Estimations were first run on the entire set of economies, followed by estimations on subgroups of economies currently classified as low-income, lower-middle-income, upper-middle-income and high-income by the World Bank to explore possible variations in the relationships between infrastructure and economies in different levels or stages of growth.[11] A set of estimations were also performed for Asian economies to examine if relationship between growth and infrastructure that are observed for the world economies are confirmed for Asia.

[10] Parental education values were derived from Barro and Lee (2010) using years of schooling of population aged 40 and above.

[11] A category of mid-income economies, which is the sum of economies classified as lower-middle and upper-middle income economies, is also introduced to exploit the asymptotic properties of instrumental variable regressions.

D. Results[12]

1. Telecommunications

There is considerable empirical evidence on how access to telecommunication infrastructure has improved the income of the poor, and thus promotes growth. Jensen (2007) documented how fishermen in Kerala increased their income by using mobile telephony for price arbitration and information coordination. These benefits translated to reduced wastage and spoilage, higher income for fishermen, and significant reduction in price variation for fishery products. Bhavani et al. (2008) likewise documented various studies demonstrating how mobile telephony has aided job search and entrepreneurship for housekeepers, porters, hairdressers in the People's Republic of China (PRC), Pakistan, and Thailand.

The results for the full set of the panel (see Appendix Tables A.1, A.2, and A.3) suggest that consistent with previous studies, telecommunication infrastructure supports growth. This is true for the different proxies of telecoms that were used (telephone main lines; total main and mobile lines; and main lines, mobile lines, and the internet).

The subpanels of Asia, and high-income economies likewise confirm the positive relationship between growth and telecoms infrastructure. Main phone lines do not exhibit influence on growth in low-income economies, but the relationship changes once mobile lines and the internet are accounted for. Meanwhile, there appears to be overinvestment on telecoms infrastructure in upper-middle-income economies. Finally, a significant link between growth and telecoms is not established for lower-middle-income economies.

2. Transportation

This paper attempted to capture the growth contributions of transport infrastructure using different variables. For the full panel (see Appendix Tables B.1 to B.5), air transport ("proxied" by air carriers and airfreight) as means of moving people as well as goods are supportive of growth. So are roads and rail networks. But rails as a means of transporting goods did not prove to support growth as much as other capital. The same conclusion applies to the combined length of roads and rail networks. This perhaps reflects a general substitution effect between the two forms of transport.

In Asia, only roads were found to be more productive than other forms of capital. The relationship between air transport and growth observed in the full panel is not detected for Asia. Meanwhile, we refrain from drawing conclusions on variables involving rail due to the smaller sample sizes involved in the analyses. IV procedures tend to yield biased estimates when sample sizes are not sufficiently large.[13]

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[12] Estimation results are in Appendix 2.

[13] Literature does not define what exactly constitutes a sufficiently large sample size for IV procedures. It has been the authors' decision to limit interpretations to estimations that have at least 100 observations.

For the income subgroups, air transport as a means for trade is only significantly associated with growth for upper-middle-income economies, perhaps reflecting the importance of trade in goods with high value to bulk ratio in such economies. Meanwhile, the number of air carrier takeoffs supports growth in lower-middle and high-income economies.

Rail network appears to be important to growth only in middle-income economies, though the same cannot be said of the volume of goods carried by rail. Roads only yield significant growth effects in lower-middle-income economies. However, the combined effect of roads and rail support growth for upper-middle-income economies. The positive relationship for the same infrastructure variable cannot be confirmed for low-income economies due to insufficient sample size. Finally, results suggest a possible overinvestment in land-related transport for high-income economies.

The results herein are supportive of evidence found in other studies such as that by Banerjee et al. (2009), which shows that in the PRC, proximity to transportation networks has led to increases in growth of per capita income. Moreover, these increases reflect expansion of aggregate output rather than just effects of productive firms replacing less productive ones near the network.

3. Energy

Electricity consumption is only significantly associated with growth for the high-income group (Appendix Tables C.1–C.5). On the other hand, electricity production does not seem to be supportive of growth for any group of economies. In fact, upper-middle-income economies appear to have overinvested in electricity consumption and production, implying that investments in other forms of capital might support growth better.

However, estimations with energy generation and consumption, which are broader variables than electricity, indicate that energy generation supports growth in the full panel of economies, in Asia and in upper-middle-income and high-income economies. Energy consumption also supports growth in high-income economies, while the same does not appear true for upper-middle-income countries.

To account for possible biases in energy generation results arising from the status of an economy as an exporter of energy, an estimation excluding all major crude oil exporting economies was performed. The results suggest that energy production (albeit with lower coefficients) and use contribute to growth in non-oil exporting economies. It is interesting to note that energy consumption while insignificant in the panel including oil-exporting economies becomes significant once these economies are taken out of the estimation.

4. General Results

In general, results of infrastructure's ability to explain growth differences across economies vary with the type of infrastructure. An examination of the subsets of economies classified according to income levels also reveals that infrastructure needs in each group may vary. Table 4 below summarizes the empirical findings by income category of economy, showing which types of infrastructure offer the greatest contribution to growth.

Table 4: Infrastructure and Stages of Growth

Income Group	Infrastructure
Low	Combined phone main lines and mobile phones
Lower Middle Income	Roads
Upper Middle Income	Combined road and rail network
Middle Income	Rail network
High Income	Energy consumption

Source: Compiled by authors based on estimation results.

Since the different forms of infrastructure have been measured in terms of their stocks rather than value, the marginal cost of a 1% increase in the infrastructure stock is not equivalent across infrastructure types and so the findings should not be taken as directly relevant for policy prescriptions. Moreover, the small sample sizes of infrastructure data in some subgroups and some categories of infrastructure did not permit complete assessment under the method employed. Nonetheless, the general findings can be taken as evidence that infrastructure does contribute to growth, and individual countries can consider their current stocks and likely contributions to growth of additional investment in different infrastructure assets. In general, the findings suggest a rough hierarchy for investment priorities, from communications for low-income countries, through transportation in middle-income economies, and to greater emphasis on energy for high-income countries.

In the case of Asia, the findings of positive contributions to growth from infrastructure can perhaps be validated by the private sector pouring substantial investments into infrastructure projects. The World Bank database on private participation in infrastructure (PPIAF) reveals that from 2000 to 2009, the private sector poured in $131 billion to the telecommunications sector. This accounts for 37% of total private participation in infrastructure projects in South Asia, and East Asia and the Pacific (2010).[14] The corresponding figure for the energy sector is $129.9 billion for the same time frame. Finally, the transport sector received $63.5 billion in the form of completed projects from 2000 to 2008 (WDI).

[14] Private investments in East Asia and the Pacific were concentrated in the PRC, Indonesia, Malaysia, and the Philippines, while those in South Asia were primarily in India and Pakistan. The figures reported account for 24 economies in the region.

It is noteworthy that aside from combined mobile and main phone lines, and internet, the results for the low-income group does not definitively identify any infrastructure as especially important to growth. A plausible explanation might be the relative importance of other investments in basic services such as health and quality education. Limitations on data availability and quality that are more severe than for the other groups have also been observed.

