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Infrastructure Investment Demands in Emerging Markets and Developing Economies

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Abstract

The authors have assembled 1960–2012 infrastructure stock data from 145 countries to estimate the demand for infrastructure services in emerging markets and developing economies. This paper identifies that the required resource flows to satisfy new demand while maintaining service for existing infrastructure amounts to $836 billion or 6.1 percent of current gross domestic product per year over the period 2014–20. The annual infrastructure investment gap for emerging markets and developing economies is $452 billion per year, which implies that emerging markets and developing economies should almost double their current spending. The paper also estimates that half of the spending should be allocated to maintenance of existing assets. Acknowledging the challenges to compare infrastructure investment estimates across different methodologies, the authors recognize this result as a lower bound estimate and compare the results with others available in the literature.

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Infrastructure Investment Demands in Emerging Markets and Developing Economies

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I. Introduction

The links between infrastructure and development are well established, including the impact of infrastructure on poverty alleviation, equality, growth and specific development outcomes such as job creation, market access, health and education.[2] These relationships are complex and dynamic; even with respect to growth and job creation, infrastructure's impacts are felt through multiple channels.[3] The demand for infrastructure is rising with the accelerating pace of globalization and urbanization. Every month in the developing world more than five million people migrate to urban areas. This demand trend is compounded by the growing need for low CO2 and climate-resilient investments to combat the challenges of climate change.[4]

The developing world suffers from an undersupply of infrastructure, constraining economic growth rates, leaving the world's most vulnerable communities without access to basic services, and hampering attempts to achieve broad-based poverty reduction. Currently, it is estimated that some $700 billion to $800 billion is invested worldwide ($550 billion in emerging markets and developing economies (EMDE)) in infrastructure every year, although data are scarce.[5] In a nutshell, more than 70% of the current infrastructure funds come from the public sector. The second largest source of financing comes from the private sector, roughly 20% of the total funds. The remaining is covered by ODA.[6]

A range of estimates on infrastructure financing requirements applying different assumptions and methodologies for achieving various global goals have been estimated over the years. Despite the challenges comparing results across different methodologies, all the latest estimates of the global infrastructure investment requirements indicate that there is a significant gap.

This paper reviews the recent global estimates and summarizes the main findings. Using a top-down approach, this paper estimates the global estimates on infrastructure investment requirements to satisfy consumer and producer's demand for infrastructure services, assuming specific economic and demographic growth rates. This paper uses Yepes' (2008) model addressing some of the limitations of the original model developed by Fay (2000), and gathers the most recent data on infrastructure stock and macro-economic variables up to 2012.[7] It is important to address that the purpose of long-term projections is not to forecast the future. Rather, it is to explore how the future infrastructure investment might evolve given a set of economic, social, technical and

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[2] Straub (2008); and Serven and Calderon (2004b, 2008 and 2010)

[3] Agénor and Moreno-Dodson (2006) for an overview. Estache, et al (2013) and Schwartz, et al (2009) for a treatment of infrastructure impacts on jobs and growth.

[4] Fay and Toman (2010) and Bhattacharya, et al (2013)

[5] These figures are author's own estimates based on a number of sources. See table 5.

[6] Adopted as a concept by the Development Assistance Committee (DAC) of the Organization for Economic Cooperation and Development in 1969, official development assistance (ODA) is a classification of resource flows from 22 DAC donor countries.

[7] It also explicitly list the countries used for the estimation for which data is available and extrapolates results for all Emerging Markets and Developing Economies (EMDE). Moreover, one of the main contributions of this study is to simplify future updates of investment needs by providing a model and database simple to update when most recent data is available.

political assumptions. The estimates from this paper should be considered as complement to the existing estimates in the literature by providing lower bound figures and filling the gap for certain sectors or regions.

II. Definitions and Previous Literature

A range of estimates on infrastructure financing requirements applying different assumptions and methodologies for achieving various goals have been estimated over the years. Terms such as “needs”, “demand”, and “gap” have been used in the literature interchangeably generating some confusion when comparing results. In order to quantify “needs”, normative targets should be established usually assuming an optimal level of infrastructure. Different targets will lead to different estimated needs. “Demand,” as used in this paper, refers to the infrastructure investment requirements to satisfy the consumer and producer demand, based on predicted GDP growth and other growth trends. The terms “gap” is used as the difference between the estimated requirements and the actual level of investments.

There are various methodologies used in the literature to estimate infrastructure investment requirements; they can be broadly classified in two categories: “top-down” and “bottom-up” (See Annex I). As the data of macroeconomic variables are relatively more comprehensive compared with the data of individual infrastructure projects, majority of the studies in fact adopt the “top-down” approach to conduct the empirical analysis.

The most recent estimates of annual infrastructure investment requirements for Emerging Markets and Developing Economies (EMDE) are Fay et al (2011) which estimate the annual needs of US$0.9-1.1 trillion with an annual gap of US$100-300 billion by extrapolating estimates from Yepes (2008) using price inflation rate. A recent G24 policy paper, Bhattacharya et al. (2013), calculates investment annual needs of US$2 trillion and investment gap of US$1 trillion by extrapolating Fay et al (2011) using economic growth rate and price inflation rate. Both studies are extrapolations of previous studies and they do not account for actual changes in infrastructure stock since 2006.[8]

McKinsey (2013)’s uses three approaches to estimate infrastructure investment requirements. First, they use the historical spending approach, which assumes that future needs will follow past spending as percentage of GDP. Using this assumption, they project spending to 2030. The main limitation of this approach is that the data are mainly limited to OECD countries and extrapolated for the rest of the world. Secondly, they use the stock of infrastructure approach that estimates its value by using a perpetual inventory model. Unfortunately, they only have data for 12 countries[9] and

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[8] Moreover, they fail to mention the list of countries for which data was not available.

[9] The model was populated with data from the following countries: Brazil, Canada, China, Germany, India, Italy, Japan, Poland, South Africa, Spain, United Kingdom and United States

they use this information to estimate the average value of infrastructure stock (calculated at 70% of GDP). This average value is used to extrapolate results for the rest of the countries until 2030. Thirdly, they use the independent estimates of future needs approach that aggregate the estimates from three different sources: (i) Global Water Intelligence for the water sector; IEA (2011) for the power sector and OECD (2012) for the remaining infrastructure sectors. Based on these three approaches, they estimate that global infrastructure investment requirements for 2013-2030 range from US$57 trillion to US$67 trillion, or about US$3.2 trillion to US$3.7 trillion annually on average.

The OECD (2006) report concluded that global infrastructure investment requirements across the transport (road, rail), telecom, electricity and water sectors would amount to around US$53 trillion over 2010-30, or about US$ 2.7 trillion annually average. Annual investment requirements for these sectors amount to some 2.5% of world GDP, which would rise to 3.5% of GDP; if electricity generation and other energy-related infrastructure investments in oil, gas and coal are included. The methodology used built on existing estimates, and extrapolates those to 2030. For the transport sector, they apply the estimated regional level elasticity (the ratio of paved road capital stock in USD billion to GDP) from Fay and Yepes (2003) assuming a fixed convergence rate. Asset replacement is calculated by assuming the economic life provision of 30 years without controlling by the current quality level. For the water sector, they extrapolate the proportion of GDP allocated to water services, varying from 0.3% to 2% based on different levels of income. For telecoms, they identify the underlying trends and drivers, and extrapolate the percentage of GDP invested in telecoms from Fay and Yepes (2003. Lastly, for the energy sector, they adopt estimates from IEA's World Energy Outlook, which uses a scenario approach to analyze the possible evolution of energy markets to 2030.

