Policy Research Working Paper 5177

Infrastructure and Economic Growth in Egypt

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January 2010

Abstract

In the past half a century, Egypt has experienced remarkable progress in the provision of infrastructure in all areas, including transportation, telecommunication, power generation, and water and sanitation. Judging from an international perspective, Egypt has achieved an infrastructure status that closely corresponds to what could be expected given its national income level. The present infrastructure status is the result of decades of purposeful investment. In the past 15 years, however, a worrisome trend has emerged: Infrastructure investment has suffered a substantial decline, which may be at odds with the country's goals of raising economic growth. Improving infrastructure in Egypt would require a combination of larger infrastructure expenditures and more efficient investment. The analysis provided in this paper suggests that an increase in infrastructure expenditures from 5 to 6 percent of gross domestic product would raise the annual per capita growth rate of gross domestic product by about 0.5 percentage points in a decade's time and 1 percentage point by the third decade. If the increase in infrastructure investment did not imply a heavier government burden (for instance, by cutting down on inefficient expenditures), the corresponding increase in growth of per capita gross domestic product would be substantially larger, in fact twice as large by the end of the first decade. This highlights the importance of considering renewed infrastructure investment in the larger context of public sector reform.

This paper—a joint product of the Middle East and North Africa Region, Social and Economic Development Group (Egypt); and the Macroeconomics and Growth Team, Development Research Group—is part of a larger effort is part of a larger effort to understand the relationship between infrastructure and economic growth.. Policy Research Working Papers are also posted on the Web at http://econ.worldbank.org. The authors may be contacted at nloayza@worldbank.org or rodawara@worldbank.org.

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* This study is part of the Public Expenditure Review process, sponsored by the World Bank in conjunction with the Egyptian Ministry of Finance and funded partly with the Dutch Government's Trust Fund established for this purpose. We also acknowledge the financial support of the Japanese Consultant Trust Fund, which funded Rei Odawara's participation in the project. For insightful advice and support throughout the preparation of the study, we are especially grateful to Santiago Herrera (Lead Country Economist for Egypt). We also thank the useful comments and suggestions provided by Farrukh Iqbal, Xavier Devictor, Michel Bellier, Sherine H. El-Shawarby, Luis Servén, César Calderón, Auguste Kouame, Alex Kremer, Ziad Nakat, Paul Noumba Um, Mustapha Rouis, Andrew Stone, Marijn Verhoeven, and other colleagues and seminar participants at the World Bank. We gratefully recognize the Egyptian Center for Economic Studies (ECES) and its director Dr. Hanaa Kheir-El-Din for hosting the dissemination of the study in Cairo; and Dr. M. Fathy Sakr (Principal Advisor to the Minster of Economic Development), Eng. Fawzeya Abou Neema (First Under-Secretary, Ministry of Electricity), and other participants of the ECES seminar for their valuable feedback and suggestions. Tomoko Wada provided excellent research assistance. The views expressed in this paper are those of the authors and do not necessarily reflect those of the World Bank, its Board of Directors, or the countries they represent.

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I. Introduction

Over the last five decades, infrastructure in Egypt has experienced a remarkable improvement. This has undoubtedly supported the relatively strong economic growth performance of the country, as well as contributed to the progress in social and economic well-being of its citizens. Despite this progress, in the last years there has been a slowdown or even a decline in some areas of infrastructure, particularly power generation and transportation. Associated with this decline, capital expenditures in Egypt have been reduced in the last decade, raising concerns that the country may have reached an unsustainably low level of infrastructure investment.

This paper analyzes the situation, trends, and effects of infrastructure in Egypt. It does so by placing the Egyptian experience in an international context. The paper examines the major sectors of infrastructure, including electricity generation, transportation, telecommunication, and water and sanitation. It assesses how infrastructure measures in Egypt currently compare with the rest of the world, particularly countries at similar level of economic development. It also reviews the historical trends in these infrastructure measures and projects their likely improvement in the future. Then, the paper describes the trends in infrastructure expenditures in Egypt, comparing to the extent possible their differing patterns across types of infrastructure and for different times in the last five decades. To serve as benchmark, the paper also presents the trends in infrastructure expenditures in a few other countries, paying special attention to the increasing role in private investment in certain infrastructure sectors.

The paper links the progress in infrastructure with an increase in the rate of economic growth in the country. This is a central task of the paper. It consists of first estimating how infrastructure investment expenditures have led to infrastructure improvements and this, in turn, to higher economic growth. Estimating the connection between expenditures and growth cannot be done in a single step for lack of sufficient data. Thus, it is done in two steps. First, using panel (cross-country and time-series) data, the paper estimates the link between the level of infrastructure and economic growth.

Using panel data allows considering various complexities in assessing the impact on economic growth, chief among them controlling for the effect of other growth determinants. In the second step, the paper evaluates how expenditures in infrastructure translate into improvements in the level of infrastructure. This is a limited and direct exercise for which only Egypt-specific data are used. Focusing on Egypt is both a necessity (given that comparable data do not exist for a sufficiently large group of countries) and an advantage (given that the expenditure-improvement connection may vary significantly across countries). The paper takes great care to make the two chains in the estimation process consistent with each other. For instance, the choice of infrastructure measures used in the growth analysis is driven by the existing data on infrastructure expenditures in Egypt. Since the latter are historically presented for only two categories, power generation and transport/telecommunication, the paper constructs indices of the level of infrastructure aggregated at exactly those categories.

Then, using the estimates just described, the paper generates some projections for the likely impact of further increases in infrastructure expenditures on the rate of economic growth of Egypt. It considers a couple of scenarios, including a moderate and a strong increase in expenditures. In assessing the growth impact of higher infrastructure investment, the paper considers the importance of evaluating the fiscal burden that these expenditure increases may entail.

The rest of the paper is structured as follows. Section II provides a review of the literature on, first, the connection between infrastructure and economic growth across the world, and, second, related issues that are especially important to Egypt. Section III analyzes the situation of infrastructure in Egypt, introducing indicators that quantify and place the Egyptian situation in an international context. Section IV presents some new results on the relationship between infrastructure measures and economic growth. Section V reviews the trends in infrastructure expenditures in the country, analyzes how they are related to improvements in infrastructure measures, and finally estimates the economic growth impact of further infrastructure improvements in Egypt**.** Section VI presents a summary of the paper and offers some concluding remarks.[1]

[1] The appendices provide information on sources of data used in the paper, present additional cross-country comparisons, describe details on econometric methodologies, and present additional regression analysis.

II. Literature Review

A. The Impact of Infrastructure on Growth

The impact of infrastructure on long-run economic growth has been studied extensively. The basic theoretical framework of the impact of public capital on economic growth was developed first by Arrow and Kurz (1970). Based on this framework, the endogenous growth literature shows that an increase in the stock of public capital can raise the steady state growth rate of output per capita, with permanent growth effects (Barro 1990, 1991, and Barro and Sala-I-Martin, 1992). Other studies focus on the differential impact of capital and current components of public spending on growth (Devarajan et al., 1996), showing a positive effect from capital expenditures and often negative effects from current or consumption expenditures.

The body of empirical literature on infrastructure and its link to economic performance has adopted various estimation methodologies on a variety of data (panel and time series data) and measures of infrastructure.[2] A majority of the literature finds a positive impact on the relationship between infrastructure and output, growth, or productivity. However, the results largely depend on the measures of infrastructure employed in the analysis. The empirical literature uses various measures of infrastructure such as physical units of infrastructure, stocks of public capital, and infrastructure spending flows.[3] Straub (2008) claims that the positive effect of infrastructure on growth is often obtained when physical indicators of infrastructure are used. The results are not so clear when infrastructure spending flows are used as proxies for infrastructure.[4] This might be due to the fact that political and institutional factors (i.e. inefficient government) (not the level of infrastructure investment) often affect the level of infrastructure stocks

[2] Empirical studies in regards to the impacts of infrastructure on growth and productivity include: Aschauer (1989), Easterly and Rebelo (1993), Canning and Fay (1993), Canning (1999), Sanchez-Robles (1998), Demitriades and Mamuneas (2000), Roller and Waverman (2001), Esfahani and Ramirez (2003), Calderon (2008), Calderon and Serven (2004, 2008).

[3] Some studies use the indices of infrastructure as proxy for infrastructure. Sanchez-Robles (1998) constructs an index of infrastructure stock by using transportation facilities, electricity generating supplies, and communications. Calderon (2008) and Calderon and Serven (2004, 2008) build synthetic indices that captures the stock of the different types of infrastructure assets and the quality of service in different infrastructure sectors.

[4] Straub (2008) surveys both theoretical and empirical papers linking infrastructure and growth.

and the quality of services in different infrastructure sectors, particularly in developing countries.

Calderon and Serven (2008) and Calderon (2008) analyze the impact of infrastructure on economic performance of African countries. Using panel data for a large sample of countries for the period 1960-2005, they employ growth regressions estimated through a Generalized Method of Moments estimator and evaluate the impact of several types of infrastructure assets, as well as measures of quality of their services. Their findings suggest that both infrastructure stock and quality are positively and significantly related to real GDP per capita growth. In addition, the latter study evaluates the impact of a higher infrastructure development in African countries over the last 15 years (comparing 2001-05 to 1991-1995). At the country level, Egypt has attained the largest contribution of infrastructure development to growth (1.51%) among Northern African countries, with a rate higher than the average of the Africa region (0.99%).

Finally, infrastructure also affects economic performance through an indirect channel related to income distribution. Higher access to infrastructure services often helps reduce income inequality by lowering logistics costs or raising the value of human capital or land (Estache, Foster and Wodon, 2002, Estache (2003), Calderon and Chong, 2004, Calderon and Serven, 2004a, 2008, Galiani et al., 2005).

B. The Impact of Infrastructure in Egypt

The share of public investment to GDP in the Middle East and North Africa (MENA) region exceeds other regions in the developing world. In particular, historically Egypt has had a high share of public investment in infrastructure even among MENA countries. Over the last few decades, however, public infrastructure investment in Egypt has been falling, and the decline in public investment has not been compensated by a rise in private investment.[5]

Reflecting the specific situation of Egypt, the impact of infrastructure in the country has been discussed from the following perspectives in the literature. 1)

[5] IFC (2003) reports that private participation in infrastructure investment in the MENA region declined in the 2000s compared to the 1990s and in fact its cumulative investment for 1990-2001 is smaller than other regions, even smaller than Sub-Saharan Africa. The World Bank (2003) concludes that the MENA region especially suffers from an unfavorable investment environment that prevents private participation in the last decade.

infrastructure as one of the determinants and binding constraints of growth performance, 2) the importance of infrastructure in order to improve the business climate and encourage private participation in the economy, and 3) the effect of infrastructure on private investment.

The first strand of the literature attempts to identify the determinants and constraints of economic performance in Egypt over time. Using diagnostic approach developed by Hausmann, et al. (2005) and growth regressions, Dobronogov and Iqbal (2005)[6] and Enders (2007) find that inadequate infrastructure is not among most urgent binding constraints in Egypt, but inefficient financial intermediations and high public debt are critical growth constraints.[7]

Kamaly (2007) analyzes the sources of growth in Egypt for the last three decades (1973-2002)[8]. Using a new consistent estimate for capital stock and growth accounting technique, he claims that capital stock seems to be the most important source of growth, and the downward trend in real output growth since the 1980s could be attributed to the slowdown in capital growth, including infrastructure.