Another aspect of the results worth noting is the insignificance of education in a number of the estimations. This runs counter to common perceptions. Such observation may arise from the limitation of average years of schooling as a proxy for human capital. Hanushek and Wößmann (2007) pointed out that growth returns from education will vary across countries not only on the basis of years of schooling, but perhaps more importantly because of variations in the quality of education, which captures the cognitive skills of a population better. Moreover, schooling alone does not capture other important aspects of human capital such as health. Including basic water and sanitation facilities might have been a satisfactory way to account for this. However, the limited data availability did not permit meaningful analysis.[15]

In the final analysis, the extent and nature of infrastructure's role in growth must be interpreted in light of the other variables included in the estimation and existing conditions in an economy. According to Ascher and Krupp (2010), high returns on infrastructure variables tend to be observed when investment in them has been lagging behind those of other factors of growth. Moreover, the marginal returns from additional infrastructure investments crucially depend on the extent to which additional investments address existing bottlenecks in the network (Romp and de Haan 2007), and the extent to which they create synergies with human capital and other investments to realize the potential for growth in an economy (Canning and Bennathan 2000).

VI. Major Issues and Challenges in Infrastructure Investment

A. What and Where to Build?

The question of what infrastructure to build can generally be answered by the results of the estimations. Economies should invest in infrastructure that yields high returns to growth. The results of the estimations above should be interpreted in the context of a

[15] Estimations on sanitation infrastructure using the same methodology were also performed. However, the results were not very meaningful (erratic behavior of coefficients) in view of large data gaps. Moreover, since the direct contribution of sanitation is supposed to affect growth or productivity through human capital, there might be a need to model the effects of sanitation through its relationship to human capital instead of treating it in the same way as other infrastructure.

panel of data. The types of infrastructure and the optimal levels are expected to vary in an economy according to the levels of other inputs to production and the particular infrastructure bottlenecks that need attention.

The question of where to build is harder, if not impossible, to answer using the framework of this study. The aggregate level of our data does not allow for the full spatial nature of infrastructure to be taken into account, nor for a proper assessment of the full potential of regional cooperation. This is one of the weaknesses of macro-level empirical study that is often pointed out. While analysis of aggregate figures may imply that returns to a certain type of infrastructure are high, it does not take into account that the infrastructure may already be overprovided in some areas, while there remains a strong need for the same infrastructure in other areas. This can potentially be addressed if more disaggregated data on infrastructure provision can be used. This scenario is, however, more feasible in a study dealing with a single economy rather than a panel of economies.

These basic guides to what needs to be built and where, however, are rarely the only considerations in deciding what infrastructure will be constructed. Legitimate considerations pertaining to maximization of social returns through means such as equitable access, physical and social integration; and possibly less legitimate considerations pertaining to maximization of political returns often come into play and define the contours of policy making in infrastructure.

Obviously the decision making process will be crucial in allocating scarce infrastructure investments. Public sector budget limitations in most countries, and technical and managerial expertise in the private sector, argue strongly for involving private investment in infrastructure. At the same time, for the reasons described in Section II above, the public sector generally has a role to play as well. To address these dual sets of concerns, public–private partnerships (PPPs) are commonly advocated. PPPs work most effectively when public and private sectors each work to manage the types of risk for which they are best suited. For example, political risk may best be borne by the public sector while credit risk can be more effectively hedged in the private sector, assuming private financial markets and institutions are sufficiently developed.

To encourage and support private sector involvement in development of infrastructure assets and provision of infrastructure services over an extended time horizon requires an enabling environment of property rights, guarantees, and good governance. This is why for more developed countries the complementary soft infrastructure becomes increasingly important. Reside and Mendoza (2010) suggest that the type of political stability that comes from a form of government with commanding authority may encourage investment, and when combined with a more flexible regulatory regime may lead to better project outcomes. This could in part explain why infrastructure investment in Indonesia during the Soeharto era appears to have outperformed that in the Philippines. However, the authors also note that the expectation of high future growth as was common in much of

Southeast Asia before the 1997–1998 Asian financial crisis can lead to moral hazard, in which unviable projects get approved after passing through less rigorous screening processes.

As mentioned earlier, success in PPPs depends on reaching appropriate risk-sharing agreements and reliable institutional structures. In much of Asia, PPPs have become increasingly subject to renegotiation, particularly where there have been currency mismatches between the investment financing and service-generated revenue, or guaranteed service (demand) offtakes that were not supported by macroeconomic developments. Divestment or buyouts have also become common, in effect shortening the implicit investment time horizon. Long-term, stable, and transparent investment climate policies should help to reverse this trend.

In most countries, the technological frontier is advanced primarily through the private sector. At the same time, this perhaps relies on public sector support for research and development, and social services that support the development of human capital and innovation. The public sector also has a critical role to play in planning the development of infrastructure where industrial policy is a priority, rather than merely reacting to bottlenecks.

B. The Way Ahead

Infrastructure plays an important role in the growth of an economy, and in the distribution of the benefits from that growth. The public goods nature of infrastructure services, the bulkiness and lengthy time horizon of investing in infrastructure assets, and the potential (local) monopoly character of markets for infrastructure services all justify at least some public sector involvement in investment in infrastructure assets, provision of infrastructure services, and regulation of the markets for those services.

Limitations on public sector budgets, and private sector advantages in infrastructure technology, financing, management, and marketing, strongly suggest a role for private sector infrastructure investment and management. To realize private sector potential in infrastructure investment, regional debt markets to mobilize and allocate regional savings are a priority. McCawley (2010) notes that two significant factors underpinning the reluctance of private sector firms to invest in infrastructure have been regulatory uncertainty and price suppression. Major reforms in the policy environment including better and more reliable policies and regulatory arrangements, and improved contract enforcement procedures, are likely to be needed to attract private investors. But complementarity of public and private sector risk and risk management capabilities highlights the potential for public–private partnerships in infrastructure. When the private investors are foreign, additional benefits and complications are possible and good governance becomes even more essential.

As economies grow and develop, their demands for infrastructure services evolve over time. The analysis here has shown that for low-income economies, where it is likely that all forms of infrastructure can raise productivity, the ability to communicate through telecommunications services may be most important. Fortunately, modern communications technology allows large geographic regions to be covered by such services at relatively low cost, with sufficient cost recovery to entice private sector investment. The spatial distribution of other infrastructure investments in these economies may be critical for poverty reduction and ensuring inclusiveness of growth while avoiding severe congestion, particularly in transport infrastructure.

In middle-income economies, road infrastructure—and, as incomes rise, railway networks—may be most significant. For high-income economies the results become more difficult to interpret beyond increasing energy consumption, but suggest that human capital may be most important. This most likely reflects the already high levels of physical infrastructure assets, more sophisticated production processes, and dominance of knowledge-based industries. In this case more attention may be needed for maintenance of existing assets and connectivity of network infrastructure, both in single sectors (such as telecommunications or transportation networks) and in more complex logistics chains.

Better understanding of the dynamics of infrastructure's contributions to growth will assist planning over the lengthy lifetimes of infrastructure assets. As urbanization is closely correlated with rising incomes, development of urban infrastructure must balance benefits for existing urban residents with potential costs of encouraging rapid rural–urban migration, and should be undertaken with a view of the overall system of cities in an economy.