There are other estimations in the literature, however, they are based on Fay and Yepes (2003), McKinsey (2013), and OECD (2006). For example, Kennedy and Corfee-Morlot (2013), based on OECD work, are in the high part of the range, with annual investment requirements estimated at US$ 6.6-7.2 trillion when buildings and vehicles included at low carbon (2°C) scenario, and US$ 2.7-3.2 trillion when those are excluded. Using McKinsey's (2013) estimates of infrastructure investment requirements, KPMG (2014) and Standard & Poor's Ratings Services present the annual investment requirements of $3.2 trillion by 2030. The World Economic Forum's (2013) estimation of annual infrastructure spending need for 2020 is calculated by taking the Fay et al (2010) estimate of US$ 1.25-1.5 trillion annually in 2013 and assuming a 4% annual growth rate from 2013-20, and an additional US$ 200-300 billion annual requirement to make the infrastructure sustainable (by providing for climate change mitigation and adaptation).

There have been previous efforts to calculate regional estimates, but some of them are outdated and do not account for changes in infrastructure stock or have significant drawbacks. Gill and Kharas (2007) estimate infrastructure investment requirements for East Asia and the Pacific using data up to 2005. Data for Latin America and the Caribbean were collected from primary sources for 1990–2005 and then extrapolated in posterior work as presented in Yepes (2008). The most recent figures are from South Asia, where Andres et al. (2013) have extrapolated previous estimations at the country level for South Asia.[10] The estimations from Sub-Saharan Africa come from Foster and Briceño-Garmendia (2010) that made a significant effort to collect data on infrastructure stock and present a bottom-up approach.

Some of the most recent sectoral estimates come from the International Energy Agency (IEA). IEA indicates that the annual investments in energy supply of $1.6 trillion need to rise steadily over the coming decades towards $2 trillion. Under IEA's expectation, future electricity usage underpins changes in the installed capacity of power generation technologies and in transmission and distribution networks, which assume global electricity demand growth rate of 2.2% per year, projected to future demand. Annual spending on energy efficiency, measured against a 2012 baseline, needs to rise from $130 billion today to more than $550 billion by 2035. OECD presents estimates at sectoral level for transport, telecoms, and water and sanitation.

Comparing the different estimates presented some significant challenges (see Annex II). Recognizing the limitation of comparing results from different methodologies, the table below presents the most recent estimates on infrastructure investment requirements/demand in the literature.

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[10] Estimates by Chatterton and Puerto (2006) follow Fay (2000) methodology to estimate investment needs in South Asia but estimates are up to 2010.

Table 1. Estimations on annual infrastructure investment requirements (US$ billion)

Global Estimates (USD billion)		
Global	$3,200-$3,700	McKinsey, 2013
	$2,680-$3,200	Kennedy&Corfee-Morlot, 2013
	$2,650	OECD, 2006
Developing	$836	Ruiz-Nuñez&Wei, 2015
	$2,000	Bhattacharya, 2013
	$1,250-$1,500	WEF, 2013
	$900-$1,100	Fay, 2011
	$1,113	Yepes, 2008
	$465	Fay&Yepes, 2003
Regional Estimates (USD billion)		
EAP	$498	Bhattacharyay, 2010
	$165	Gill and Kharas, 2007
	$34	Bhattacharyay, 2010
LAC	$260-$434	Kohli&Basil, 2011
	$186	Perrotti& Sanchez, 2011
	$57	Fay, 2000
MENA	$78.50	World Bank. 2009
SAR	$137-$206	Andrés et al, 2013
	$234	Bhattacharyay, 2010
	$62	Chatterton&Puerto, 2006
SSA	$93	Foster&Briceño-Garmendia,2010
Sectoral Estimates (USD billion)		
Electricity	$2,000	IEA,2012
Transport	$805	OECD, 2011
Telecoms	$600	OECD, 2007
W&W+WW	$1,320	OECD, 2007

Source: Authors' summary

III. Methodology

This paper uses Fay's (2000) model to estimate infrastructure investment demand and tries to address some of the limitations in the methodology following Yepes (2008). See Annex III with details of the methodology used. The model estimates the infrastructure investment requirements needed to satisfy consumer and producer demand given an expected growth rate. The model follows a top-down approach and accounts for global, regional and sectoral estimates.

As described in the previous section, most of the methodologies in the literature have significant drawbacks, and Yepes (2008) is not innocuous to those. This methodology does not account for regional or sector specificities and supply constraints.[11] Importantly, the model does not estimate the level of infrastructure that would maximize growth or socio-economic targets, that is to say the model assumes no optimality. The relationship between income level and infrastructure service demand is

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[11] Data limitations does not allow to address those constraints.

established on the basis of past observed behavior in a sample of countries and extrapolated for the future using predicted income growth.

Using Yepes (2008) as starting point, we constructed an annual panel of infrastructure stocks, macro variables, and demographics for 145 countries for 1960–2012. Due to missing data the numbers of periods observed for each country differ and therefore, the database is an unbalanced panel. (See Annex IV for data sources.)

The infrastructure variables gathered are:

- Telephones (mobile and landlines) subscribers per 1,000 persons;
- Kms of paved roads per Km2 of land
- Kms of unpaved roads per Km2 of land
- Kms of rail per 1,000 persons
- Total TEU handled
- KW of installed electricity generation capacity per capita;
- Percentage of households with access to electricity
- Percentage of households with access to water and sanitation
- Percentage of households with access to sanitation
- Percentage of households with access to wastewater treatment

After obtaining the annual database, we followed Yepes (2008) by taking five-year averages of all variables for each country, and obtaining a panel that contains the five-year average of annual flows (for flow variables) or the average stock held over the five-year period (for stock variables).

The main motivation for this transformation comes from the lack of annual data on infrastructure stock and the fact that infrastructure accumulation is a slow process that happens over long periods of time. Therefore, we are not able to capture the short-term dynamics of the investment process. Instead, Yepes's (2008) model aims to reveal the relationship between income flows and infrastructure stocks at low frequencies. Therefore the model is estimated on a panel with five-year periodicity.

The benchmark GDP growth scenarios are created by extrapolating the 5-year-long regional growth rate to predict future GDP. This approach provides a region-specific scenario that is tailored to forecast. Then, the model applies the average growth rate of 5 years (2010–2015) GDP series, including the forecasted value of year 2014 and 2015, to predict the GDP trend for 2014–2020, which results in an implied annual growth rate for regions GDP projection.

Table 2. Regional GDP growth rate used to forecast GDP 2014-2020

Region	EAP	ECA	MENA	LAC	SAR	SSA
GDP Growth rate	7.79%	3.95%	1.64%	3.32%	6.32%	4.63%

Source: Authors' estimation based on Global Economic Prospects, WDI

To obtain the demand function for infrastructure, the model includes some additional regressors: (i) agricultural share of value added, (ii) manufacturing share of value added, (iii) urbanization rate, and (iv) population density. For each country, we created scenarios for these variables by obtaining their growth rate for the 1990–2012 period, and then applying that growth rate to obtain a forecast for the 2014–20 period. Projections of GDP composition are not available (share in agriculture and in manufacturing) so we keep them at 2010 values. For urbanization and population, we use the 2014–20 projections provided by the United Nations.