Nabli and Vefganzounes-Varoudakis (2007) investigate the linkage between economic reforms, human capital, infrastructure, and economic growth in the MENA region.[9] Employing growth regressions that include different composite indicators of infrastructure[10] on panel data consisting of 44 countries from 1970 (or 1980) to 1999, they find that the contribution of infrastructure on growth is substantial. At the country level, comparing the period for 1980-89 to 1990-99, the contribution of infrastructure to growth in Egypt fell from 1.0 to -0.9, while that of the average of MENA countries fell from 1.4 to 1.0. The drop in the contribution from infrastructure in Egypt was due to the decline in their measure of road networks experienced in the 1990s.

[6] They conducted growth regressions that determine Egypt's GDP per capita growth for 1986-2003 on key variables, but they did not include infrastructure as one of explanatory variables.
[7] Egypt has a dense road network, including the new Cairo-Alexandria highway, major ports in Suez and Alexandria, and a new airport in Cairo. Electricity is cheap and highly subsidized, as is natural gas (Enders, 2007).
[8] Kheir-El-Din and Moursi (2003) also examined the growth experience in Egypt by using the data from 1960-1998.
[9] They generate the aggregate indicators for economic reforms, human capital, and physical infrastructure using principal component analysis.
[10] The physical infrastructure indicator is based on the density of the road network (in km per km^2) and the number of phone lines per 1,000 people (both are in logs).

As for the second strand of the literature, the World Bank report (2008) emphasizes the importance of securing long-term fiscal sustainability in its basic infrastructure sectors while sustaining the quality of service delivery in them. Moreover, Ragab (2005) argues that better performance of infrastructure and more efficient regulatory framework are critical to improve the business climate and promote private domestic and foreign investment in Egypt.

The third strand of the literature has analyzed the effects of public investment on private capital formation to identify whether public infrastructure investment complements or crowds out private investment in Egypt. The majority of previous studies on this topic find a positive impact of public infrastructure investment on private investment. Shafik (1992) claims that public investment tends to crowd in private investment through infrastructure investment in Egypt. Dhumale (2000) finds a positive effect of public infrastructure investment on private investment in the non oil-exporting countries (including Egypt) within the MENA region, while a crowding out effect in oil-exporting countries. In a recent paper, Agenor et al. (2005) investigate the impact of public infrastructure on private investment in three countries in the MENA region (Egypt, Jordan, and Tunisia). They use a vector auto regression (VAR) model that accounts for both the flows and stocks of public infrastructure and controls for simultaneous interactions between these variables and private credit, output, and the real exchange rate.[11] The impulse response analysis indicates that public infrastructure has both flow and stock effects on private investment in Egypt.

III. The State of Infrastructure in Egypt: International Context

A. Cross-Country Comparison Using Current Data

We start by presenting cross-country data of various infrastructure indicators for different sectors in order to compare the performance of Egypt with the rest of the world.

[11] They propose two aggregate quality indicators of infrastructure: an "ICOR-based" and "excess demand" measures. They combine these two quality indicators in order to derive the composite index by using the principal component analysis technique.

We collect a pooled data set of cross-country observations for 150 countries[12] using the latest available data of each indicator. As for the measures of infrastructure assets, we select different indicators in stock and quality of services from four infrastructure sectors: transport, telecommunications, electricity, and water and sanitation. All the indicators used in this section are the following.

(a) Transport: total road length in km, normalized by square root of the county's 1,000 workers multiplied by its mean arable land[13] (in logs), paved roads (the ratio to total road length), quality of roads, quality of railroads, quality of port facilities, and quality of air transport.

(b) Telecommunications: main phone lines per 1,000 workers (in logs), cell phone lines per 1,000 workers (in logs), telephone faults per 100 main lines, and waiting list for main line installation as ratio of main lines[14].

(c) Electricity: electricity generating capacity (EGC), megawatts per 1,000 workers (in logs), power loss (% of total output), access to electricity (% of electrification rate), and quality of electricity supply.

(d) Water and sanitation: access to improved water source (% of population with access), and access to sanitation facilities (% of population with access).

Figure 1 provides correlations between various indicators for different infrastructure sectors by using per capita real income level (average of 1995-2007) in PPP terms and indicates the expected level of different infrastructure indicators at a given level of economic development across countries. Panels (a) through (c) display that Egypt is located above or on the predicted regression line, except for total road length and

[12] In this exercise, we exclude countries with less than 1 millions population. The pooled data set is unbalanced.
[13] The country's arable land varies over time. Thereby, we use mean arable land for the period 1971-2005 for each country.
[14] This indicator serves as a proxy of unmet demand for main line installation.

access to sanitation facilities, which are located just below the line[15]. The results suggest that Egypt has attained (or exceeded for some cases) the level of infrastructure performance, expected to achieve at a given level of development in comparison with the rest of the world.

In Appendix 2, we provide two additional sets of figures to examine whether these results remain the same when we compare Egypt with a group of fast growing countries[16] (in Figure 1-A), and when we use per capita real income growth (in Figure 1-B) instead of per capita real income level. The former confirms that infrastructure performance in Egypt has achieved what is expected (or more than expected in some cases) at a given level of development even compared with a group of fast growing countries.

[15] As for telephone faults, waiting list, and power loss, the lower value means high quality in services. Thereby, Egypt being below the predicted regression line indicates that the performance of these indicators in Egypt is better than the expected level at a given level of economic development.

[16] There is a criteria used to select the sub-group of countries. Using real GDP per capita data for 1983-2005, we calculate average growth rates for each country. The sub-group consists of countries that satisfy greater than median real growth rates, which are close to the average real growth rates of Sweden (0.019).

Figure 1. Full-sample, correlations between infrastructure indicators vs per capita GDP, PPP (constant 2005 int'l $)

(a) Transport

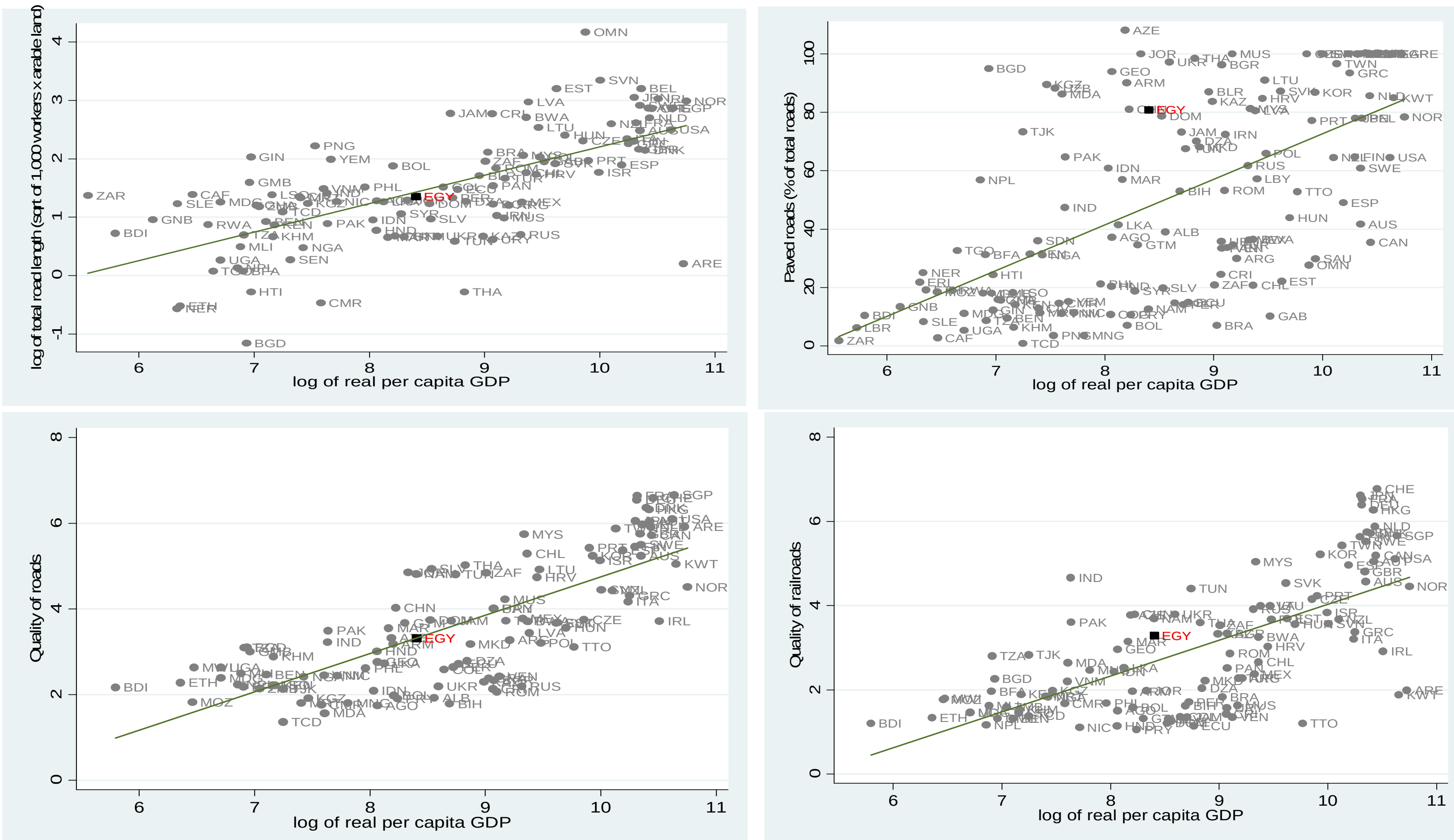
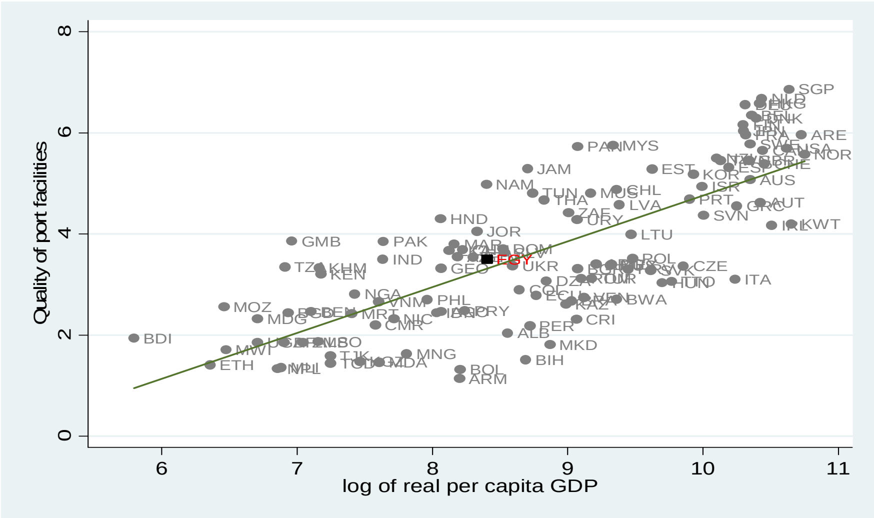