Allocating scarce resources for efficient infrastructure investment currently relies on imperfect measurement and assessment of both costs and benefits. For example, at present we cannot adequately reflect the benefits of low carbon transportation systems designed for road safety and fuel savings through public transport options. The issue of climate change mitigation and adaptation further complicates such evaluations.

Costs are also difficult to assess, particularly where there are sizable externalities and poor governance. It is often possible to raise the provision of infrastructure services without investing in new infrastructure assets simply through efficiency gains in public utilities (such as reducing piped water losses or increasing meterage of electricity). Various empirical studies show that in some instances returns from infrastructure maintenance outweigh returns from new infrastructure investments (Hulten 1996, Heggie 1995). The greater visibility (and probably political returns) of new infrastructure however tends to create bias against maintenance (Ascher and Krupp 2010). Better regulation of markets for public utilities, and particularly price regulation, can often yield substantial efficiency improvements.

Regional cooperation is particularly important for infrastructure supporting international trade and investment (Brooks and Stone 2010, Hummels 2009). In the Asian context, where international production networks are essential parts of many supply chains and exports have accounted for such a large share of growth, international public sector agreements offer a critical framework for regional integration to capitalize on growth spillovers.

Although beyond the scope of the current paper, the financing of infrastructure investments may also limit their scale, frequency, location, and technical efficiency. To reduce risks of foreign currency transactions, long-term local currency bond markets can play a key role in infrastructure development. Particularly for poorer countries, foreign sources of finance (including multilateral financial institutions) can be important contributors of capital, technology, and governance practices. Their involvement may be dependent on opportunities for cost recovery, as well as alternative modalities and innovative instruments for financing. Also particularly for poorer countries, the size of infrastructure projects can be disproportionately large, with macroeconomic implications, suggesting the need for careful attention to financing modalities (Brooks and Zhai 2008).

The rapid economic growth of Asia has benefited billions of people. It has also strained its infrastructure resources, its physical environment, and in some cases, social justice. For infrastructure to contribute effectively and sustainably to Asia's future growth will require that it be cost-effective, technologically efficient, environmentally benign, and socially inclusive. To accomplish this, better understanding of how infrastructure contributes to growth will be essential.

Appendix

Appendix 1: Data Profile

Economy	Main Line Phone	Mobile & Main Line Phone	Internet, Mobile, & Main Line	Air-Freight	Air Carrier Take Offs	Rail Network	Rail Goods Transport	Road Network	Road and Rail Network	Electricity Consumption	Electricity Production	Energy Production	Energy Consumption
Asian Economies (no. of observations)													
Bangladesh	7	7	7	7	7	6	6	4	4	7	7	7	7
Brunei Darussalam	6	6	6	5	5	0	0	4	4	7	7	7	7
Cambodia	4	4	4	3	3	4	6	4	4	3	3	3	3
China, People's Rep. of	7	7	7	7	7	6	6	6	6	7	7	7	7
Fiji, Rep. of	7	7	7	7	7	0	0	4	4	4	4	4	4
Hong Kong, China	7	7	7	2	4	0	0	7	7	7	7	7	7
India	7	7	7	7	7	6	6	7	6	7	7	7	7
Indonesia	7	7	7	7	7	6	6	7	5	7	7	7	7
Japan	7	7	7	7	7	6	6	7	6	7	7	7	7
Korea, Rep. of	7	7	7	7	7	6	6	7	6	7	7	7	7
Lao PDR	7	7	7	7	7	0	0	4	4	4	4	4	4
Macao, China	5	5	5	2	2	0	0	3	3	0	0	0	0
Malaysia	7	7	7	7	7	6	5	7	6	7	7	7	7
Maldives	7	7	7	7	7	0	0	0	0	4	4	0	4
Mongolia	5	5	5	4	4	6	6	4	4	5	5	5	5
Nepal	7	7	7	7	7	0	0	7	7	7	7	7	7
Pakistan	7	7	7	7	7	6	6	7	6	7	7	7	7
Papua New Guinea	7	7	7	7	7	0	0	3	3	3	3	4	4
Philippines	7	7	7	7	7	4	6	6	4	7	7	7	7
Singapore	7	7	7	7	7	0	0	6	6	7	7	0	7
Sri Lanka	7	7	7	7	7	6	6	7	6	7	7	7	7
Taipei,China	6	6	6	0	0	0	0	5	5	4	4	6	6
Thailand	7	7	7	7	7	6	6	7	6	7	7	7	7
Tonga	7	7	7	2	5	0	0	2	2	4	4	0	4
Viet Nam	7	7	7	4	7	5	6	7	5	7	7	7	7
Low Income Economies (no. of observations)													
Benin	7	7	7	5	5	1	1	5	5	7	7	7	7
Burundi	7	7	7	2	5	0	0	5	2	0	0	0	0
Cambodia	4	4	4	3	3	4	6	4	4	3	3	3	3
Cent. African Rep.	6	6	6	5	7	0	0	7	7	0	0	0	0

continued.

Appendix 1. *continued.*

Economy	Main Line Phone	Mobile & Main Line Phone	Internet, Mobile, & Main Line	Air-Freight	Air Carrier Take Offs	Rail Network	Rail Goods Transport	Road Network	Road and Rail Network	Electricity Consumption	Electricity Production	Energy Production	Energy Consumption
Congo, Dem. Rep.	0	0	0	6	6	6	6	6	6	7	7	7	7
Gambia, The	7	7	7	0	0	0	0	6	0	0	0	0	0
Ghana	7	7	7	7	7	7	5	7	4	7	7	7	7
Haiti	5	5	5	5	5	0	0	3	3	7	7	7	7
Kenya	7	7	7	7	7	6	6	7	6	7	7	7	7
Lao PDR	7	7	7	7	7	0	0	4	4	4	4	4	4
Malawi	7	7	7	7	7	6	6	7	6	0	0	0	0
Mali	7	7	7	7	7	6	6	7	6	0	0	0	0
Mauritania	7	7	7	0	7	0	1	0	0	4	0	0	0
Mozambique	7	7	7	7	7	1	1	6	0	7	7	7	7
Nepal	7	7	7	7	7	0	0	7	7	7	7	7	7
Niger	7	7	7	7	7	0	0	7	7	0	0	0	0
Rwanda	7	7	7	3	4	0	0	7	7	0	0	0	0
Sierra Leone	7	7	7	7	7	0	0	7	7	0	0	0	0
Tanzania	7	7	7	7	7	6	6	7	6	7	7	7	7
Uganda	7	7	7	7	7	6	5	7	6	0	0	0	0
Zambia	7	7	7	7	7	6	6	6	4	7	7	7	7
Zimbabwe	7	7	7	7	7	5	5	6	5	7	7	7	7
Lower Middle Income Economies (no. of observations)													
Belize	7	7	7	0	0	0	0	1	1				
Bolivia	6	6	6	7	7	0	1	4	4	7	7	7	7
China, People's Rep. of	7	7	7	7	7	6	6	6	6	7	7	7	7
Congo, Republic of	7	7	7	7	7	6	5	6	6	7	7	7	7
Cote d'Ivoire	7	7	7	7	7	6	6	4	4	7	7	7	7
Ecuador	7	7	7	7	7	0	0	6	6	7	7	7	7
Egypt	7	7	7	7	7	6	6	6	6	7	7	7	7
El Salvador	7	7	7	7	7	0	0	4	4	6	6	6	6
Guatemala	7	7	7	7	7	0	0	7	7	7	7	7	7
Guyana	7	7	7	7	7	0	0	3	3	0	0	0	0
Honduras	7	7	7	5	5	0	0	4	4	7	7	7	7
India	7	7	7	7	7	6	6	7	6	7	7	7	7
Indonesia	7	7	7	7	7	6	6	7	5	7	7	7	7
Iraq	7	7	7	4	5	0	0	7	7	7	7	7	7
Jordan	6	6	6	7	7	6	6	7	6	7	7	7	7
Lesotho	7	7	7	4	6	0	0	6	6	0	0	0	0

continued.