Since infrastructure stocks tend to change reasonably slowly over time and have a long life span, we included a lagged value of the dependent variable in the regression in order to increase the explanatory power. We take Fay and Yepes (2003) estimate equation below to estimate the infrastructure demand:

$$I_{i,t}^{j} = \alpha_0 + \alpha_1 I_{i,t-1}^{j} + \alpha_2 y_{i,t} + \alpha_3 A_{i,t} + \alpha_4 M_{i,t} + \alpha_5 D_i + \alpha_6 D_t + \varepsilon_{i,t}$$

where all variables are in natural logs to linearize the model, $I^{j}_{i,t}$ is demand for infrastructure stock of type j in country i at time t; Iji,t-1 is the lagged value of the infrastructure stock; y is income per capita; A is share of agriculture value added in GDP; M is the share of manufacturing value added in GDP; Di is a country fixed effect; Dt is a time dummy; and ε is the error term.[12]

In order to calculate maintenance cost, the report provides estimates based on a top-down approach of using data on infrastructure and parameters for maintenance costs. The maintenance cost is calculated by applying a depreciation rate to the predicted total value of the capital stock.

The unit costs used to value infrastructure were obtained by applying GDP deflator inflation rate to previously estimated unit cost values presenting prices at 2011 level. Unit costs are assumed constant over time. Since more recent data were not available, these numbers were validated by World Bank experts.

For transport, energy and water sectors, a GDP deflator inflation rate is applied to the lasted available price in the literature and they were later validated by World Bank experts. In terms of telecoms sector, the costs have come down significantly in the last decade, mainly due to competition, technological change, market entry by Chinese companies and market volume. However, according to experts in the field, the projected price level is expected to remain constant in the coming decade.[13]

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[12] Manufacturing rather than industry was used here because industry includes mining, which has very different implications on the demand for infrastructure.

[13] This is due to: (i) decline in shipments, due to market saturation, (ii) technological change is now pushing in favor of higher performance networks (eg DSL, fibre, 4G) which will tend to swap out performance for price, (iii) the shake up to the market

Table 3. Unit Costs (USD), by Sector

	2011 Price Level	
Sector	*Cost per unit*	*Unit*
Electricity generation	2,700	kW
Paved roads	500,000	kilometer
Unpaved roads	51,000	kilometer
Rails	1,200,000	kilometer
Rural water and sanitation	150	person
Urban sanitation	150	person
Urban water	80	person
Main telephone lines*	200-300	line
Mobile lines*	90-130	line
Access to electricity	250	person
Ports	360	TEU
Wastewater treatment	150	person

Source: Authors' estimation validated with World Bank experts.

*Main telephone lines unit price ranges from US$200-US$300 per line per connections in areas greater than 3km of an existing exchange. The lower bound is used for India (US$200) and the upper bound for the rest of the countries.

*Mobile lines unit price is related to the urbanization rate. US$100 for new 3G connection in urban areas and US$ 160 for new 3G connections in rural areas. We take the average of the rural and the urban areas, as the projected urbanization rate is nearly 50% in developing countries. Therefore, US$130 unit price is used all countries except India where the numbers would be closer to US$60 and US$120, respectively with an average of US$90 per connection.

IV. Main Results

The results of the estimated regression are included in Annex V. This study indicates that the developing world will require annual investments about $819 billion (6 percent of GDP in developing countries) through 2020 to satisfy consumer and producer demand for infrastructure services. Of this amount, about 49 percent is required for capital expansion of infrastructure and 51 percent for maintenance of both current and future infrastructure. In addition, high income countries will require about $ 285 billion (0.8 percent of GDP in developed countries) of annual infrastructure investments during the 2014- 2020 period.

The table below describes the results for the expected annual investment requirements, including capital expenditure and maintenance cost, by income groups (low income, upper

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caused by the entry of Chinese manufacturers like Huawei and ZTE won't happen again for a while.

middle-income and lower middle income), regions, and infrastructure sector (i.e transport, telecom, electricity, and water and sanitation).

As expected, the investment requirements as a share of GDP are the highest in low-income countries (14.1%). This is followed by lower-middle income (3.4%), and upper-middle income (2.6%) countries. The sectors accounting for the greatest share of infrastructure investment requirements is electricity (39%). Transport is the second largest (31%), followed by telecommunications (23%). The Water and sanitation sector only account for 7% of the share.

Table 4: Expected Annual Investment Requirements, 2014–20 (at 2011 prices)

	Capital		Maintenance		Total	
	US$Mn	%GDP	US$Mn	%GDP	US$Mn	%GDP
By income group						
Low Income	176,217	7.1%	172,089	6.9%	348,306	14.1%
Lower Middle Income	35,821	1.1%	72,063	2.3%	107,884	3.4%
Upper Middle Income	160,251	2.0%	203,047	2.6%	363,298	2.6%
Developing countries by region						
SAR	159,074	7.8%	144,427	7.1%	303,501	14.9%
SSA	28,946	3.2%	27,108	3.0%	56,054	6.2%
EAP	115,897	2.0%	96,244	1.7%	212,140	3.7%
MENA	14,826	1.1%	32,244	2.5%	47,070	3.7%
LAC	65,828	1.7%	74,450	1.9%	140,277	3.6%
ECA	24,178	0.8%	36,267	1.1%	60,445	1.9%
Developing countries by sector						
Electricity	152,577	1.1%	167,754	1.2%	320,331	2.4%
Transport	76,201	0.6%	178,818	1.3%	255,019	1.9%
Telecoms	123,351	0.9%	63,755	0.5%	187,105	1.4%
W&S+WW	20,160	0.1%	36,873	0.3%	57,033	0.4%

All developing countries	819,488	6.0%
High Income countries	285,045	0.8%
World	1,104,532	2.2%

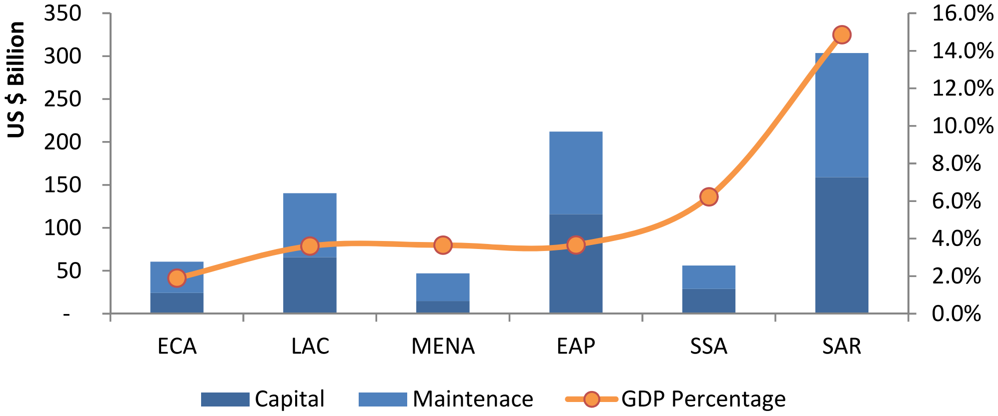
Source: Authors' estimation.

Note: GDP percentage is calculated based on the projected GDP2015 by income level and by region. For sectors, we used average projected GDP2015 for developing countries.

Income level, regions and sectors are defined according to the World Bank's World Development Indicators Report.

Figure 1 shows the distribution of investment requirements by region. South Asia has the largest annual infrastructure investment requirements of $304 billion (14.9 percent of GDP). The investment requirements in ECA, MENA and SSA range from $47-$60 billion annually.