Figure 1 (continued). Full-sample, correlations between infrastructure indicators vs per capita GDP, PPP (constant 2005 int'l $)

(a) Transport (continued)



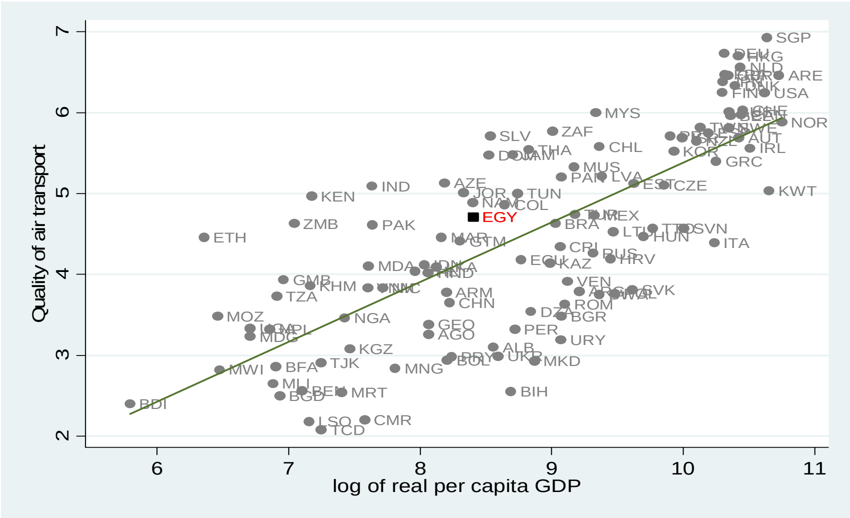


Figure 1 (continued). Full-sample, correlations between infrastructure indicators vs per capita GDP, PPP (constant 2005 int'l $)

(b)Telecommunications

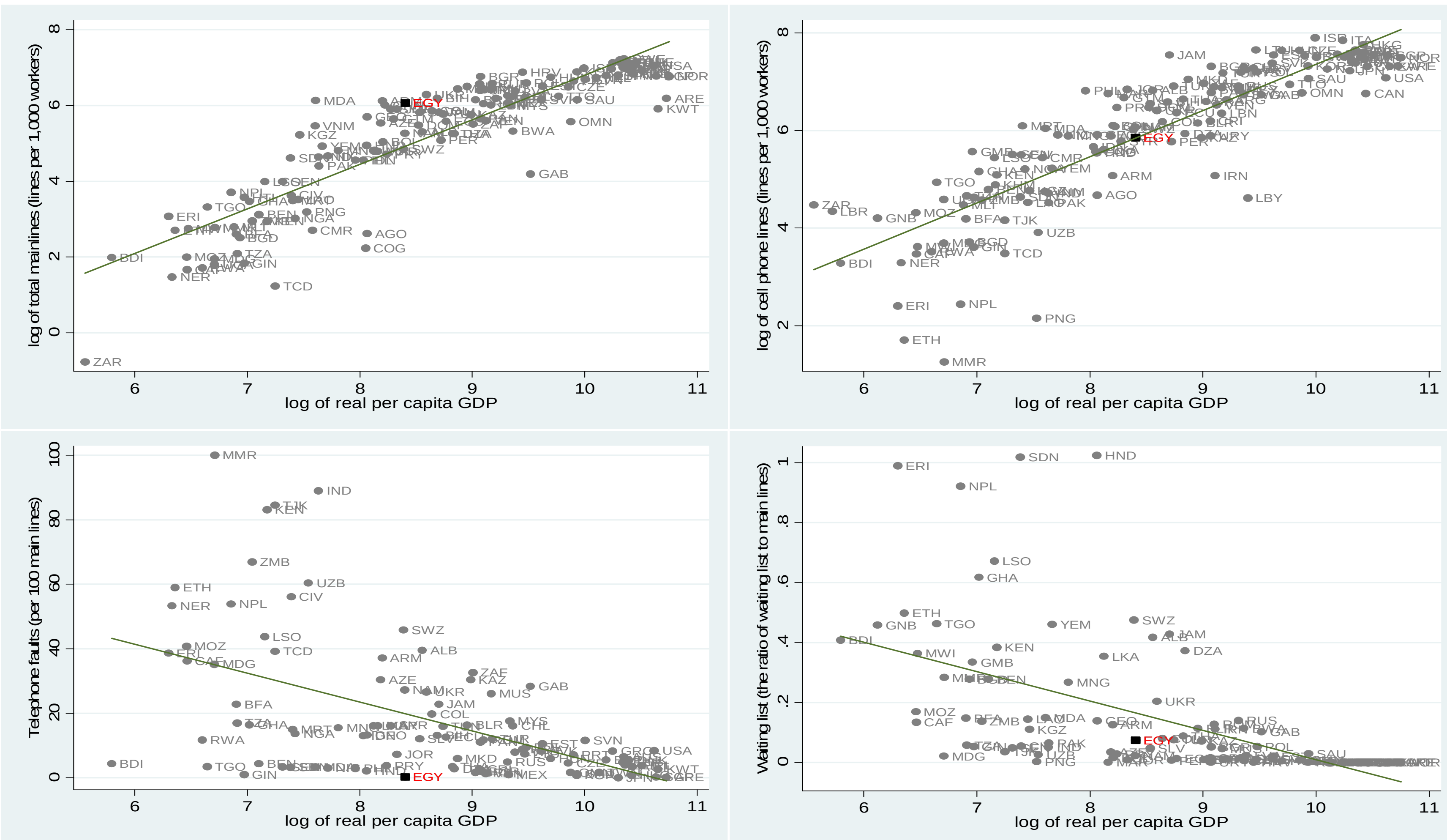


Figure 1 (continued). Full-sample, correlations between infrastructure indicators vs per capita GDP, PPP (constant 2005 int'l $)

(c) Electricity

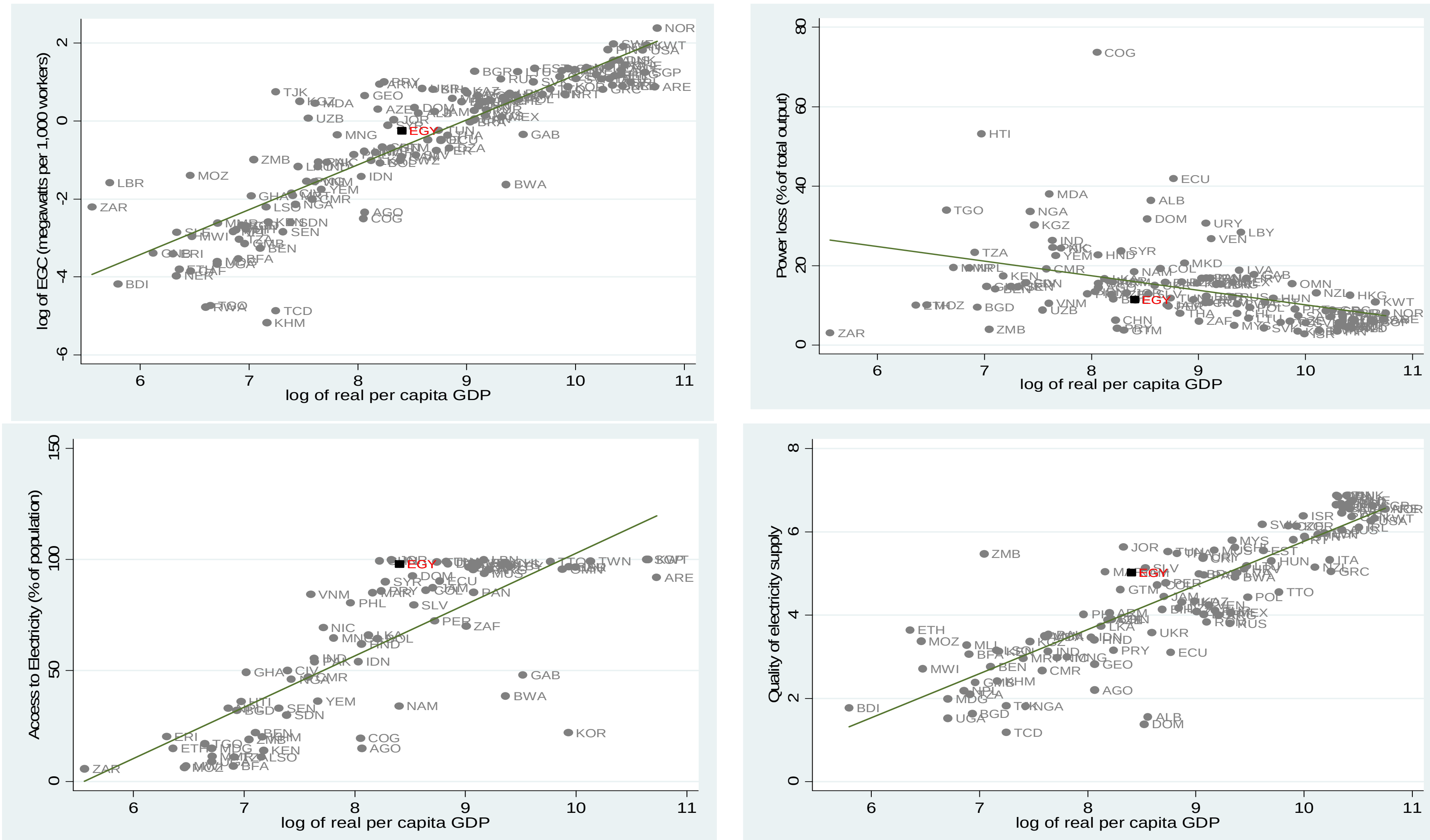
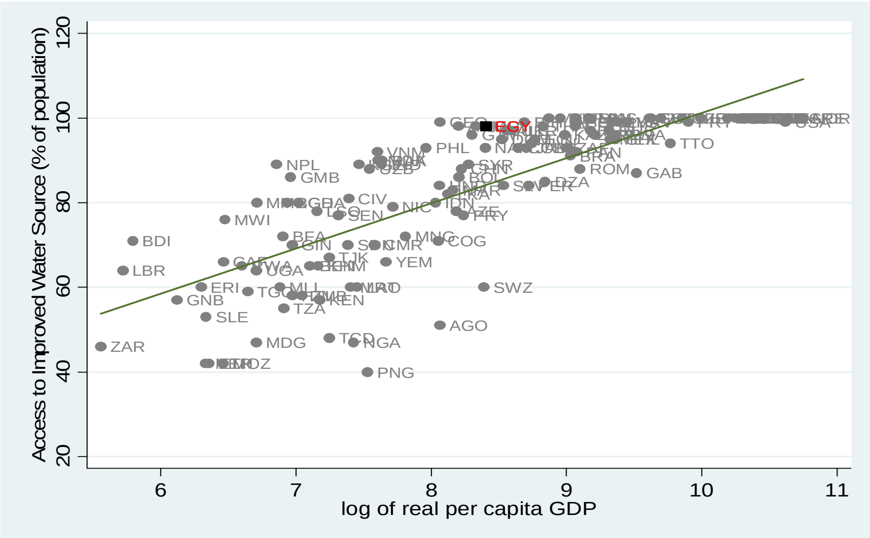