Appendix 1. *continued.*

Economy	Main Line Phone	Mobile & Main Line Phone	Internet, Mobile, & Main Line	Air-Freight	Air Carrier Take Offs	Rail Network	Rail Goods Transport	Road Network	Road and Rail Network	Electricity Consumption	Electricity Production	Energy Production	Energy Consumption
Maldives	7	7	7	7	7	0	0	0	0	4	4	0	4
Mongolia	5	5	5	4	4	6	6	4	4	5	5	5	5
Morocco	7	7	7	7	7	6	6	7	6	7	7	7	7
Nicaragua	7	7	7	6	6	0	0	6	6	7	7	7	7
Pakistan	7	7	7	7	7	6	6	7	6	7	7	7	7
Papua New Guinea	7	7	7	7	7	0	0	3	3	3	3	4	4
Paraguay	7	7	7	5	7	0	0	6	6	7	7	7	7
Philippines	7	7	7	7	7	4	6	6	4	7	7	7	7
Senegal	7	7	7	7	7	7	7	7	5	7	7	7	7
Sri Lanka	7	7	7	7	7	6	6	7	6	7	7	7	7
Swaziland	7	7	7	5	6	0	0	6	6	0	0	0	0
Thailand	7	7	7	7	7	6	6	7	6	7	7	7	7
Tonga	7	7	7	2	5	0	0	2	2	4	4	0	4
Tunisia	7	7	7	7	7	6	6	7	6	7	7	7	7
Viet Nam	7	7	7	4	7	5	6	7	5	7	7	7	7
Upper Middle Income Economies (no. of observations)													
Albania	7	7	7	2	3	6	6	4	4	7	7	7	7
Algeria	7	7	7	7	7	6	6	7	6	7	7	7	7
Argentina	7	7	7	7	7	6	4	7	6	7	7	7	7
Botswana	7	7	7	5	6	0	0	7	0	6	6	6	6
Brazil	7	7	7	7	7	6	6	7	6	7	7	7	7
Bulgaria	6	6	6	7	7	6	6	7	6	7	7	7	7
Chile	7	7	7	7	7	6	6	6	5	7	7	7	7
Colombia	7	7	7	7	7	6	6	7	6	7	7	7	7
Costa Rica	7	7	7	7	7	5	3	6	5	7	7	7	7
Cuba	7	7	7	7	7	5	5	0	0	7	7	7	7
Dominican Rep.	6	6	6	5	6	0	0	5	5	7	7	7	7
Fiji, Rep. of	7	7	7	7	7	0	0	4	4	4	4	4	4
Gabon	5	5	5	7	7	6	6	7	6	7	7	7	7
Iran	7	7	7	7	7	6	6	7	6	7	7	7	7
Jamaica	7	7	7	7	7	0	0	4	4	7	7	7	7
Libya	7	7	7	7	7	0	0	3	3	7	7	7	7
Malaysia	7	7	7	7	7	6	5	7	6	7	7	7	7
Mauritius	7	7	7	7	7	0	0	6	6	0	0	0	0
Mexico	7	7	7	7	7	6	6	7	6	7	7	7	7

continued.

Appendix 1. *continued.*

Economy	Main Line Phone	Mobile & Main Line Phone	Internet, Mobile, & Main Line	Air-Freight	Air Carrier Take Offs	Rail Network	Rail Goods Transport	Road Network	Road and Rail Network	Electricity Consumption	Electricity Production	Energy Production	Energy Consumption
Namibia	7	7	7	4	4	2	2	3	0	4	4	4	4
Panama	6	6	6	7	7	0	0	6	6	7	7	7	7
Peru	7	7	7	7	7	5	6	7	6	7	7	7	7
Romania	7	7	7	7	7	6	6	7	6	7	7	7	7
South Africa	7	7	7	7	7	6	6	6	5	7	7	7	7
Turkey	7	7	7	7	7	6	6	7	6	7	7	7	7
Uruguay	7	7	7	7	7	6	6	7	6	7	7	7	7
Venezuela	7	7	7	7	7	3	3	7	3	7	7	7	7
High Income Economies (no. of observations)													
Australia	7	7	7	7	7	6	5	7	6	7	7	7	7
Austria	7	7	7	7	7	6	6	7	6	7	7	7	7
Barbados	7	7	7	4	6	0	0	4	4	0	0	0	0
Belgium	7	7	7	7	7	6	6	7	6	7	7	7	7
Brunei	6	6	6	5	5	0	0	4	4	7	7	7	7
Canada	7	7	7	7	7	5	5	7	5	7	7	7	7
Cyprus	7	7	7	7	7	0	0	7	7	7	7	7	7
Denmark	7	7	7	7	7	6	6	7	6	7	7	7	7
Finland	7	7	7	7	7	6	6	7	6	7	7	7	7
France	7	7	7	7	7	6	6	7	6	7	7	7	7
Germany	7	7	7	7	7	3	3	7	3	7	7	7	7
Greece	7	7	7	7	7	6	6	7	6	7	7	7	7
Hong Kong, China	7	7	7	2	4	0	0	7	7	7	7	7	7
Hungary	7	7	7	7	7	6	6	7	6	7	7	7	7
Iceland	7	7	7	7	7	0	0	7	0	7	7	7	7
Ireland	7	7	7	7	7	6	6	7	6	7	7	7	7
Israel	7	7	7	7	7	6	6	7	6	7	7	7	7
Italy	7	7	7	7	7	6	6	7	6	7	7	7	7
Japan	7	7	7	7	7	6	6	7	6	7	7	7	7
Korea, Rep. of	7	7	7	7	7	6	6	7	6	7	7	7	7
Kuwait	7	7	7	7	7	0	0	7	7	7	7	7	7
Luxembourg	7	7	7	2	7	1	1	7	7	7	7	7	7
Macao, China	5	5	5	2	2	0	0	3	3	0	0	0	0
Malta	7	7	7	7	7	0	0	5	5	7	7	1	7

continued.