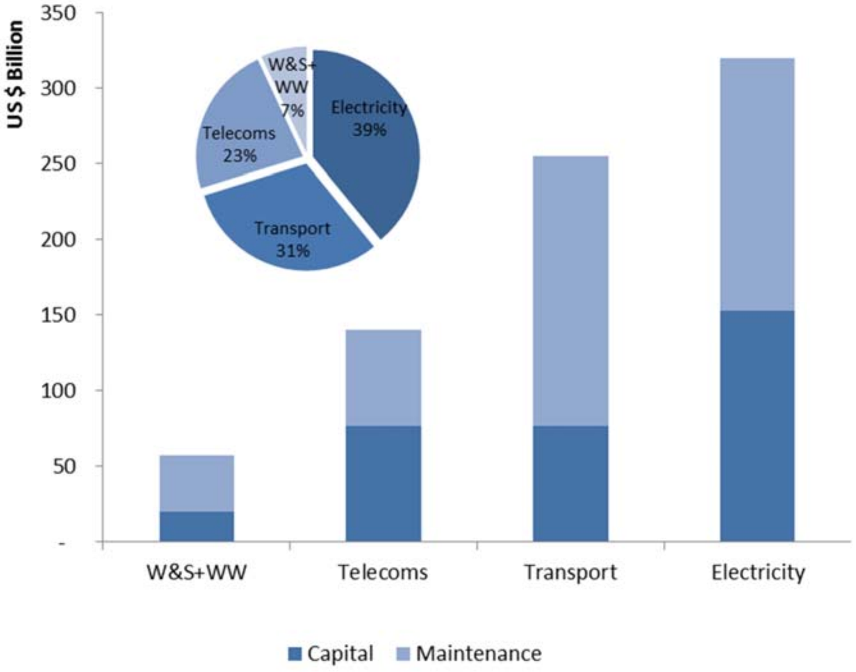
Figure 1. Total Annual Infrastructure investment requirements, by Region



Source: Authors' estimation

Figure 2 shows each sector's total investment requirements, giving an idea of the variation in priorities and requirements between two different investment types (capital expenditure and maintenance cost). Except for the telecommunication sector, the other three sectors have greater percentage in maintenance cost than capital expenditure.

Figure 2. Total Annual Infrastructure investment requirements, by Sector



Source: Authors' estimation

V. Infrastructure Investment Gap

The infrastructure investment gap is estimated as the difference between the estimated investment requirements and actual spending on infrastructure. The lack of data on infrastructure spending has been long recognized as a serious impediment to deriving reliable gaps estimates (Fay et al., 2011). There have been many efforts to calculate figures on infrastructure spending but they have had significant drawbacks (See Annex VI with the description of those attempts). The table below describes total spending in infrastructure by applying GDP deflator for inflation to the latest and most reliable regional data.

Table 5: Total Spending in Infrastructure by region in 2011 USD billion.

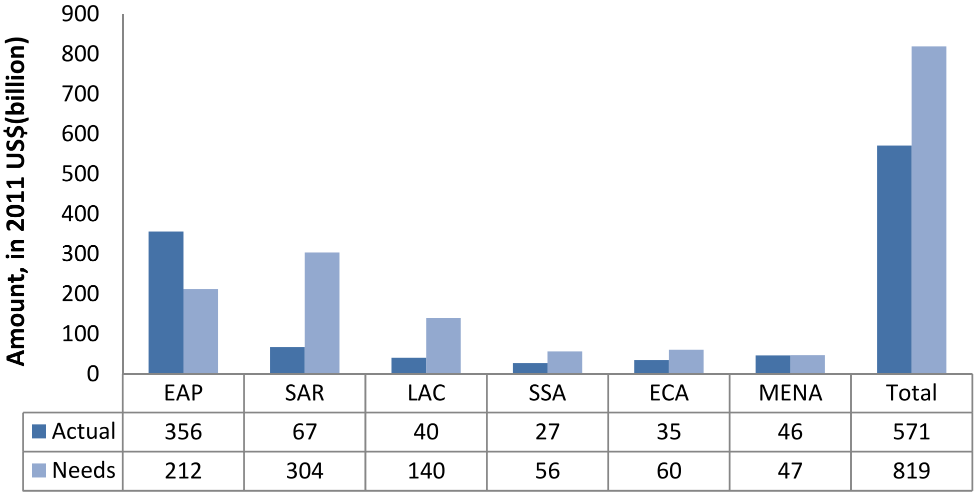
Region	**% of GDP**	**Spending in 2011 USD billion**	**Source of figure as reported in Fay and Toman (2010)**
EAP	6.8	356	Yepes (2008a) with Original source from Gill and Kharas (2007)
SAR	4.2	67	Estimates of India's public infrastructure spending from the country's public expenditure plans and extrapolated to the rest of the region.
LAC	1.2	40.3	Estimates from original data collection efforts. Data was collected for 1990–2005 as presented in Yepes (2008b).
SSA	3.2	27.4	Foster and Briceño-Garmendia, 2010.
ECA	1.2	34.6	No data. Investments share is assumed to be similar to that of Latin America.
MENA	4.2	46	No data. Assumed to be the weighted sample average. Based on Agénor et al. (2005), Public capital expenditure in infrastructure (as % of GDP) is estimated as 2 percent.
TOTAL	**4.3**	**571.3**	

Source: Authors' estimation

Note: The developing countries that are included in our dataset are listed by regions: EAP (Indonesia, Lao PDR, Fiji, Malaysia, Mongolia, China, Papua New Guinea, Cambodia, Vietnam, Philippines, and Thailand); SAR (Pakistan, Sri Lanka, India, Nepal, and Bangladesh); LAC (Argentina, Uruguay, Costa Rica, Guatemala, Guyana, Trinidad and Tobago, Jamaica, El Salvador, Venezuela, RB, Colombia, Peru, Bolivia, Nicaragua, Honduras, Brazil, Suriname, Ecuador, Haiti, Panama, Paraguay, Mexico, Dominican Republic, Belize, and Chile); SSA (Chad, Niger, Angola, Mauritania, Kenya, Swaziland, Gambia, The, Tanzania, Comoros, Burundi, Ghana, Botswana, Cape Verde, Equatorial Guinea, Liberia, Nigeria, Central African Republic, South Africa, Mali, Zambia, Mozambique, Cameroon, Lesotho, Ethiopia, Congo, Rep., Zimbabwe, Malawi, Uganda, Senegal, Cote d'Ivoire, Sudan, Benin, Madagascar, Namibia, Djibouti, Guinea-Bissau, Guinea, Rwanda, Gabon, Togo, Mauritius, Sierra Leone and Burkina Faso); ECA (Lithuania, Belarus, Russian Federation, Armenia, Estonia, Turkey, Albania, Croatia, Kyrgyz Republic, Tajikistan, Bulgaria, Poland, Azerbaijan, Georgia, Kazakhstan, Slovak Republic, Czech Republic, Romania, Uzbekistan, Latvia, Turkmenistan, Hungary, and Ukraine); and MENA (Tunisia, Iran, Islamic Rep., Oman, Saudi Arabia, Egypt, Arab Rep., Jordan, Morocco, Syria, Yemen, and Algeria)

The figure below shows the annual infrastructure investment requirements against actual investments disaggregated over 2014-2020 for the countries included in the sample.

Figure 3. Infrastructure investment requirements Vs. Actual for the subset of EMDE countries that were included in the estimation



	EAP	SAR	LAC	SSA	ECA	MENA	Total
■ Actual	356	67	40	27	35	46	571
■ Needs	212	304	140	56	60	47	819

Source: Authors' calculation for the countries included in the estimation (See Note in Table 2).