Figure 1 (continued). Full sample, correlations between infrastructure indicators vs per capita GDP, PPP (constant 2005 int'l $)

(d) Water and Sanitation



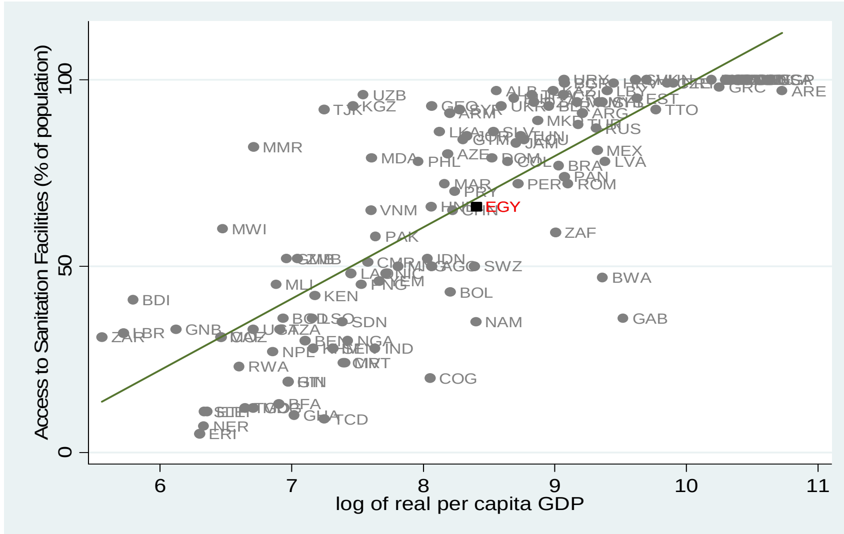


Table 1. Definitions and Sources of Infrastructure Quantity and Quality Indicators

Variable	Definition	Year	Source
roads	Length of total roads (km, sqrt of 1,000 workers x mean arable land for 1971-2005)	2004	International Road Federation (IRF)
paved roads	Paved roads (the ratio of paved roads to total road length)	2004	International Road Federation (IRF)
ml	The number of main phone lines (per 1,000 workers)	2004	Int'l Telecommunications Union (ITU)
cell	The number of cell phone lines (per 1,000 workers)	2004	Int'l Telecommunications Union (ITU)
telf	Telephone faults (the number of reported telephone faults for the year per 100 main phone lines)	Avg. of 2001-06	Int'l Telecommunications Union (ITU)
wl	Waiting list for main line installation (the ratio of waiting list to main lines)	Avg. of 2000-04	Int'l Telecommunications Union (ITU)
egc	Electricity generating capacity (megawatts, per 1,000 workers)	2004	Statistical Yearbook, United Nations. US- Energy Information Administration
pl	Power loss (% of total output)	2004	WDI, The World Bank.
q_roads	Quality of roads	2006	Global Competitiveness Report
q_railroads	Quality of railroads	2006	Global Competitiveness Report
q_ports	Quality of port facilities and inland waterways	2006	Global Competitiveness Report
q_air	Quality of air transport	2006	Global Competitiveness Report
q_elec	Quality of electricity supply	2006	Global Competitiveness Report
elec_accesss	Access to electricity: Electrification rate (%)	2006	World Energy Outlook
water	Access to water: Improved water sources (% of population with access)	2006	WDI, The World Bank.
sanitation	Access to sanitation: Improved sanitation facilities (% of population with access)	2006	WDI, The World Bank.

Table 2 displays pairwise correlations of the components of infrastructure by sector (used in Figure 1) and the correlations between the representative components from each sector. As shown in the top panel of Table 2, all the components within sector are significantly mutually correlated at either the 5 or 10 percent level of significance. The bottom panel also indicates that the representative components are correlated across sectors at the 5 percent significance level.

Among all the indicators listed above, our main focus is on the following five indicators: total road length in km per square root of the country's 1,000 workers multiplied by its mean arable land, paved roads as ratio of total road length, the number of main phone lines per 1,000 workers, electricity generating capacity in megawatts per 1,000 workers, and power loss (% to total output). These five indicators are used to construct sectoral infrastructure indices for transport, telecommunications, and electricity, which are explained in detail in Part C in this section. The definitions and sources of the entire set of infrastructure indicators used in Figure 1 as well as Figures 1-A and 1-B in Appendix 2 are shown in Table 1.

B. Cross-Regional Comparison Using Trend Data

In this section, we assess the time trends in the main infrastructure indicators over the last few decades, comparing Egypt with developing countries as well as the group of both developing and developed countries (called "World").

We select five main indicators of infrastructure quantity and quality from the three core infrastructure sectors, transport, telecommunications, and electricity. A quality indicator for telecommunications, telephone faults per 100 main lines, is excluded as the time dimension of the indicator is very limited and is only available for the last few years[17].

[17] The cross-country comparison of telephone faults by using the most recent data is shown in Panel (b) of Figure 1.

Table 2. Pairwise correlation of infrastructure measures

1.) Components by sector

(a) Transport

	roads (in logs)	paved roads	q_roads	q_railroads	q_ports	q_air
roads (in logs)	1					
paved roads	0.2701**	1				
q_roads	0.5106**	0.5382**	1			
q_railroads	0.5787**	0.5787**	0.7769**	1		
q_ports	0.5487**	0.4610**	0.8900**	0.7579**	1	
q_air	0.5506**	0.4737**	0.8565**	0.6957**	0.8690**	1

(b) Telecommunications

	ml (in logs)	cell (in logs)	telf	wl
ml (in logs)	1			
cell (in logs)	0.8223**	1		
telf	-0.4902**	-0.5916**	1	
wl	-0.3950**	-0.4665**	0.1866*	1

(c) Electricity

	egc (in logs)	pl	q_elec	elec_access
egc (in logs)	1			
pl	-0.4230**	1		
q_elec	0.7331**	-0.6391**	1	
elec_access	0.8295**	-0.2005*	0.6069**	1

(d) Water & Sanitation

	water	sanitation
water	1	
sanitation	0.8112**	1

Notes:
** denotes the significance level at 5 percent, and * at 10 percent.

2.) The representative component from each sector

	roads (in logs)	ml (in logs)	egc (in logs)	water
roads (in logs)	1			
ml (in logs)	0.5727**	1		
egc (in logs)	0.6374**	0.8727**	1	
water	0.4902**	0.8644**	0.7785**	1

Notes:
** denotes the significance level at 5 percent, and * at 10 percent.

Panels (a) through (e) of Figure 2 display the evolution of the main infrastructure indicators[18]: the length of total roads per square root of the country's 1,000 workers multiplied by its mean arable land (in km), paved road (the ratio to total road length), the number of main phone lines per 1,000 workers, and EGC per 1,000 workers (in megawatts), and power loss (percentage of total output), respectively. In each case, the group median for each decade is shown.

Transport:

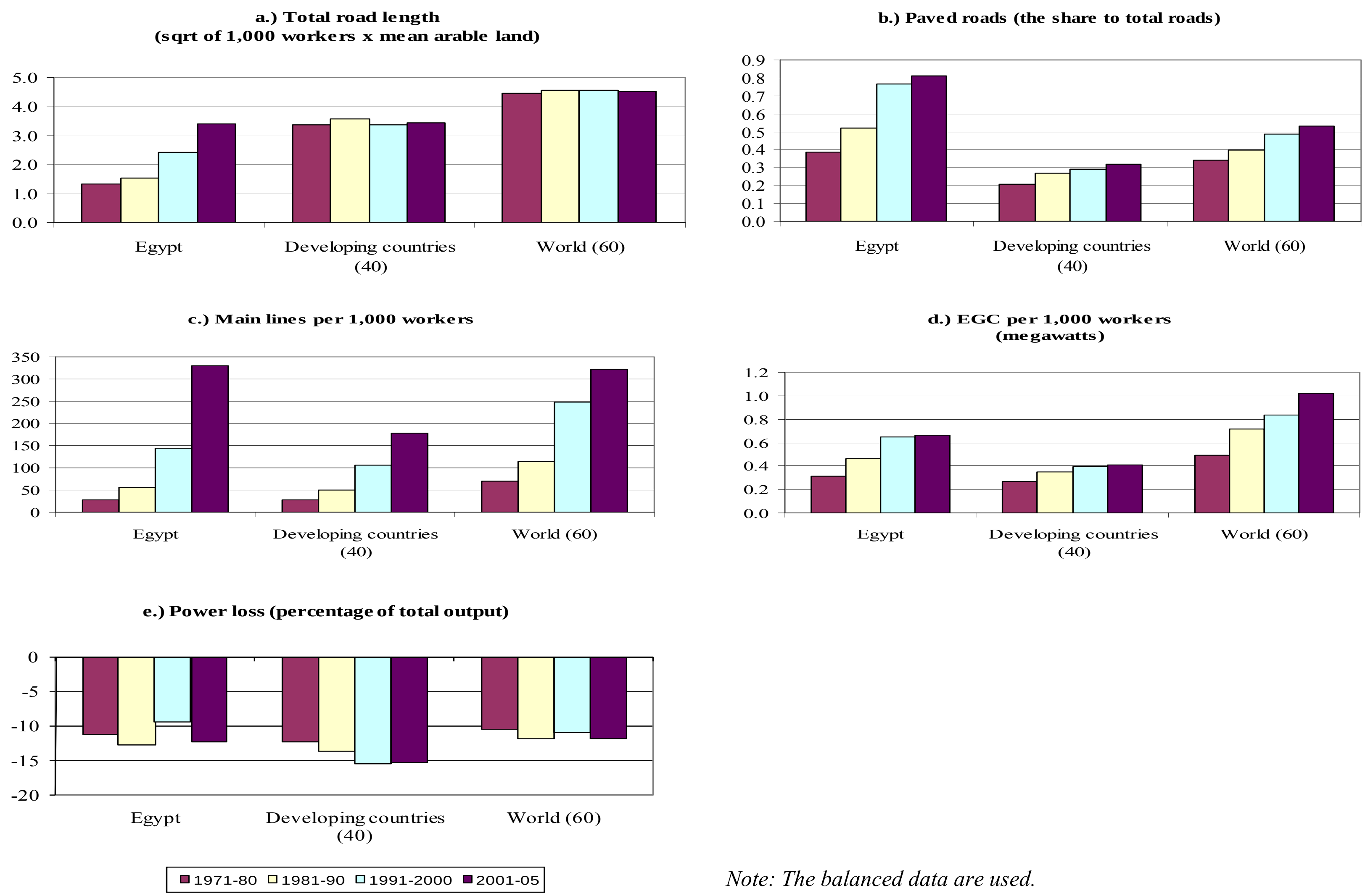
Panel (a) presents road networks as a measure of transport stock and the ratio of paved roads to total road length as a proxy of transport quality, respectively. We normalize the measure of transport stock, dividing it by the square root of the country's 1,000 labor force times its mean arable land. Although Egypt has lagged behind the other two groups in terms of total road length since the 1970s through the 1990s, the growth in total road length drastically picked up in the 1990s onwards, while that in the other two groups has stagnated. As Panel (b) shows, Egypt has far exceeded the typical country in the two comparator groups regarding the ratio of paved roads to total road length.[19]

Telecommunications:

Egypt experienced rapid growth in its quantity indicator of telecommunications over time. As for the number of main lines in Panel (c), the gap between Egypt and World has significantly narrowed in the latest period.