Appendix 1. *continued.*

Economy	Main Line Phone	Mobile & Main Line Phone	Internet, Mobile, & Main Line	Air-Freight	Air Carrier Take Offs	Rail Network	Rail Goods Transport	Road Network	Road and Rail Network	Electricity Consumption	Electricity Production	Energy Production	Energy Consumption
Netherlands	7	7	7	7	7	6	6	7	6	7	7	7	7
New Zealand	7	7	7	7	7	5	5	7	5	7	7	7	7
Norway	7	7	7	7	7	1	1	7	0	7	7	7	7
Poland	7	7	7	7	7	6	6	7	6	7	7	7	7
Portugal	7	7	7	7	7	6	6	7	6	7	7	7	7
Qatar	7	7	7	7	7	0	0	4	0	7	7	7	7
Saudi Arabia	7	7	7	7	7	6	6	7	6	7	7	7	7
Singapore	7	7	7	7	7	0	0	6	6	7	7	0	7
Spain	7	7	7	7	7	6	6	7	6	7	7	7	7
Sweden	7	7	7	7	7	6	6	7	6	7	7	7	7
Switzerland	7	7	7	7	7	6	6	7	6	7	7	7	7
Syria	7	7	7	7	7	6	6	7	0	7	7	7	7
Taipei,China	6	6	6	0	0	0	0	5	5	4	4	6	6
Trinidad & Tobago	7	7	7	7	7	0	0	4	0	7	7	7	7
United Arab Emirates	7	7	7	7	7	0	0	4	4	7	7	7	7
United Kingdom	7	7	7	7	7	6	6	7	6	7	7	7	7
United States	7	7	7	7	7	6	6	7	6	7	7	7	7

Source: Authors' estimates.

Appendix 2

A. Telecommunications

A.1. Telephone Main lines

	OLS (1)							2 SLS IV (2)						
Explanatory Variables	**All**	**Asia**	**Low Income**	**Low Mid Income**	**Upper Mid Income**	**Mid Income**	**High Income**	**All**	**Asia**	**Low Income**	**Low Mid**	**Upper Mid Income**	**Mid Income**	**High Income**
Capital	0.3741	0.3000	0.1891	0.3585	0.4754	0.4135	0.5837	0.5198	0.4311	0.2723	0.5452	0.6460	0.6091	0.6380
	[6.86]***	[3.21]***	[3.68]***	[7.73]***	[5.48]***	[8.15]***	[7.85]***	[17.57]***	[4.56]***	[7.37]***	[5.82]***	[8.68]***	[10.97]***	[11.71]***
Schooling	−0.0003	0.0498	−0.0431	−0.0221	−0.0108	−0.0192	0.0150	0.0433	0.0094	−0.0327	0.0371	0.1616	0.0589	−0.0023
	[−0.05]	[1.17]	[−1.63]	[−0.59]	[−0.31]	[−0.77]	[0.48]	[2.94]***	[0.34]	[−1.24]	[0.72]	[2.40]***	[2.07]**	[−0.09]
Phone	0.1132	0.1391	0.0827	0.1498	0.1045	0.1313	0.0949	0.0447	0.1332	0.0601	0.0598	−0.2352	0.0045	0.1779
	[3.51]***	[2.56]***	[1.86]*	[3.81]***	[1.70]*	[3.50]***	[1.23]	[1.79]*	[2.92]***	[1.50]	[0.91]	[−1.78]*	[0.10]	[3.04]***
Obs	828	152	141	220	177	397	290	790	141	136	207	170	377	277
Economies	121	23	21	32	26	58	42	121	23	21	32	26	58	42
R–Squared	0.5486	0.7355	0.4786	0.6612	0.6583	0.6543	0.5927	0.5331	0.7652	0.3791	0.5905	0.4323	0.5743	0.7298

A.2. Mobile and Telephone Main lines

	OLS (1)							2 SLS IV (2)						
Explanatory Variables	**All**	**Asia**	**Low Income**	**Low Mid Income**	**Upper Mid Income**	**Mid Income**	**High Income**	**All**	**Asia**	**Low Income**	**Low Mid**	**Upper Mid Income**	**Mid Income**	**High Income**
Capital	0.3899	0.3630	0.1960	0.4187	0.4852	0.4483	0.5749	0.5310	0.4846	0.2824	0.5787	0.5975	0.6115	0.6356
	[7.37]***	[4.50]***	[4.03]***	[7.89]***	[6.13]***	[9.54]***	[7.86]***	[18.78]***	[5.75]***	[7.87]***	[8.21]***	[8.51]***	[13.24]***	[10.76]***
Schooling	0.0039	0.0517	−0.0463	−0.0041	−0.0026	−0.0008	0.0109	0.0391	−0.0001	−0.0445	0.0466	0.1638	0.0605	−0.0450
	[0.21]	[1.28]	[−1.75]*	[−0.10]	[−0.08]	[−0.33]	[0.35]	[2.23]**	[0.00]	[−1.44]	[0.98]	[2.35]***	[2.17]**	[−1.03]
Mobile	0.0662	0.0806	0.0478	0.0815	0.0586	0.0759	0.0651	0.0307	0.0893	0.0409	0.0302	−0.1543	0.0011	0.1579
Phone	[3.20]***	[2.51]***	[2.09]***	[3.03]***	[1.66]*	[3.45]***	[1.39]	[1.68]*	[2.82]***	[1.65]*	[0.78]	[−1.73]*	[0.04]	[2.68]***
Obs	828	152	141	220	177	397	290	790	141	136	207	170	377	277
Economies	121	23	21	32	26	58	42	121	23	21	32	26	58	42
R-Squared	0.5421	0.7220	0.4867	0.6391	0.6548	0.6417	0.5918	0.5331	0.7516	0.3734	0.5721	0.4191	0.5720	0.6993

continued.

Appendix 2. *continued.*

A.3. Internet, Mobile and Telephone Lines

	OLS (1)							2 SLS IV (2)						
Explanatory Variables	**All**	**Asia**	**Low Income**	**Low Mid**	**Upper Mid Income**	**Mid Income**	**High Income**	**All**	**Asia**	**Low Income**	**Low Mid Income**	**Upper Mid Income**	**Mid Income**	**High Income**
Capital	0.3900	0.3722	0.1972	0.4243	0.4867	0.4524	0.5704	0.5309	0.4892	0.2824	0.5819	0.5924	0.6115	0.6382
	[7.36]***	[4.7]***	[3.96]***	[7.80]***	[6.21]***	[9.59]***	[7.73]***	[18.81]***	[6.00]***	[7.85]***	[8.42]***	[8.68]***	[13.49]***	[10.65]***
Schooling	0.0035	0.0502	−0.0442	−0.0005	−0.0016	−0.0060	0.0098	0.0366	−0.0036	−0.0473	0.0495	0.1506	0.0603	−0.0405
	[0.19]	[1.24]	[−1.65]*	[−0.01]	[−0.05]	[−0.24]	[0.34]	[2.04]**	[−0.11]	[−1.51]	[1.06]	[2.38]***	[2.20]**	[−0.97]
Internet, Mobile, Phone	0.0619	0.0743	0.0426	0.0730	0.0531	0.0683	0.0612	0.0309	0.0853	0.0407	0.0260	−0.1258	0.0012	0.1330
	[3.27]***	[2.52]***	[1.93]*	[2.88]***	[1.66]*	[3.33]***	[1.69]*	[1.79]*	[2.90]***	[1.72]*	[0.73]	[−1.69]*	[0.05]	[2.70]***
Obs	828	152	141	220	177	397	290	790	141	136	207	170	377	277
Economies	121	23	21	32	26	58	42	121	23	21	32	26	58	42
R-Squared	0.5418	0.7206	0.4802	0.6348	0.6547	0.6389	0.5931	0.5263	0.7505	0.3667	0.5688	0.4518	0.572	0.6982