In order to present figures for all EMDE countries,[14] we extrapolated the results of investment requirements and spending as percentage of GDP for the countries not included in our estimation due to data limitations.[15] We apply the estimated regional investment requirements (as percentage of GDP) to the countries not included in the estimation. Figure 4 illustrates infrastructure investment requirements for EMDE countries and disaggregates the results by region. The infrastructure investment requirements for EMDE countries is $836 billion per year over 2014-2020. The estimated actual spending is $580 billion per year. This estimated gap only includes the following sectors: roads (paved and unpaved), ports, railways, water, sanitation, waste water management, electricity (generation and distribution), telephone and mobile lines.

As presented in the figure below, South Asia has the highest investment gap. The opposite occurs in East Asia and the Pacific as China drives up the average. In that region, investments actually exceed requirements to keep up with economic and

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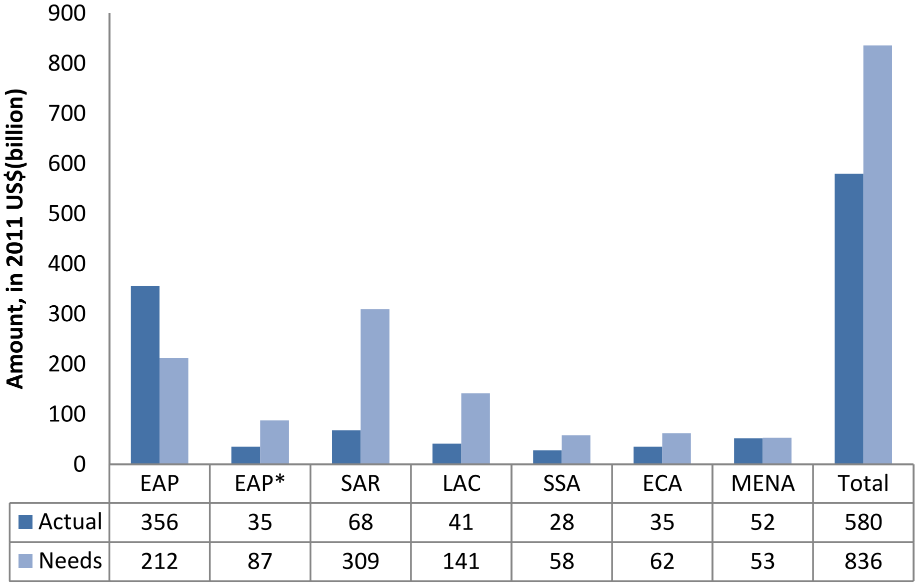
[14] The definition of EMDE country list comes from two parts: Emerging market countries come from IMF World Economic Outlook Update: http://www.imf.org/external/pubs/ft/weo/2012/update/02/index.htm, and Developing economies list come from WBG: http://data.worldbank.org/about/country-and-lending-groups.

[15] List of countries not included in the regression due to limited data:
EAP : American Samoa, Kiribati, Korea, Dem. Rep., Marshall Islands, Micronesia, Fed. Sts, Myanmar, Palau, Samoa, Solomon Islands, Timor-Leste, Timor-Leste, Tuvalu, Tonga, Vanuatu;
SAR: Afghanistan, Bhutan, Maldives;
LAC: Belize, Bolivia, Grenada, St. Lucia, St. Vincent and the Grenadines
SSA: Botswana, Cabo Verde, Côte d'Ivoire, Eritrea, São Tomé and Principe, Seychelles, Somalia
ECA: Kosovo, Macedonia, FYR, Moldova, Montenegro, Serbia
MENA: Djibouti, Lebanon, Libya, Tunisia, West Bank and Gaza

demographic growth. However, if we exclude China from the EAP estimation, the rest of EAP countries do have a positive investment gap.

Figure 4. EMED Infrastructure investment requirements Vs. Actual



	EAP	EAP*	SAR	LAC	SSA	ECA	MENA	Total
■ Actual	356	35	68	41	28	35	52	580
■ Needs	212	87	309	141	58	62	53	836

Source: Authors' estimation Note: EAP*: Exclude China's data from EAP region.

VI. Main Conclusions

This study presents estimations of investment requirements over 2014-2020 accounting for the most recent changes in stock of infrastructure. The annual infrastructure investment requirements for EMDE countries is $836 billion or 6.1% of current GDP per year over 2014-2020.

The table below shows the investment gap for EMDE excluding China.[16] The annual infrastructure investment gap for EMDE countries is $452 billion over 2014-2020, which implies that EMDE countries should almost double their current spending.

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[16] China is overinvesting in infrastructure, and including it in the calculation of the infrastructure investment gap will underestimate the gap for the rest of EMDE countries since investment is done at country level.

Table 6: EMDE* Infrastructure investment requirements, Actual Spending and Investment Gap in annual US$ billion over 2014-2020

	EAP*	SAR	LAC	SSA	ECA	MENA	**Total**
Requirements	87	309	141	58	62	53	711
Actual	35	68	41	28	35	52	259
Gap	**52**	**241**	**100**	**30**	**27**	**1**	**452**

Source: Authors' estimation Note: (*) EAP* includes EMDE in EAP excluding China.

The breakdown between capital expenditure and maintenance cost shows that roughly half of the estimated amount should be spent on maintenance.

When results are disaggregated by region, SAR has the biggest gap followed by LAC and EAP (without China). It is important to note that the results are less robust when data are further disaggregated as the quality of data varies significantly across regions.

Our estimates are lower than the most recent extrapolation presented in the literature. While our methodology has some drawbacks, other available estimates have used extrapolation techniques not accounting for infrastructure stock changes in developing countries and are based on a very small sample of countries mainly in the developed world.

The estimation of this study should be used to complement the existing ones and it should be considered as a lower bound of the actual global requirements since, due to data limitations, it does not include the cost of upgrading and rehabilitating existing infrastructure in bad condition (except for roads where the regional percentage of road in bad conditions is available). Moreover, this estimation does not include sectors such as airports, urban transport, energy transmission, and solid waste management that could account for a significant cost.

Expenditures related to GHG mitigation and adaptation to climate change could add some $170-$220 billion per year to the cost of developing country infrastructure.[17]

The table below compares the estimations of this paper with the latest estimates in the literature. While the methodologies are not strictly comparable, it offers a sensitivity analysis around estimates that are highly constrained by data availability.

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[17] From Fay and Toman (2010): This includes some $30-40 billion for adaptation in infrastructure (World Bank 2009a) and some $140-175 billion associated with mitigation in the energy sector (World Bank 2009b).

Table 7: Global Estimates Comparison

Global Estimates (USD billion)		
Developing	$836	Ruiz-Nuñez&Wei, 2015
	$2,000	Bhattacharya, 2013
	$1,250-$1,500	WEF, 2013
	$900-$1,100	Fay, 2011
	$1,113	Yepes, 2008
	$465	Fay&Yepes, 2003
Global	$3,200-$3,700	McKinsey, 2013
	$2,680-$3,200	Kennedy&Corfee-Morlot, 2013
	$2,650	OECD, 2006

Source: Authors' summary

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ANNEX I

Methodologies for estimating investment requirements[18]

The methodologies for estimating investment requirements can be classified as "top-down" and "bottom-up."

The "top-down" approach utilizes econometric analysis techniques to quantitatively estimate national infrastructure needs and, by extension, regional need. It involves creating an econometric model that could be used across countries to project physical capacity needs per sector during a determined period (most of the studies are based on Fay and Yepes (2003)). After the projections of the physical capacities were derived, standard unit costs based on international "best practice" norms were applied to estimate the investment requirements for new capacity. In addition, it projected the investments required to maintain or replace the existing stock is included.