[18] The balanced data is used for all five indicators.
[19] We also normalized total road length by 1,000 workers and obtained very similar results to those in Panel (a).

Figure 2. Transition of main infrastructure indicators over time (medians)



Note: The balanced data are used.

Electricity:

Panel (d) shows the trends in EGC per 1,000 workers (in megawatts). Egypt exceeds developing countries in this measure, but has fallen far behind World. The gap between Egypt and World has even widened in the recent period as growth in EGC has stagnated in Egypt since the 1990s. The quality indicator of electricity, power loss (in percentage of total output), displayed in panel (e), improved in the 1990s, but it reversed to the 1980s level in the most recent period.[20] Although a decline in electricity quality seems to be a worldwide trend, the electricity sector in Egypt shows some signs of weakening in both indicators of quality and quantity.

C. Infrastructure Indices by Sector

Some empirical literature that studies the impact of infrastructure on economic performance uses a single infrastructure sector (i.e. the number of main lines for telecommunications) as a proxy for infrastructure.[21] Others build aggregate indices of infrastructure quantity and quality that capture the stock of different types of infrastructure assets and the quality of services in different infrastructure sectors separately (i.e. quantity and quality indices for telecommunications).[22]

In this paper, however, instead of focusing on a single sector or building synthetic indices capturing either quantity or quality aspect of infrastructure assets, we construct indices by major infrastructure sectors that simultaneously capture both quantity and quality features of infrastructure. In order to build the sectoral indices, we combine the information of quantity and quality indicators for the following three sectors, respectively: transport, telecommunications, and electricity.[23]

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[20] The measure of power loss is transformed in a way such that an increase in value indicates an improvement in quality.

[21] Easterly (2001) and Loayza, et al (2005).

[22] In a series of works by Calderon (2008) and Calderon and Serven (2004, 2008), they constructed synthetic indices of infrastructure quantity and quality, which consist of quantity and quality indicators from the three infrastructure sectors: roads, telecommunications, and power.

[23] In order to construct the indices, we used time series data for infrastructure stock and quality indicators in Egypt. When we closely checked the original data, we encountered some issues. That is, some indicators had missing observations, and others fluctuated in an unreasonable way over time. In order to solve these problems, we first interpolated the missing observations for the length of roads and the paved road ratio to

The construction of a single infrastructure index per sector is based on the assumption that both quantity and quality aspects of infrastructure assets are closely related to and even depend on each other. Consider for example, the electricity sector: higher power loss (a proxy for quality) may be caused by having too few power plants in the country and thereby not holding enough electricity generating capacity (a proxy for quantity) to satisfy the electrical power demand.

For the transport index, we select the length of total roads in km as a measure of quantity and the ratio of paved roads to total roads as a proxy for quality. As for the communications index, we use the number of main lines for the physical measure of communications. As mentioned earlier, the time series coverage of the quality indicator of telecommunications (telephone faults per 100 main lines) is very limited, and thereby only the physical measure of telecommunications is used to construct the index. Lastly, the electricity index consists of electricity generating capacity (EGC) in megawatts and power loss (percentage of total output) for quantity and quality indicators, respectively. All stock measures are normalized by 1,000 workers and then transformed in logs. The exception is total road length, which is normalized by square root of the country's 1,000 workers multiplied by its surface area.

Table 3. Variance by Sector Using Principal Component Analysis

Sector	Variance
Transport	0.7231
Telecommunications	1.000
Electricity	0.7330
Transport & Telecommunications	0.9018

In order to standardize the components for each sector, we use the principal component analysis (PCA) technique, which allows us to obtain a series of uncorrelated and normalized linear combinations of the components for each sector. We standardize a

total road. Then, we smoothed out some indicators (power loss and paved road ratio), so that the time path in each component became relatively smooth.

pair of quantity and quality indicators for each sector (only a quantity indicator for telecommunications), and then obtain the new index. The principal component for each sector explains over 70 percent of the variance of the underlying individual indicators, as shown in Table 3.

Once the three indices are constructed, the transport and telecommunications indices are combined and transformed into a single new index by using principal component analysis again. These infrastructure indices: the electricity index, the transportation index, telecommunications index, and a combined transport and telecommunications index are used in order to investigate both the effect of infrastructure on economic growth and the relationship between the performance of infrastructure assets and infrastructure expenditures in each sector (to be presented in Sections IV and V).

We now observe the transition of the combined transport and telecommunications and electricity indices with respect to Egypt's own history for 1971-2005, given in the top left panel of Figure 3. Panels (a) through (c) illustrate the time paths of all five indicators used to construct these indices.

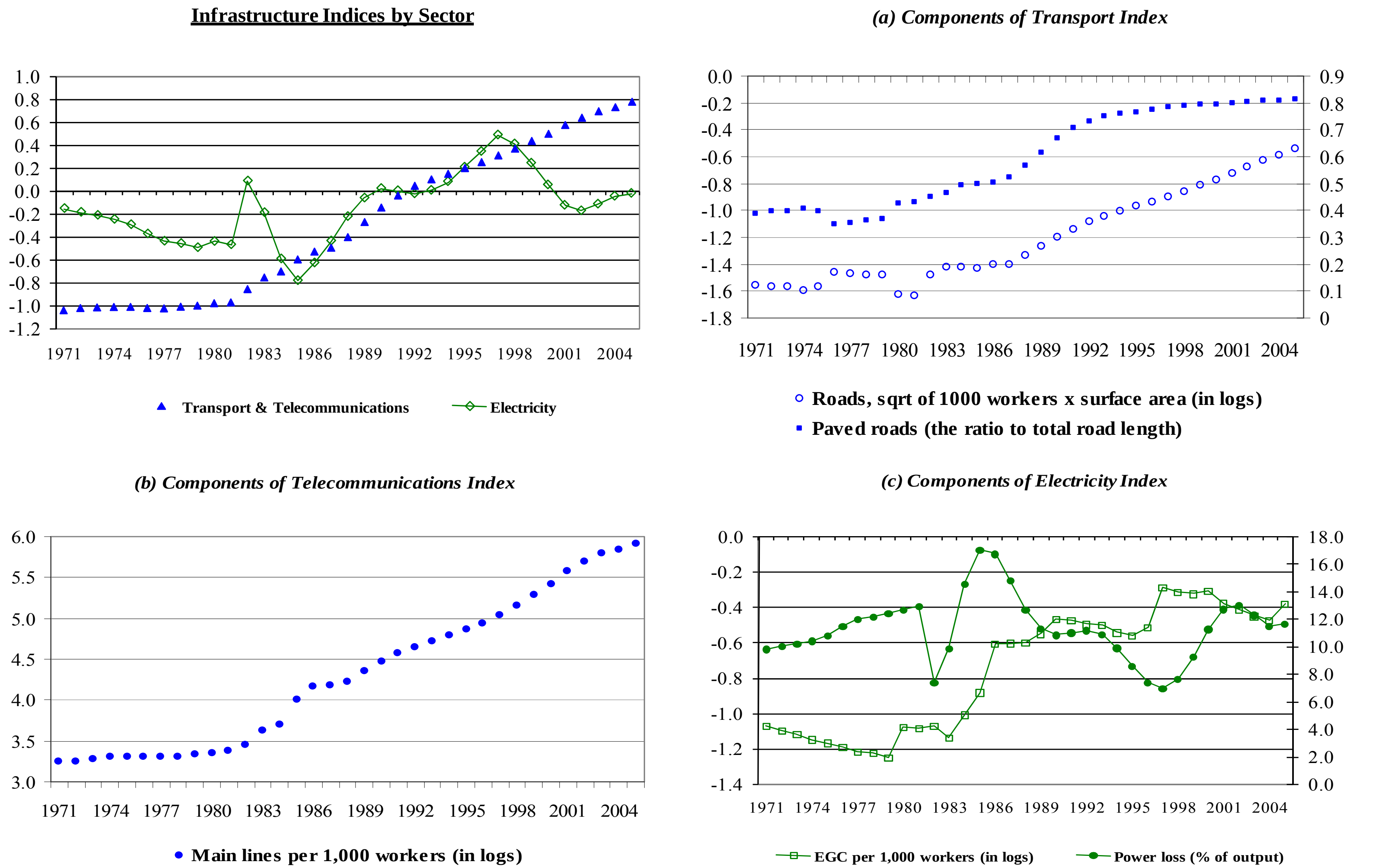
As shown in the top left panel, starting with a negative value, the transport and telecommunications index was clearly on an upward trend after 1981. After turning to a positive value in the early 1990s, the index has continued to rise. In fact, the index rose more than 1.8 point for over three decades. Also starting with a negative value, the electricity index has been falling during the 1970s and through the mid-1980s (except for a sharp increase in 1982). After having a positive turn in the mid-1980s, it has been on a rise along with the transport and telecommunications index for a decade. Reaching its peak in the late 1990s, the electricity index declined until 2002 but has shown some recovery in recent years.

As for the components of transport and telecommunications index, Panels (a) displays a clear upward trend in the length of total roads after the late 1980s, and the ratio of paved roads to total road length after the early 1980s. For the later, a rise in the indicator became slow down in the late 1990s. The number of main lines shown in Panel (b) also illustrates the upward trend, which became more prominent in the early 1980s, and the indictor continued to rise through recent years. Thus, all three components contribute to a continuous improvement in the transport and telecommunications index over the last three decades.

Finally, Panel (c) reveals the quite volatile time path of the electricity index which stems from both components, EGC and power loss. Their trends are clearly more volatile compared to the other three components used to construct the transport and telecommunications index.

Having stagnated during the 1970s through the mid-1980s, EGC finally took off in 1983 and has maintained the level for a decade. After a sharp increase in 1997, it has continued to fall. As for the other component, power loss rose during the 1970s, declined through the mid-1980s, and then recovered till 1997. It then fell until recently, where some signs of improvement are visible.

Figure 3. Infrastructure Indices by Sector in Egypt (1971-2005)



IV. Infrastructure and Growth: Regression Analysis

The purpose of this section is to study the effect of infrastructure on the rate of per capita GDP growth. The goal is to obtain a sensible measure for this effect that can be used in the quantitative projections for Egypt. To perform our estimations, we use pooled cross-country and time-series data covering 78 countries over the period 1961-2005. The data is organized in non-overlapping five-year periods, with each country having at most 9 observations. The panel is unbalanced, with some countries having more observations than others. We build on the panel-data growth regression literature that uses a GMM procedure to address endogeneity and control for unobserved country-specific factors. This was introduced by Arellano and Bond (1991 and 1998) and applied, for example, in Levine, Loayza, Beck (2000) and Dollar and Kraay (2004).[24] The econometric methodology is explained in detail in Appendix 3.