B. Transport Infrastructure

B.1. Airfreight

	OLS (1)							2 SLS IV (2)						
Explanatory Variables	**All**	**Asia**	**Low Income**	**Low Mid Income**	**Upper Mid Income**	**Mid Income**	**High Income**	**All**	**Asia**	**Low Income**	**Low Mid Income**	**Upper Mid Income**	**Mid**	**High Income**
Capital	0.4000	0.5068	0.2290	0.4420	0.4049	0.4459	0.6311	0.4868	0.6291	0.3031	0.4412	0.4146	0.4450	0.7464
	[6.49]***	[4.89]***	[3.58]***	[4.71]***	[9.65]***	[7.60]***	[11.60]***	[14.21]***	[3.30]***	[6.97]***	[3.27]***	[4.37]***	[6.09]***	[12.06]***
Schooling	0.0280	0.0786	−0.0207	0.0678	0.0031	0.0308	0.0599	0.0463	−0.2776	−0.0025	0.0332	0.0209	0.0291	0.0749
	[2.25]***	[2.71]***	[−0.76]	[2.82]***	[0.20]	[2.06]**	[2.47]***	[4.94]***	[−0.88]	[−0.13]	[0.91]	[1.30]	[1.88]*	[3.52]***
Airfreight	0.0496	0.0057	0.0551	0.0503	0.0667***	0.0563	−0.0347	0.0519	0.3845	0.0366	0.1566	0.0734	0.1005	−0.0423
	[2.95]***	[0.18]	[2.71]***	[1.57]	[4.16]	[2.87]***	[−0.80]	[3.06]***	[1.08]	[1.59]	[1.57]	[2.30]**	[2.75]***	[−1.36]
Obs	787	127	122	192	172	364	267	705	112	111	181	165	346	252
Economies	118	22	20	31	26	57	41	116	22	19	31	25	56	41
R-Squared	0.5665	0.7359	0.4665	0.6775	0.6635	0.6524	0.5947	0.5263	.	0.4120	0.5116	0.6469	0.5894	0.7159

continued.

Appendix 2. *continued.*

B.2. Air Carriers

	OLS (1)							2 SLS IV (2)						
Explanatory Variables	**All**	**Asia**	**Low Income**	**Low Mid Income**	**Upper Mid Income**	**Mid Income**	**High Income**	**All**	**Asia**	**Low Income**	**Low Mid Income**	**Upper Mid Income**	**Mid Income**	**High Income**
Capital	0.3694	0.4441	0.2257	0.3666	0.4923	0.4349	0.5249	0.477	0.5280	0.3482	0.2970	0.5378	0.4776	0.6674
	[6.23]***	[5.06]***	[3.04]***	[5.20]***	[7.72]***	[8.18]***	[7.83]***	[12.66]***	[3.19]***	[6.39]***	[2.26]**	[6.71]***	[7.08]***	[9.19]***
Schooling	0.0481	0.0917	0.0100	0.0889	0.0267	0.0484	0.0214	0.0636	0.0640	−0.009	0.1072	0.0468	0.0634	0.0373
	[3.97]***	[2.86]***	[0.47]	[3.65]***	[1.77]*	[3.32]***	[0.85]	[9.40]***	[2.02]**	[−0.27]	[5.60]***	[4.39]***	[7.10]***	[2.47]***
Air Carriers	0.1007	0.0713	0.0455	0.1286	0.0142	0.0860	0.1587	0.0798	0.0840	−0.0182	0.2273	0.0439	0.1085	0.0574
	[4.54]***	[1.36]	[1.30]	[2.44]***	[0.37]	[2.30]**	[2.30]**	[3.16]***	[0.59]	[−0.32]	[2.51]***	[0.77]	[2.22]**	[1.82]*
Obs	787	135	135	204	176	380	275	748	121	126	194	170	364	262
Economies	119	22	21	31	26	57	41	119	22	21	31	26	57	41
R-Squared	0.5665	0.7537	0.4076	0.7058	0.6254	0.6496	0.6347	0.5651	0.7699	0.2617	0.6515	0.5844	0.6101	0.7426

B.3. Rail Network

	OLS (1)							2 SLS IV (2)						
Explanatory Variables	**All**	**Asia**	**Low Income**	**Low Mid Income**	**Upper Mid Income**	**Mid Income**	**High Income**	**All**	**Asia**	**Low Income**	**Low Mid Income**	**Upper Mid Income**	**Mid Income**	**High Income**
Capital	0.4459	0.3796	0.3768	0.3814	0.3904	0.4211	0.6284	0.5406	0.3069	0.6642	0.3029	0.5233	0.4814	0.6679
	[9.10]***	[5.67]***	[2.83]***	[5.56]***	[8.76]***	[7.60]***	[8.64]***	[13.28]***	[4.77]***	[4.01]***	[3.71]***	[4.63]***	[8.20]***	[12.59]***
Schooling	0.0710	0.1977	0.0879	0.1974	0.0440	0.0848	0.0296	0.1073	0.2914	−0.2130	0.3050	0.1363	0.1659	0.0120
	[4.17]***	[3.23]***	[0.56]	[4.26]***	[2.31]***	[3.23]***	[1.71]*	[5.48]***	[4.68]***	[−0.59]	[5.68]***	[3.72]***	[6.11]***	[0.63]
Rail	0.0422	0.1319	0.3698	0.1747	0.0469	0.0164	−0.0794	0.1801	0.4197	−0.4334	0.4882	0.3306	0.2581	−0.0852
	[0.63]	[0.60]	[0.60]	[1.45]	[0.67]	[0.22]	[−1.16]	[2.58]***	[2.00]**	[−0.42]	[3.23]***	[2.23]**	[2.76]***	[−1.32]
Obs	419	66	64	97	108	205	154	342	54	52	80	89	169	125
Economies	76	12	12	17	19	36	28	73	12	11	17	19	36	26
R-Squared	0.6178	0.8582	0.4399	0.7427	0.6260	0.6299	0.8790	0.5691	0.7699	0.3044	0.6799	0.2609	0.5024	0.8648

continued.

Appendix 2. *continued.*

B.4. Goods Transported by Rail

	OLS (1)							2 SLS IV (2)						
Explanatory Variables	**All**	**Asia**	**Low Income**	**Low Mid Income**	**Upper Mid Income**	**Mid Income**	**High Income**	**All**	**Asia**	**Low Income**	**Low Mid Income**	**Upper Mid Income**	**Mid Income**	**High Income**
Capital	0.4537	0.3733	0.3222	0.3715	0.3880	0.4205	0.6425	0.5089	0.3290	−4.7343	0.4301	0.5074	0.5066	0.6273
	[10.12]***	[7.87]***	[3.13]***	[5.17]***	[8.82]***	[7.34]***	[9.25]***	[12.56]***	[5.38]***	[−0.12]	[6.91]***	[5.15]***	[9.58]***	[10.91]***
Schooling	0.0665	0.1930	0.0554	0.1592	0.0313	0.0776	0.0351	0.0837	0.2162	1.9829	0.1723	0.0664	0.1045	0.0384
	[4.73]***	[4.72]***	[2.85]***	[3.60]***	[2.15]**	[3.49]***	[1.81]*	[6.41]***	[6.29]***	[0.13]	[6.11]***	[3.44]***	[6.39]***	[2.04]**
Rail Goods	0.0092	0.0599	0.1658	0.062	−0.0280	−0.0106	−0.0207	0.0374	0.0676	5.1897	0.0571	−0.0665	−0.0148	0.0467
	[0.36]	[3.35]***	[1.96]**	[2.44]***	[−1.43]	[−0.56]	[−0.72]	[1.44]	[1.97]*	[0.14]	[1.45]	[−1.90]	[−0.54]	[1.18]
Obs	419	71	64	102	104	206	154	338	59	50	84	85	169	123
Economies	78	12	13	18	19	37	28	73	12	11	17	19	36	26
R-Squared	0.6297	0.8710	0.5510	0.7188	0.6002	0.6075	0.8765	0.6212	0.8746	.	0.7088	0.5051	0.5808	0.8586