Within the "top-down" approach, there are two econometric technics are used to estimate requirements. (1) Kohli et al. (201X) developed a structural equation model with instrumental variables implemented using a simultaneous two-stage least-square regression frame work. A structural equation model treats certain variables as endogenous to the system a remaining variables as exogenous. (2) Computable General Equilibrium (CGE) models are commonly used tools for quantifying the costs and benefits of policy. One group of CGE model applications were practically implemented with the focus of modeling the joint production of the goals at the country level for MDG costing estimates (Reddy and Heuty, 2005, 2006). For instance, the World Bank's MAMS model provides a general equilibrium framework for countries to simulate the effect of improvements in one MDG on progress in others (Bourguignon et al., 2008).

The "bottom-up" approach reviews infrastructure investment demand at the project level, specifically for regional or cross-border projects. The "bottom-up" methodology is a conservative approach that identifies individual infrastructure projects and estimate costs of their implementation. The compiled project information is then used to obtain the total infrastructure service demand by region, by sub-regional program, and by sector.

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[18] Bhattacharyay (2010) and United Nations (2012).

Annex II

Challenges to compare estimates[19]

The United Nations (2012)'s report points out to the main challenges to compare estimates across different methodologies:

Data issues: Data in infrastructure are very limited not only for stock of capital but also for quality, making the analysis more challenging. Data are in many cases not standardized across countries, making international comparison very difficult.

Varying scope: The definition of infrastructure and of the sectors varies and there is not a well-accepted definition. For example in the energy sector, some models focus on electricity production, others on broader definitions of the energy system. The types of technologies considered differ and therefore their costs.

Choice of the baseline: Estimating additional investment requirements under any scenario requires the choice of a baseline. This choice has a critical importance on the "needs" or requirements that will be estimated. There is no a clear agreement on the BAU assumptions.

Choice of goals and targets: Modelers producing estimates of costs or investment requirements usually do not choose exactly the goals or same targets in their scenarios.

Inconsistency: Cost estimates obtained from different models generally cannot be added. Methods used differ in the sectors included (usually due to data availability), in the assumptions used, as well as, in the degree of detail to which specific policies are modeled. This can affect estimated needs several-fold.

Non-additivity: The cost or implied investment requirement of reaching a set of goals is not equal to the sum of the costs of reaching the goals separately. Moreover, targets may not be compatible to each other..

Differing time scales: A last caveat to keep in mind when comparing estimates is the differing time scale of various goals and targets. Access to a particular target could be reached in a decade while changing the technology used could take decades.

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[19] United Nations (2012)

Annex III

Methodology to estimate Investment Needs

This paper uses Fay and Yepes (2003)' model and tries to address some limitations in the methodology. The model presented in Fay and Yepes (2003) estimates future demand for infrastructure, where infrastructure services are demanded both as consumption goods by individuals and as inputs into the production process by firms. On the consumption side, the amount of services demanded is a function of income and prices:

$$I_j^c = f(Y_j; q_I) \qquad (1)$$

Demand for a particular type of infrastructure service I by individual j is a function of j's income, Y_j, and the price of infrastructure service I, q_I. Aggregating over the population, national per capita demand of infrastructure service for consumption, I^c, will then be given as:

$$\frac{I^c}{P} = \frac{1}{P}\sum_j I_j^c = F\left(\frac{Y}{P}; q_I\right) \qquad (2)$$

where Y/P is income per capita.

On the production side, the demand of each individual firm for infrastructure service i will be based on a profit maximization decision, which yields the usual first order condition:

$$\frac{\partial Y_i}{\partial I_i^p} = \frac{q_I}{w_i} \qquad (3)$$

where Y_i is output of good i by the firm, and w_i is the price of that good.

To go any further, a specific functional form for the production function needs to be adopted. Assuming a Cobb-Douglas production function, the paper can rewrite the first order condition as:

$$K_i^{\alpha} L_i^{\beta} \phi I_i^{\phi-1} = \frac{q_I}{w_i} \qquad (4)$$

where K is physical capital (excluding infrastructure), L is labor or human capital, and I is the flow of infrastructure services consumed by the individual firm in the production of good i. Solving for I_i yields the derived demand for infrastructure services of firm i:

$$I_i^p = \left[\phi \frac{w_i}{q_I} K_i^{\alpha} L_i^{\beta}\right]^{1/(1-\phi)} \qquad (5)$$

Aggregating over all firms yields the following:

$$I^{p}=\sum_{i} I_{i}^{p}=\sum_{i}\left[\phi \frac{w_{i}}{q_{I}} K_{i}^{\alpha} L_{i}^{\beta}\right]^{1/(1-\phi)} \qquad (6)$$

The derived demand for any given infrastructure service I^p is the sum of the weighted demand of individual firms. However, the usefulness of equation 6 is limited because there is no firm-level data. A reasonable proxy for firms' aggregate demand for infrastructure is given by aggregate output. However, it is unlikely that the elasticity of demand for a particular infrastructure service, ϕ, is the same across all sectors of the economy. Thus the weight attributable to the demand of a given firm depends on the sectoral composition of the economy. Also, as technology changes, ϕ may change. Finally, the weighted average of the relative price w_i/q_I can be proxied by the real price of the infrastructure good—q_I/w, where w is the price level. The reduced form of equation 6 is then given as:

$$I^{p}=F\left(Y, \frac{w}{q_{I}}, Y_{AG}, Y_{ind}; A\right) \qquad (7)$$

where Y is aggregate output, Y_{AG} and Y_{IND} are the share of GDP derived from agriculture and industry, and A is a term representing technology level. Combining equations 2 and 7, and expressing infrastructure demand in per capita terms, yields the following equation for overall production and consumption demand for infrastructure services:

$$\frac{I}{P}=F\left(\frac{Y}{P}; \frac{q_{I}}{w}; Y_{AG}; Y_{IND}; A\right) \qquad (8)$$

Estimating infrastructure demand empirically

To estimate the flow of services from the endowment of physical infrastructure, data on stocks of infrastructure is used, assuming that services are proportional to the physical stock (though intensity of use may vary). Therefore, equation (8) can easily be understood as demand for physical stocks of infrastructure.

Lacking measures of technological change or actual real prices of infrastructure services, time dummies and country fixed effects are used as a proxy. The country fixed effect allows each country to have a different intercept that, combined with the time dummy, allows to capture (albeit roughly) the price variable.

The purpose of this paper is not to establish a causal relationship between infrastructure stocks and various economic variables. Instead, the objective is to use this regression for projection, and therefore we needed to obtain the best fit possible and the highest explanatory power. Thus, since infrastructure stocks tend to change reasonably slowly over time and have a long life span, we include lagged value of the dependent variable in the regression in order to increase explanatory power.

Fay and Yepes (2003) estimate equation (8) as follows:

$$I_{i,t}^{j} = \alpha_0 + \alpha_1 I_{i,t-1}^{j} + \alpha_2 y_{i,t} + \alpha_3 A_{i,t} + \alpha_4 M_{i,t} + \alpha_5 D_i + \alpha_6 D_t + \varepsilon_{i,t} \quad (9)$$

where all variables are in natural logs to linearize the model, $I^j_{i,t}$ is demand for infrastructure stock of type j in country i at time t; $I^j_{i,t-1}$ is the lagged value of the infrastructure stock; y is income per capita; A is share of agriculture value added in GDP; M is the share of manufacturing value added in GDP; D_i is a country fixed effect; D_t is a time dummy; and ε is the error term.[20]

Most infrastructure goods are provided through networks so that the price of the service is often reduced with higher population density. Urbanization, in particular, allows easier and cheaper access to electricity and telephone service. Average costs of water and sanitation actually tend to be higher in urban areas, but this is because the standard service offered there is typically much higher. However, access is always much higher in cities, partly because of the higher income of the population and partly because of public health considerations that make piped water and reasonably sophisticated sanitation services necessary. In the case of roads, kilometers per capita tend to decrease with higher population density. Therefore, equation (9) also includes urbanization and population density to capture the density effect and its impact on demand (both direct and through price).