A. Data and Regression Specification

Our point of departure is a standard growth regression equation designed for estimation using (cross-country, time-series) panel data:

$$y_{i,t} - y_{i,t-1} = \beta_0 y_{i,t-1} + \vec{\beta}_1' CV_{i,t} + \beta_2 I_{i,t} + \mu_t + \eta_i + \varepsilon_{i,t} \qquad (4.1)$$

Where the subscripts i and t represent country and time period, respectively; y is the log of output per capita, CV is a set of control variables, and I represents infrastructure; μ_t and η_i denote unobserved time- and country-specific effects, respectively; and ε is the error term. The dependent variable ($y_{i,t}$-$y_{i,t-1}$) is the average rate of real output growth, that is, the log difference of GDP per capita normalized by the length of the period. The regression equation is dynamic in the sense that it includes the level of output per capita ($y_{i,t-1}$) at the start of the corresponding period in the set of

[24] The estimation results presented in the text follow the standard procedure. To check robustness, we applied the standard-error correction proposed by Windmeijer (2005) in exercises not presented here. The qualitative results were, however, the same. In particular, the coefficients related to the infrastructure indices remained statistically significant.

explanatory variables. Unless stated otherwise, all data are obtained from the World Bank's World Development Indicators.

The set of explanatory variables can be divided into four groups. The first consists of the initial level of per capita GDP and is included to capture "transitional convergence," that is, the tendency of economies to grow slower as they become richer and converge to their steady state. The second set of variables accounts for the role of external conditions related to international prices and global economic conditions. To capture changes in international prices, we use the rate of change of the terms of trade; and to account for global conditions, we use a period specific dummy variable. The third group focuses on macroeconomic stability in both aggregate domestic prices and output. It includes the (log of 1 plus) the CPI inflation rate and a measure of "crisis" volatility based on negative deviations of trend beyond a certain threshold (see Hnatkovska and Loayza, 2004, for details).

The fourth group consists of variables that measure structural conditions in areas such as educational investment, financial depth, trade openness, government burden, and infrastructure, the variables of particular interest for this study. Educational investment is measured as (the log of) the gross rate of enrollment in secondary school. Financial depth is proxied by the ratio of private domestic credit by private financial institutions to GDP. The outward orientation of the economy is proxied by (the log of) the volume of trade (exports and imports) to GDP. Government burden is measured as (the log of) the ratio of general government expenditure to GDP. And infrastructure is measured by the indices of electric power generation, transportation, and telecommunications, presented in detail in the previous section.

Except for the variables measuring external conditions, all variables are potentially jointly endogenous with economic growth (that is, caused by previous and current innovations in per capita GDP growth, the dependent variable).

B. Estimation Results

We now present and discuss the estimation results. We present different variations dealing with how the measures of infrastructure are included in the growth regression. Table 4 presents the estimation results when we include the infrastructures indices one at a time. Table 5 presents the results when we include the indices simultaneously in the regression.

To establish the validity of our results in the context of the growth literature, let's start by analyzing the results corresponding to the standard growth determinants and the regression specification tests. In brief, the results are consistent with the previous empirical literature. Initial GDP per capita carries a significantly negative coefficient, commonly interpreted as evidence of "conditional convergence"; that is, holding constant (or conditioning for) structural and stabilization conditions, poorer countries tend to grow faster and, thus, converge towards richer ones. External shocks are also important growth determinants. Specifically, favorable terms-of-trade shocks affect positively economic growth. Representing global conditions, the period shifts (not shown in the tables to save space) indicate that the international trend in economic growth experienced a declining drift over 1960-2005, resulting in less favorable external conditions in the last three decades than in the previous ones.

Suggesting a beneficial impact on economic growth, the proxies of educational investment, depth of financial intermediation, and trade openness have positive and statistically significant coefficients. Government expenditures, price inflation, and crisis volatility, on the other hand, carry negative and statistically significant coefficients, indicating the harmful consequence of government burden and macroeconomic instability.

Finally, regarding the specification tests, the Hansen tests indicate that the null hypothesis of correct specification cannot be rejected, lending support to our estimation results. This is the case for all exercises presented below, and we only mention it here in order to avoid redundancy.

Let's now focus the discussion on the growth effects of infrastructure. As mentioned above, in Table 4 we include the infrastructure indices one at a time. They are, respectively, the electricity index, the transportation index, the telecommunications index, and a combined transportation and telecommunications index. The latter is relevant for our purposes because the historical data for Egypt aggregates investment in transportation and telecommunications. All of them carry positive and significant coefficients. This is a strong indication that infrastructure in general is an important determinant of economic growth. It also suggests that each of the aspects of infrastructure considered in the analysis –electricity, transportation, and telecommunications—is relevant for economic growth. However, this cannot be stated conclusively given that each index can capture the significance of the rest when they are introduced one at a time in the regression. For this reason, we turn to Table 5.

In Table 5, the infrastructure indices enter simultaneously in the regression. In the first column, we introduce the electricity, transportation and telecommunications indices together. In the second column, we replace the latter two by the combined transportation and telecommunication index. Interestingly, all infrastructure indices carry positive and statistically significant coefficients. This indicates that each aspect of infrastructure considered here is a relevant determinant of economic growth. The size of the estimated coefficients is also informative. The coefficients presented in Table 5 are much smaller than those in Table 4, where the indices were introduced one at a time. This confirms the conjecture mentioned above that each index represents not only its own specific area but, to some extent, overall infrastructure.

In the next section, we consider in detail the quantitative importance of the estimated coefficients for the Egyptian case. Here we only consider two brief exercises. For both, we use the estimated coefficients presented in Table 5, column 1, where the three basic indices and included simultaneously in the regression. The first exercise is to consider the growth effect of changing each of the indices by 1 standard deviation of its world sample distribution. The estimated effects of this improvement are 0.89 percentage points of per capita GDP growth for electricity, 1.24 for transportation, and 1.26 for telecommunications. The second exercise is to measure the growth effect of changing each of the indices from the 25^{th} to the 75^{th} percentile of its world sample distribution. This is a much larger improvement and, therefore, the estimated growth effects are correspondingly stronger. They are 1.23 percentage points of per capita GDP growth for electricity, 2.05 for transportation, and 2.08 for telecommunications.

Table 4. Economic Growth and Infrastructure – Individual Effects

Sample: 78 countries, 1961-2005 (5-year period observations)
Estimation Method: System GMM

	Dependent Variable: GDP per capita Growth			
	[1]	**[2]**	**[3]**	**[4]**
Infrastructure Variables:				
Electricity Index[1]	1.539 ***			
	[6.436]			
Transportation Index[2]		2.45 ***		
		[5.631]		
Telecommunication Index[3]			1.476 ***	
			[6.687]	
Transportation & Telecommunication Index[4]				2.81 ***
				[7.171]
Control Variables:				
Initial GDP per capita	-1.592 ***	-2.072 ***	-1.512 ***	-2.688 ***
in logs	[-5.175]	[-5.900]	[-7.133]	[-7.576]
Education	0.949 **	1.008 ***	0.239	0.367
secondary school enrollment rate, in logs	[2.424]	[2.973]	[0.813]	[1.186]
Financial Depth	0.403 **	0.719 ***	1.206 ***	1.075 ***
private credit/GDP, in logs	[2.114]	[4.226]	[7.165]	[5.925]
Crisis Volatility	-1.876 ***	-1.734 ***	-1.937 ***	-1.761 ***
std dev of GDP per capita growth[5]	[-15.070]	[-15.400]	[-20.300]	[-16.120]
Government Burden	-0.919 *	-0.224	-0.274	0.102
government expenditure/GDP, in logs	[-1.957]	[-0.429]	[-0.611]	[0.213]
Inflation	-0.227	-2.033 ***	-3.036 ***	-2.841 ***
1+Growth rate of CPI, in logs	[-0.362]	[-3.189]	[-5.071]	[-4.561]
Trade Openness	4.221 ***	2.062 ***	1.287 **	1.586 ***
(exports+imports)/GDP, in logs	[9.487]	[4.358]	[2.432]	[3.504]
Growth rate of Terms of Trade	0.038 ***	0.035 ***	0.046 ***	0.045 ***
log differences of terms of trade index	[3.294]	[2.942]	[4.167]	[4.019]
Constant	0.733	16.826 ***	21.379 ***	26.997 ***
	[0.208]	[3.624]	[5.036]	[5.750]
Observations	522	522	522	522
Number of Countries	78	78	78	78
Number of Instruments	58	58	58	58
Arellano-Bond test for AR(1) in first differences	0.000	0.000	0.000	0.000
Arellano-Bond test for AR(2) in first differences	0.064	0.0517	0.134	0.072
Hansen test of overidentifying restrictions	0.182	0.357	0.471	0.435

Numbers in brackets are the corresponding t-statistics.
** significant at 10%; ** significant at 5%; *** significant at 1%*
Period fixed effects were included (coefficients not reported).

[1] First principal component of two indicators: power loss (as % of electricity output) & electricity generating capacity (in MW per 1000 workers, in logs).
[2] First principal component of two indicators: share of paved roads in the overall road network & length of roads (in km, sqrt of per 1000 workers*surface area, in logs).
[3] First principal component of two indicators: main telephone lines per 1000 workers, in logs & main telephone lines per 1000 workers, in logs.
[4] First principal component of two indicators: Transportation index & Telecommunication index.
[5] Crisis volatility is the portion of the standard deviation of GDP per capita growth that corresponds to downward deviations below the world-wide 1-std-dev threshold.

Table 5. Economic Growth and Infrastructure –Joint Effects

Sample: 78 countries, 1961-2005 (5-year period observations)
Estimation Method: System GMM

	Dependent Variable: GDP per capita Growth [1]	[2]
Infrastructure Variables:		
Electricity Index[1]	0.749 ***	0.975 ***
	[5.353]	[5.292]
Transportation Index[2]	1.093 ***	
	[3.102]	
Telecommunication Index[3]	1.097 ***	
	[4.754]	
Transportation & Telecommunication Index[4]		2.135 ***
		[5.637]
Control Variables		
Initial GDP per capita	-2.452 ***	-2.814 ***
in logs	[-8.264]	[-8.092]
Education	0.604 *	0.668 *
secondary school enrollment rate, in logs	[1.749]	[1.925]
Financial Depth	0.859 ***	0.849 ***
private credit/GDP, in logs	[5.486]	[5.494]
Crisis Volatility	-1.679 ***	-1.627 ***
std dev of GDP per capita growth[5]	[-18.420]	[-13.560]
Government Burden	-0.530	-0.413
government expenditure/GDP, in logs	[-1.390]	[-0.864]
Inflation	-2.918 ***	-2.113 ***
1+Growth rate of CPI, in logs	[-6.696]	[-3.781]
Trade Openness	1.881 ***	2.265 ***
(exports+imports)/GDP, in logs	[5.164]	[5.657]
Growth rate of Terms of Trade	0.060 ***	0.060 ***
log differences of terms of trade index	[6.785]	[6.424]
Constant	26.779 ***	23.764 ***
	[7.257]	[5.336]
Observations	522	522
Number of Countries	78	78
Number of Instruments	70	64
Arellano-Bond test for AR(1) in first differences	0.000	0.000
Arellano-Bond test for AR(2) in first differences	0.170	0.107
Hansen test of overidentifying restrictions	0.164	0.340

Numbers in brackets are the corresponding t-statistics.
** significant at 10%; ** significant at 5%; *** significant at 1%*
Period fixed effects were included (coefficients not reported).