B.5. Road Network

	OLS (1)							2 SLS IV (2)						
Explanatory Variables	**All**	**Asia**	**Low Income**	**Low Mid Income**	**Upper Mid Income**	**Mid Income**	**High Income**	**All**	**Asia**	**Low Income**	**Low Mid Income**	**UpperMid Income**	**Mid Income**	**High Income**
Capital	0.3912	0.3833	0.2145	0.3798	0.4628	0.4253	0.6033	0.4959	0.3348	0.3072	0.2835	0.6113	0.4719	0.6807
	[6.19]***	[7.23]***	[2.94]***	[5.02]***	[8.64]***	[9.35]***	[7.96]***	[14.46]***	[4.10]***	[4.50]***	[3.08]***	[7.60]***	[8.60]***	[10.13]***
Schooling	0.0610	0.1505	−0.0249	0.0838	0.0528	0.0627	0.0585	0.0806	0.1711	0.0217	0.1287	0.0649	0.0788	0.0738
	[4.17]***	[5.33]***	[−0.96]	[2.00]**	[2.97]***	[3.36]***	[2.08]**	[9.60]***	[5.78]***	[0.54]	[5.54]***	[5.57]***	[7.55]***	[4.56]***
Road	0.0790	0.1040	0.1292	0.1627	0.0837	0.1163	−0.0263	0.1001	0.2011	0.5405	0.2335	0.1070	0.1394	−0.0735
	[1.42]	[1.38]	[1.45]	[1.10]	[1.04]	[1.41]	[−0.28]	[2.18]**	[2.24]**	[1.61]	[2.57]***	[1.32]	[2.44]***	[−1.29]
Obs	717	118	127	172	155	327	267	661	103	118	151	146	297	251
Economies	119	22	21	31	25	56	42	118	22	21	30	25	55	42
R-Squared	0.5242	0.8499	0.3742	0.6041	0.6412	0.6116	0.6563	0.5400	0.894	0.2034	0.6047	0.5847	0.6180	0.8104

continued.

Appendix 2. *continued.*

B.6. Road and Rail Network

	OLS (1)							2 SLS IV (2)						
Explanatory Variables	**All**	**Asia**	**Low Income**	**Low Mid Income**	**Upper Mid Income**	**Mid Income**	**High Income**	**All**	**Asia**	**Low Income**	**Low Mid Income**	**Upper Mid Income**	**Mid Income**	**High Income**
Capital	0.3710	0.3556	0.1767	0.4075	0.4046	0.4106	0.6892	0.4822	0.3649	0.1663	0.5107	0.6396	0.5189	0.7703
	[5.23]***	[5.05]***	[3.37]***	[4.83]***	[7.18]***	[7.89]***	[10.89]***	[11.03]***	[3.73]***	[2.68]***	[4.24]***	[5.31]***	[6.98]***	[9.63]***
Schooling	0.0628	0.1701	0.0099	0.0779	0.0526	0.0619	0.0366	0.0898	0.1911	0.0381	0.0864	0.0806	0.0831	0.0518
	[3.45]***	[5.18]***	[0.47]	[1.45]	[4.00]***	[2.42]***	[1.03]	[6.91]***	[4.77]***	[0.97]	[2.97]***	[4.28]***	[5.31]***	[2.18]**
Rail & Road	0.1069	0.0321	0.392	0.04834	0.1779	0.0990	0.0671	0.0849	−0.0097	0.7126	−0.1247	0.2819	0.0386	−0.2100
	[1.52]	[0.33]	[1.70]*	[0.23]	[1.91]*	[0.76]	[0.73]	[1.24]	[−0.08]	[3.51]***	[−0.95]	[2.44]***	[0.49]	[−2.17]**
Obs	584	107	100	150	128	278	206	481	86	85	119	105	224	172
Economies	109	22	19	30	24	54	36	108	22	19	29	24	53	36
R-Squared	0.4885	0.8300	0.4049	0.5391	0.6032	0.5482	0.6754	0.4622	0.8783	0.3628	0.4569	0.3596	0.4807	0.7905

C. Energy Infrastructure

C.1.Electricity Consumption

	OLS (1)							2 SLS IV (2)						
Explanatory Variables	**All**	**Asia**	**Low Income**	**Low Mid Income**	**Upper Mid Income**	**Mid Income**	**High Income**	**All**	**Asia**	**Low Income**	**Low Mid Income**	**Upper Mid Income**	**Mid Income**	**High Income**
Capital	0.4358	0.2362	0.3335	0.3016	0.4987	0.4009	0.5255	0.5590	0.2347	0.4423	0.4602	0.7892	0.5934	0.4861
	[8.48]***	[1.42]	[3.10]***	[3.20]***	[5.57]***	[5.56]***	[5.72]***	[13.16]***	[1.24]	[1.32]	[4.76]***	[7.64]***	[8.91]***	[7.37]***
Schooling	0.0071	0.0881	−0.0549	−0.0341	0.0386	−0.0015	0.0162	0.0512	0.0569	−0.0571	0.0401	0.1622	0.0781	0.0324
	[0.51]	[1.73]*	[−1.87]*	[−0.72]	[2.09]**	[−0.07]	[0.68]	[3.79]***	[0.98]	[−1.03]	[0.95]	[3.50]***	[2.94]***	[1.66]*
Elec. Consum	0.1177	0.1351	0.0977	0.2678	−0.0606	0.1458	0.1136	0.0127	0.1775	0.0618	0.0935	−0.4807	−0.0614	0.1596
	[2.54]***	[1.17]	[2.24]**	[3.37]***	−0.60	[2.39]***	[1.24]	[0.30]	[1.22]	[0.22]	[0.95]	[−2.80]***	[−0.83]	[2.65]***
Obs	709	129	81	183	171	354	277	675	118	76	174	164	338	265
Economies	106	22	13	28	25	53	40	106	22	13	28	25	53	40
R-Squared	0.5443	0.6310	0.5651	0.6230	0.6042	0.5882	0.5361	0.5616	0.6475	0.5416	0.5827	0.3124	0.4910	0.6658

continued.