Using ordinary least squares regression with fixed effects, both the basic model described by equation (9) and an extended model that included density and urbanization was run on all five infrastructure variables.

Country fixed effects proxy for differences in technology and price across nations. Their use also allows us to obtain consistent parameter estimates. Canning (1998) shows that per capita infrastructure levels are nonstationary, which implies that running the regressions in levels may produce misleading results unless the variables used in the regressions are cointegrated. Unfortunately, cointegration would not yield an easy system with which to make predictions, leaving us with two possible solutions. One is to run the regressions on first differences, which Canning shows to be stationary. This would reduce our sample size considerably since we only have up to eight time-series observations, and the series are often incomplete. The second possibility—which we use—is to include fixed effects. Kao (1997) shows that in this case the estimates of parameters are consistent even if the estimated relationship is not cointegrating.

In this paper, the author use the updated Yepes(2008)'s refined methodology and take into cosideration of the infrastrucure qaunlity. For example in transport sector, the maintenance component is obtained by applying a depreciation rate to the predicted total value of the stock in kilometers. This is the same method used in Fay and Yepes (2003). Here, however, the depreciation comes from a stylized model of a maintenance and rehabilitation program. Though a maintenance program is a complex dynamic process associated with level of traffic, geography, and other factors, we rely on fixed initial parameters and an assumption of equal

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[20] Manufacturing rather than industry was used here because industry includes mining, which has very different implications on the demand for infrastructure.

levels of traffic among regions to justify the same cycle of routine and periodic maintenance. Below, we argue that a reasonable model of maintenance and rehabilitation over a 10-year horizon can be collapsed into a time invariant annual maintenance and rehabilitation unit cost. The cost factor is obtained from the following equation:

$$\begin{aligned} AMUC_{i,j} = & \left[RoutineAUC_j \times \left(\%Kr + \%Bad_{i,j} / 2 \right) \right] + \left[PeriodicAUC_j \times \%Kp \right] \\ & + \left[\mathrm{Re}\, habilitationAUC_j \times \left(\%Kh + \%Bad_{i,j} / 10 \right) \right] \end{aligned} \tag{10}$$

Where *i* indexes regions *j* indexes types of roads (paved or unpaved).

At any time period between year 1 and year 10, each kilometer of road is in one of four states: *routine, periodic, rehabilitation,* or *bad.* The time zero fraction of type j roads in bad state is denoted by $\%Bad$. A bad road is one that is 16 years old or older. At any point in time, a given kilometer of good roads might be under *routine or periodic rehabilitation* maintenance. *Rehabilitation* maintenance is applied to good roads that are 15 years old. The fraction of 15-year old, good roads, is denoted by $\%Kh$. Good roads that are 5 years old undergo *periodic* maintenance. The fraction of good roads that are 5 years old is denoted by $\%Kp$. All good roads have to undergo *routine* maintenance every year except at years 5 and 15, when they receive one of the other two types of maintenance. Bad roads do not receive *routine* or *periodic* maintenance, as this would be a waste of resources.

To account for bad roads, we assume that there is a special rehabilitation program to reduce the percentage of bad roads to zero over a 10-year span. The program operates by performing *rehabilitation* maintenance on 10 percent of the time zero stock of roads that are bad. As bad roads undergo *rehabilitation* and enter the normal maintenance cycle for good roads, some of them will undergo *routine* and *periodic* maintenance. We simplify things by ignoring *periodic* maintenance of these roads and noting that, on average, half of the initial number of bad roads will undergo *routine* maintenance over the 10-year period. Furthermore, if we assume that the growth rate of kilometers prior to time zero was constant, then the fraction of roads in each state will be constant in the absence of the special rehabilitation program. This completes the necessary assumptions for equation 10. Levels of quality used in these estimates were collected for this study from different World Bank sources.

ANNEX IV

Data Sources

GDP in constant USD of year 2000, comes from the World Development Indicators (WDI) of the World Bank (http://www.worldbank.org/data/.)

Agriculture share and **manufacture share** of value added come from the WDI database of The World Bank (http://www.worldbank.org/data/.)

Total population and **urban population**, in percentage are from the United Nations Population Projections (http://www.un.org/popin/wdtrends.htm)

Historical data on **telephone lines**, **paved roads** and **rails** come from Canning (1998) for 1960 to 1995. See data section for information on data combination. Data are available at: http://www.worldbank.org/html/dec/Publications/Workpapers/WPS1900series/wps1929/canning1.xls

Containerization, as the total number of trafficking containers is obtained from the Containerization International Yearbook (1970-2006), published by Containerization International (http://www.ci-online.co.uk).

Telephone lines, mobile phones (in subscribers per 1000 inhabitants), **paved roads** and **rails** (in thousands of kilometers), come from the WDI database of The World Bank (http://www.worldbank.org/data/.)

Electricity generating capacity in millions of kilowatts per hour is from the US Energy Information Administration, (http://www.eia.doe.gov/neic/historic/hinternational.htm).

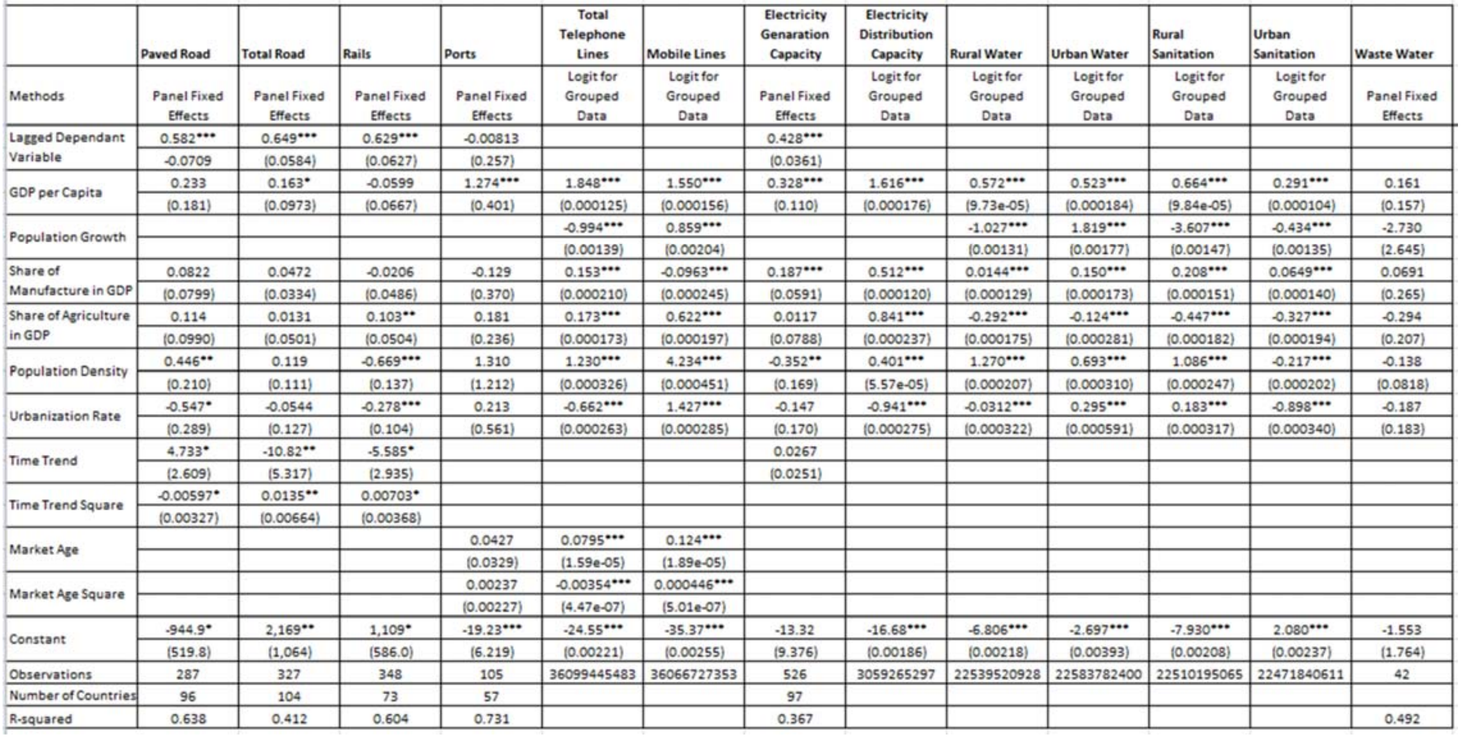
Electrification rate, measured as the fraction of population with access to electricity, is obtained from Annex B of the World Energy Outlook 2006, published by the International Energy Agency (www.iea.org/w/bookshop/pricing.html).