[1] First principal component of two indicators: power loss (as % of electricity output) & electricity generating capacity (in MW per 1000 workers, in logs).
[2] First principal component of two indicators: share of paved roads in the overall road network & length of roads (in km, sqrt of per 1000 workers*surface area, in logs).
[3] First principal component of two indicators: main telephone lines per 1000 workers, in logs & main telephone lines per 1000 workers, in logs.
[4] First principal component of two indicators: Transportation index & Telecommunication index.
[5] Crisis volatility is the portion of the standard deviation of GDP per capita growth that corresponds to downward deviations below the world-wide 1-std-dev threshold.

V. Infrastructure Investment and Growth in Egypt

A. Trends in Infrastructure Investment

We now turn to reviewing the long-term trends in infrastructure investment in Egypt. The investment data are disaggregated by sector of origin: public and private, and by destination of industry. Infrastructure investment includes both capital expenditures (the construction of new infrastructure) and current expenditures (operations and maintenance spending).

There are two kinds of time series data available for Egypt's infrastructure investment. The first data range from 1960 through 2007 with the disaggregation of two infrastructure sectors: transportation (including Suez Canal) and communications, and electricity. The second data cover the more recent period: 2003-2007, with a higher degree of disaggregation, that is, five infrastructure sectors: transportation, communications, electricity, water, and Suez Canal.

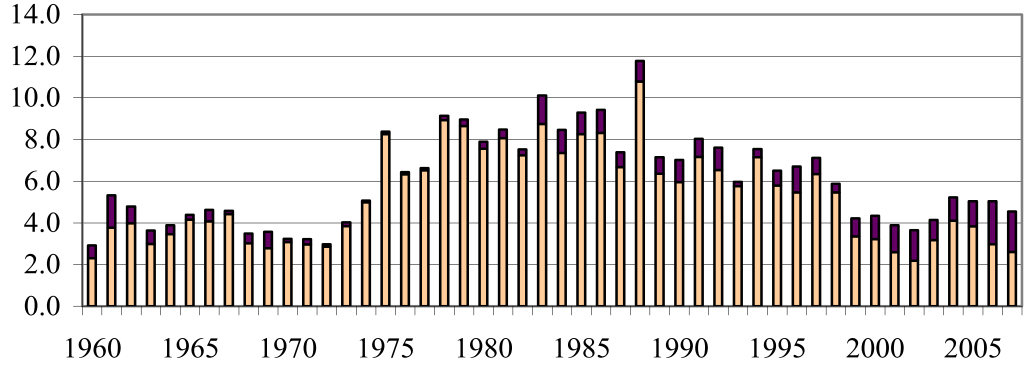
Figure 4 offers a comprehensive view of infrastructure investment in Egypt relative to GDP from 1960 through 2007. Panel (a) of Figure 4 illustrates the time path of total infrastructure investment that consists of investment in two infrastructure sectors: transportation and communications and electricity, with a disaggregation of public and private investment. Total investment rose until the late 1980s, and then it declined until the mid 2000s, when it stabilized. Total investment in recent years has returned to its level in the early 1960s at roughly 5 percentage of GDP. It is clear that public investment has been a dominant force for more than four decades in Egypt. In contrast, after having stagnated for more than two decades since the 1960s, private investment finally took off in the mid-1980s. The magnitude of private investment has been growing and is roughly two-thirds of the amount of public investment in recent years. Though considerable, rising private investment in the last two decades has not fully offset the decline in public investment.

From Panels (b) and (c) of Figure 4, there is an apparent downward trend in total investment which originated from a decline in public investment in both the transportation/communications and electricity sectors. Public investment in the former has been declining since the early 1980s, while that in the later since the late 1980s.

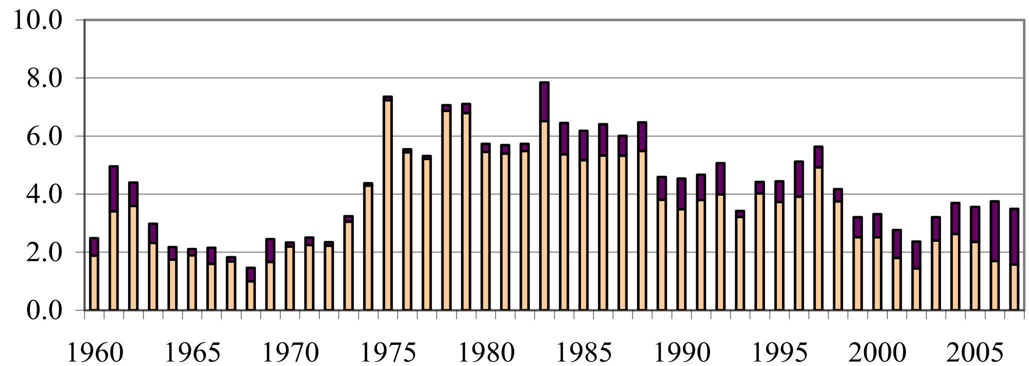
Figure 4. Infrastructure Investment in Egypt (1960-2007)

(Percentage of GDP)

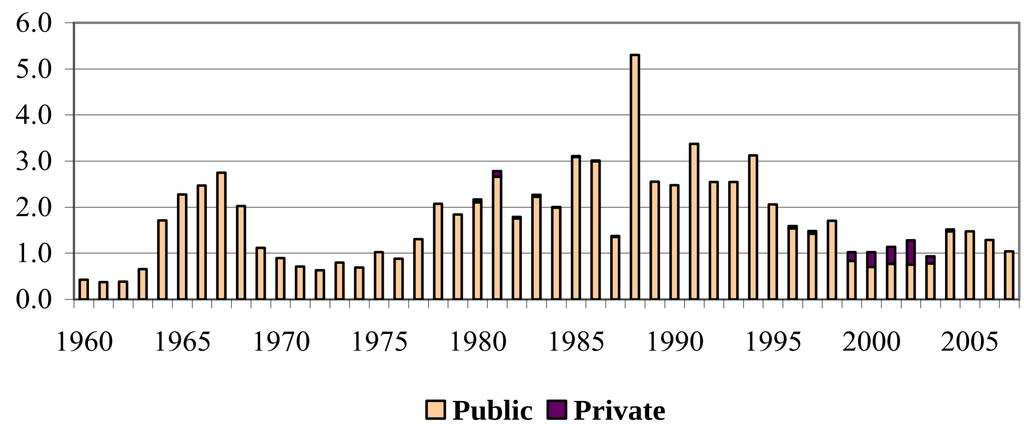
(a) Total Investment



(b) Transportation (incl. SC) & Communications



(c) Electricity



Conversely, private investment in transportation and communications has maintained its level after its sharp increase in the mid-1980s and has been on the rise again in recent years. Private participation in the electricity sector is still quite limited.

Figure 5 depicts the time path of more recent investment for 2003-2007 by destination of five infrastructure sectors and by sector of origin. In particular, investment data in the three core infrastructure sectors (transportation, communications, and electricity) are presented separately, allowing a more precise assessment of their recent trends.[25]

As shown in Panels (a) through (e) of Figure 5, the shares of investments in both water and Suez Canal are quite small compared to three core sectors. Investment in the water sector increased drastically in 2007, while that in Suez Canal has fallen since 2004. In additions, the figure reveals that public sector continues to play a major role in investment in electricity, water, and Suez Canal.[26]

Repeating the findings in Figure 4, public investment in transportation, communications, and electricity has been falling, while a rise in private investment has become more obvious in transportation and communications in recent years. In particular, the private sector has become a dominant player in investment in the communications sector since 2005.

B. Cross-Country Comparison of Infrastructure Investment

In this section, we compare the level of infrastructure investment in Egypt to that of other developing countries. Panels (a)–(c) of Figure 6 plot infrastructure investment (total, public, and private) as ratio to GDP for 2000-05 against GDP per capita in 2000 across countries.[27] Total and public infrastructure investment fall as the income level of the country increases, while the opposite happens for private investment.

[25] In Appendix 4, we present disaggregated investment data for transportation (including investment in Suez Canal) and communications as ratio to GDP for 1983-2007 (see Figure 4-A). These data has been made available only recently.

[26] There is no private investment for water and Suez Canal. As for electricity, no private investment has been carried out after 2004.

[27] Infrastructure investment data are obtained from Calderon, Odawara, and Serven (2008). Total investment consists of investment in three major infrastructure sectors: transport, telecommunications, and electricity.

Figure 5. Infrastructure Investment in Egypt (2003-2007)
(Percentage of GDP)