Appendix 2. *continued.*

C.2. Electricity Production

	OLS (1)							2 SLS IV (2)						
Explanatory Variables	**All**	**Asia**	**Low Income**	**Low Mid Income**	**Upper Mid Income**	**Mid Income**	**High Income**	**All**	**Asia**	**Low Income**	**Low Mid Income**	**Upper Mid Income**	**Mid Income**	**High Income**
Capital	0.4698	0.2429	0.4199	0.3862	0.4893	0.4351	0.5451	0.5701	0.2362	0.4048	7.27	0.6944	0.5757	0.5546
	[9.73]***	[1.57]	[3.38]***	[4.42]***	[5.95]***	[6.96]***	[5.76]***	[16.22]***	[1.29]	[3.61]***	[0.5362]***	[8.54]***	[11.22]***	[8.61]***
Schooling	0.0197	0.0865	−0.0388	0.0177	0.0344	0.0158	0.0243	0.0550	0.0527	−0.0609	0.0690	0.1342	0.0724	0.0447
	[1.42]	[1.70]*	[−1.50]	[0.38]	[1.86]*	[0.78]	[0.95]	[4.81]***	[0.88]	[−2.19]**	[2.24]**	[3.45]***	[3.72]***	[2.33]***
Electricity	0.0598	0.1365	0.0129	0.1077	−0.0401	0.0773	0.0730	−0.0032	0.1879	0.0883	0.0098	−0.3495	−0.0382	0.0827
Production	[1.66]*	[1.21]	[0.32]	[1.34]	[−0.42]	[1.56]	[0.82]	[−0.11]	[1.25]	[1.04]	[0.18]	[−2.56]***	[−0.84]	[1.44]
Obs	705	129	77	183	171	354	277	672	118	73	174	164	338	265
Economies	105	22	12	28	25	53	40	105	22	12	28	25	53	40
R-Squared	0.5392	0.6308	0.5721	0.5783	0.6027	0.5769	0.5313	0.5616	0.6458	0.5442	0.5292	0.4031	0.5056	0.6604

C.3. Energy Generation

	OLS (1)							2 SLS IV (2)						
Explanatory Variables	**All**	**Asia**	**Low Income**	**Low Mid Income**	**Upper Mid Income**	**Mid Income**	**High Income**	**All**	**Asia**	**Low Income**	**Low Mid Income**	**Upper Mid Income**	**Mid Income**	**High Income**
Capital	0.4543	0.2856	0.4262	0.4356	0.421	0.4488	0.4651	0.5167	0.3312	0.5029	0.5432	0.4537	0.5224	0.5144
	[9.23]***	[2.38]***	[3.89]***	[5.88]***	[7.00]***	[8.06]***	[4.15]***	[15.94]***	[3.38]***	[7.02]***	[8.32]***	[6.87]***	[11.58]***	[7.98]***
Schooling	0.0282	0.0949	−0.0321	0.0529	0.0291	0.0350	0.0336	0.0460	0.0827	−0.0455	0.0730	0.0524	0.0582	0.0466
	[2.33]***	[2.13]**	[−0.95]	[1.49]	[2.01]**	[2.06]**	[2.37]***	[6.53]***	[1.96]**	[−1.82]*	[4.01]***	[4.95]***	[6.08]***	[3.69]***
Energy	0.1311	0.3919	0.1000	0.0376	0.1771	0.0781	0.1734	0.0954	0.3207	−0.0073	0.0019	0.1551	0.0430	0.1290
Generation	[2.23]**	[1.38]	[0.49]	[0.42]	[1.87]*	[0.96]	[2.51]***	[4.62]***	[3.11]***	[−0.03]	[0.05]	[2.74]***	[1.38]	[4.78]***
Obs	687	117	77	176	171	347	266	656	108	73	169	164	333	254
Economies	102	19	12	26	25	51	39	101	19	12	26	25	51	38
R-Squared	0.5827	0.6857	0.5736	0.05565	0.6536	0.5830	0.6252	0.5986	0.6978	0.5512	0.5199	0.6110	0.5457	0.7071

continued.

Appendix 2. *continued.*

C.4. Energy Consumption

Explanatory Variables	OLS (1) All	Asia	Low Income	Low Mid Income	Upper Mid Income	Mid Income	High Income	2 SLS IV (2) All	Asia	Low Income	Low Mid Income	Upper Mid Income	Mid Income	High Income
Capital	0.4515	0.3034	0.4183	0.4077	0.5488	0.4714	0.4727	0.5398	0.3623	0.5024	0.552	0.6800	0.6173	0.4939
	[8.02]***	[2.50]***	[3.81]***	[4.80]***	[6.11]***	[6.60]***	[3.88]***	[15.28]***	[3.60]***	[6.74]***	[7.42]***	[10.01]***	[11.90]***	[7.63]***
Schooling	0.0256	0.0811	−0.0305	0.0435	0.0322	0.0391	0.0200	0.0518	0.0604	−0.0450	0.0734	0.0565	0.0666	0.0533
	[2.06]**	[1.72]*	[−0.95]	[1.35]	[2.45]***	[2.70]***	[1.02]	[6.72]***	[1.13]	[−1.89]*	[3.23]***	[4.79]***	[6.04]***	[3.85]***
Energy	0.1743	0.296	0.1591	0.1412	0.2116	−0.0168	0.3153	0.0671	0.2889	0.0066	−0.0128	−0.3013	−0.1494	0.2084
Consumption	[2.19]**	[1.85]*	[0.92]	[0.94]	[−1.43]	[−0.15]	[3.01]***	[1.41]	[1.42]	[0.03]	[−0.09]	[−3.60]***	[−1.97]**	[3.42]***
Obs	708	132	77	184	171	355	279	675	121	73	175	164	339	267
Economies	105	22	12	28	25	53	40	105	22	12	28	25	53	40
R-Squared	0.5560	0.6623	0.5759	0.5620	0.6330	0.5659	0.5994	0.5812	0.7167	0.5519	0.5165	0.5518	0.4999	0.7063

C.5. Energy Production and Consumption without Crude Petroleum Exporting Economies

Explanatory Variables	Energy Production OLS (1)	Energy Production IV (2)	Energy Consumption OLS (1)	Energy Consumption IV (2)
Capital	0.4689	0.5387	0.4495	0.5134
	[11.15]***	[18.25]***	[7.84]***	[16.24]***
Schooling	0.0540	0.0681	0.0524	0.0694
	[4.36]***	[9.76]***	[4.48]***	[9.54]***
Energy	0.0662	0.0483	0.1673	0.1321
	[1.50]	[2.63]***	[2.06]**	[2.91]***
Observations (no.)	610	586	631	605
Economies (no.)	91	90	94	94
R-Squared	0.6297	0.6643	0.6979	0.6802

* denotes significance at 10; ** denotes significance at 5%; and *** denotes significance at 1%.

[1] Robust t and z statistics are in brackets.

IV = instrumental variables, OLS = ordinary least squares, 2SLS = 2-stage least squares.

Note: Intercepts are not reported and simply reflect the average value of the fixed effects (Gould 2001) in the estimations.

Source: Authors' estimates.

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About the Paper

Douglas H. Brooks and Eugenia C. Go provide a comprehensive overview of the issues, policies, and political economy of infrastructure investment, and a review of empirical literature of the relationship between growth and infrastructure. Empirical estimations using the growth accounting framework for a panel of 123 economies confirm that while infrastructure contributes to growth, the extent of the contribution generally varies according to the level of income of countries. Telecommunications are most important for low-income countries, while transportation and energy are the most relevant for middle-income and high-income economies, respectively.

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