Access to improved water and **sanitation** in **urban** and **rural** areas is defined as fraction of total population with access to services. It comes from the Joint Monitoring Program (JMP) for water supply and sanitation of the World Health Organization and UNICEF (http://www.wssinfo.org/en/watquery.html).

Waste Water treatment, measured as the fraction of the population connected to public waste water treatment plants in 2004, is obtained from the United Nations Statistical Division (http://unstats.un.org/unsd/environment/wastewater.htm

ANNEX V
RESULTS FROM EMPIRICAL ESTIMATION

All relevant variables in logarithms



	Paved Road	Total Road	Rails	Ports	Total Telephone Lines	Mobile Lines	Electricity Genaration Capacity	Electricity Distribution Capacity	Rural Water	Urban Water	Rural Sanitation	Urban Sanitation	Waste Water
Methods	Panel Fixed Effects	Panel Fixed Effects	Panel Fixed Effects	Panel Fixed Effects	Logit for Grouped Data	Logit for Grouped Data	Panel Fixed Effects	Logit for Grouped Data	Logit for Grouped Data	Logit for Grouped Data	Logit for Grouped Data	Logit for Grouped Data	Panel Fixed Effects
Lagged Dependant Variable	0.582***	0.649***	0.629***	-0.00813			0.428***						
	-0.0709	(0.0584)	(0.0627)	(0.257)			(0.0361)						
GDP per Capita	0.233	0.163*	-0.0599	1.274***	1.848***	1.550***	0.328***	1.616***	0.572***	0.523***	0.664***	0.291***	0.161
	(0.181)	(0.0973)	(0.0667)	(0.401)	(0.000125)	(0.000156)	(0.110)	(0.000176)	(9.73e-05)	(0.000184)	(9.84e-05)	(0.000104)	(0.157)
Population Growth					-0.994***	0.859***			-1.027***	1.819***	-3.607***	-0.434***	-2.730
					(0.00139)	(0.00204)			(0.00131)	(0.00177)	(0.00147)	(0.00135)	(2.645)
Share of Manufacture in GDP	0.0822	0.0472	-0.0206	-0.129	0.153***	-0.0963***	0.187***	0.512***	0.0144***	0.150***	0.208***	0.0649***	0.0691
	(0.0799)	(0.0334)	(0.0486)	(0.370)	(0.000210)	(0.000245)	(0.0591)	(0.000120)	(0.000129)	(0.000173)	(0.000151)	(0.000140)	(0.265)
Share of Agriculture in GDP	0.114	0.0131	0.103**	0.181	0.173***	0.622***	0.0117	0.841***	-0.292***	-0.124***	-0.447***	-0.327***	-0.294
	(0.0990)	(0.0501)	(0.0504)	(0.236)	(0.000173)	(0.000197)	(0.0788)	(0.000237)	(0.000175)	(0.000281)	(0.000182)	(0.000194)	(0.207)
Population Density	0.446**	0.119	-0.669***	1.310	1.230***	4.234***	-0.352**	0.401***	1.270***	0.693***	1.086***	-0.217***	-0.138
	(0.210)	(0.111)	(0.137)	(1.212)	(0.000326)	(0.000451)	(0.169)	(5.57e-05)	(0.000207)	(0.000310)	(0.000247)	(0.000202)	(0.0818)
Urbanization Rate	-0.547*	-0.0544	-0.278***	0.213	-0.662***	1.427***	-0.147	-0.941***	-0.0312***	0.295***	0.183***	-0.898***	-0.187
	(0.289)	(0.127)	(0.104)	(0.561)	(0.000263)	(0.000285)	(0.170)	(0.000275)	(0.000322)	(0.000591)	(0.000317)	(0.000340)	(0.183)
Time Trend	4.733*	-10.82**	-5.585*				0.0267						
	(2.609)	(5.317)	(2.935)				(0.0251)						
Time Trend Square	-0.00597*	0.0135**	0.00703*										
	(0.00327)	(0.00664)	(0.00368)										
Market Age				0.0427	0.0795***	0.124***							
				(0.0329)	(1.59e-05)	(1.89e-05)							
Market Age Square				0.00237	-0.00354***	0.000446***							
				(0.00227)	(4.47e-07)	(5.01e-07)							
Constant	-944.9*	2,169**	1,109*	-19.23***	-24.55***	-35.37***	-13.32	-16.68***	-6.806***	-2.697***	-7.930***	2.080***	-1.553
	(519.8)	(1,064)	(586.0)	(6.219)	(0.00221)	(0.00255)	(9.376)	(0.00186)	(0.00218)	(0.00393)	(0.00208)	(0.00237)	(1.764)
Observations	287	327	348	105	36099445483	36066727353	526	3059265297	22539520928	22583782400	22510195065	22471840611	42
Number of Countries	96	104	73	57			97						
R-squared	0.638	0.412	0.604	0.731			0.367						0.492

Standard errors in parentheses *** p<0.01, **p<0.05, *p<0.1

ANNEX VI
Efforts to calculate spending on Infrastructure

When calculating the actual spending on infrastructure, the authors faced significant challenges. The data on infrastructure spending is very limited and there is no common statistical standard. There have been many efforts to calculate these figures but they have significant drawbacks. In this part, we illustrate relevant research results, which we adopted for different regions, to address the dataset resources of infrastructure spending.

We relied on the shares of GDP reported in Yepes 2008 for East Asia and the Pacific (6.8%; original source: Gill and Kharas 2007); for South Asia (4.2%) we used estimates of India's public infrastructure spending from L. Andres (Pers. Com.); for LAC (1.2%) from original data collection efforts. These shares were applied to 2011 GDP figures from the World Development Indicators. Figures for Sub-Saharan Africa are from Foster and Briceño-Garmendia (2010). For ECA we assumed investments share was similar to that of Latin America; for MENA, where no data was available either, we used the weighted sample average (4.2%). No data are available on how much is spent on maintenance except in Africa where O&M represents 45% of total expenditure on infrastructure (Foster and Briceño-Garmendia 2010).