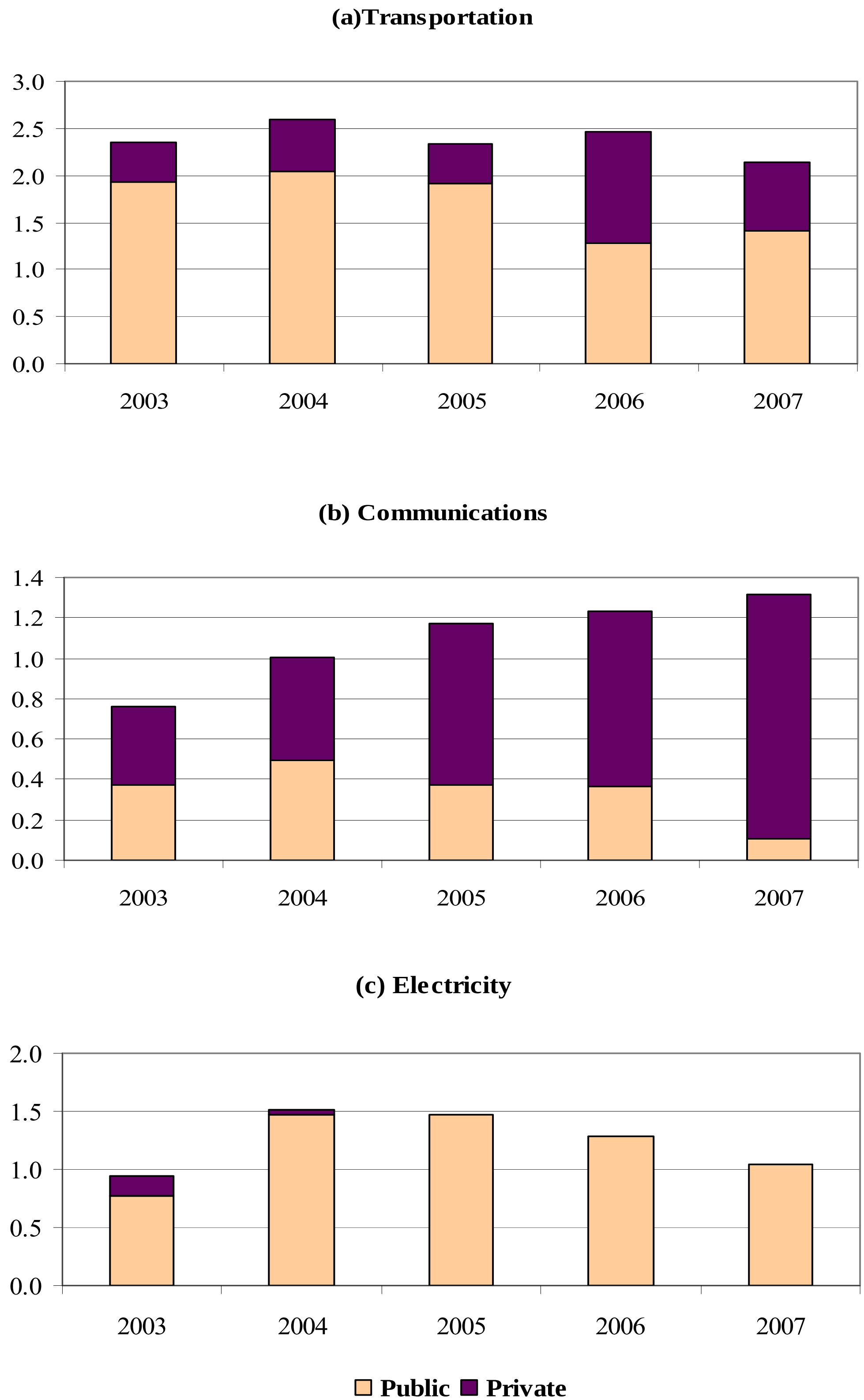
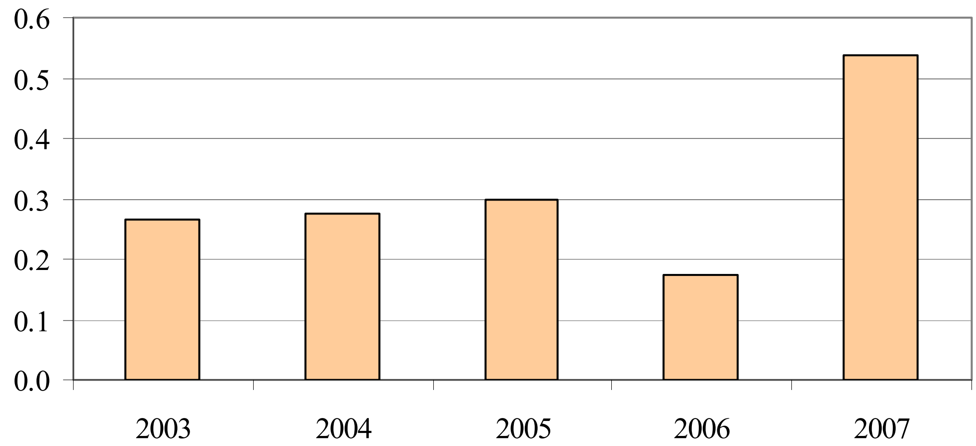
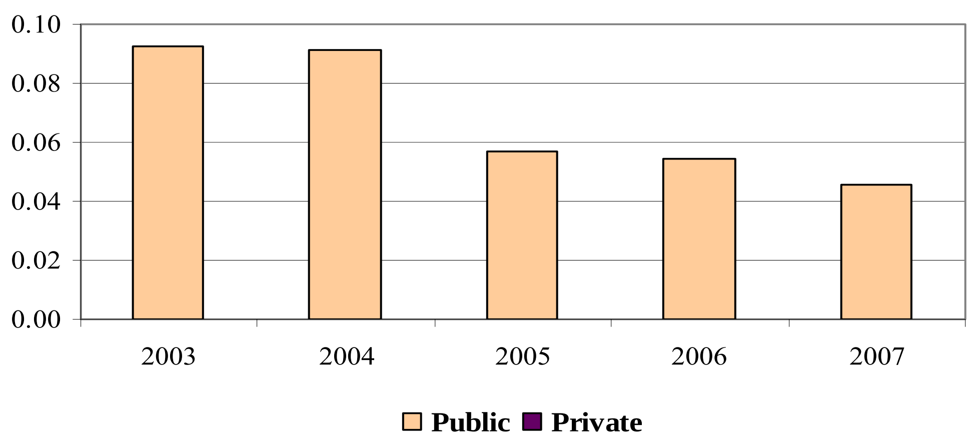


Figure 5 (continued). Infrastructure Investment in Egypt (2003-2007) (Percentage of GDP)

(d) Water



(e) Suez Canal



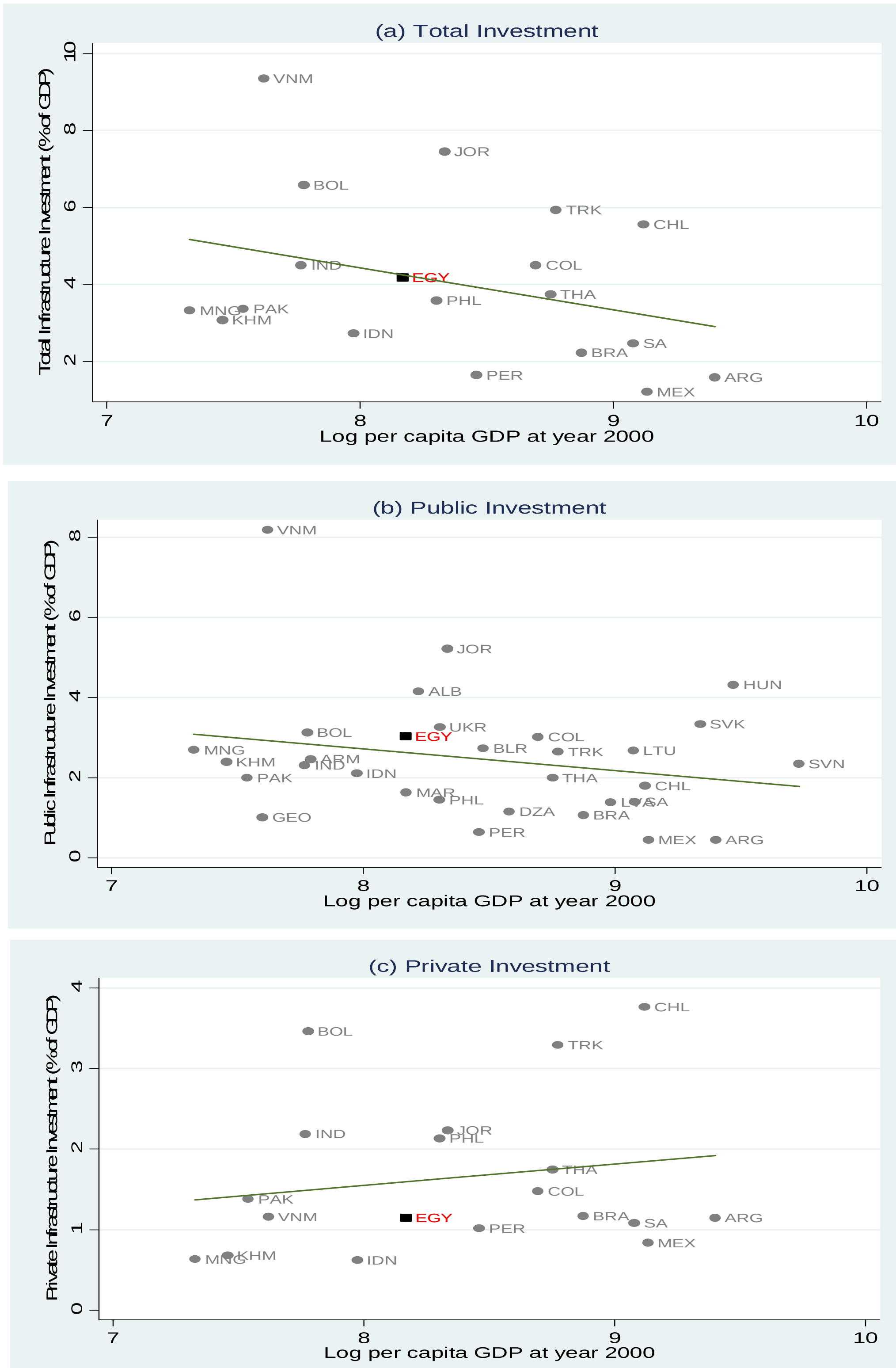
This may indicate that poorer countries, especially through their public sectors, tend to make larger infrastructure investments until they build a certain level of infrastructure assets (a number of electricity plants and a road network). As they become richer, they tend to spend less in new infrastructure, focusing on maintaining existing assets. Panels (a) shows that Egypt is located on the predicted regression line for total investment. In contrast, for public and private investment Egypt shows interesting discrepancies with respect to the international norm (Panels (b) and (c)). While public investment in infrastructure in Egypt is much larger than what would be expected according to the country's income level, its private investment is considerable smaller than the standard set by other developing countries.

Finally, we turn to reviewing the trends of infrastructure investment across countries. Figures 7.1 and 7.2 provide an overview of the level of infrastructure investment in six countries, divided into two groups: India (IND), Pakistan (PAK), and Indonesia (IDN) in Figure 7.1, and Egypt (EGY), Turkey (TRK), and South Africa (SA) in Figure 7.2. Panels (a) through (c) of Figures 7.1 and 7.2 offer the trends of total, public, and private investment as a share of GDP for over the last two decades, respectively.

The top panels of Figures 7.1 and 7.2 illustrate that total investment has been slightly falling over time. This tendency is more obvious in the mid 1990s or the early 2000s, when even countries which investment had remained roughly constant over time (i.e. India, Pakistan, and Turkey) experienced a downward trend. The middle panel shows that the path of public investment has been declining in all six countries. In contrast, private investment, shown in the bottom panel, presents a clear upward trend (except for Indonesia). Private investment in infrastructure has increased so much than it has equaled and, in some cases, even surpassed public investment.

Thus, public and private investments display contrasting patterns, which indicates that those countries have experienced a composition shift between public and private investment. The share of private investment to total investment has been rising, while that of public investment has been falling. However, rising private investment has not fully offset the fall in public investment in most cases.

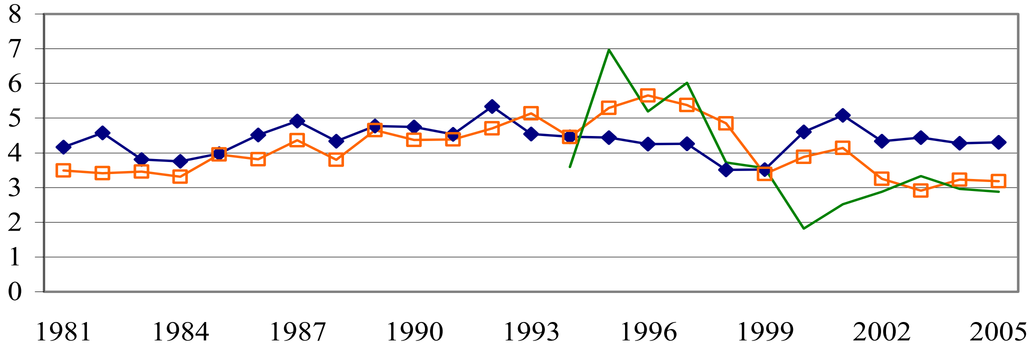
Figure 6. Infrastructure Investment (average of 2000-05, % of GDP)



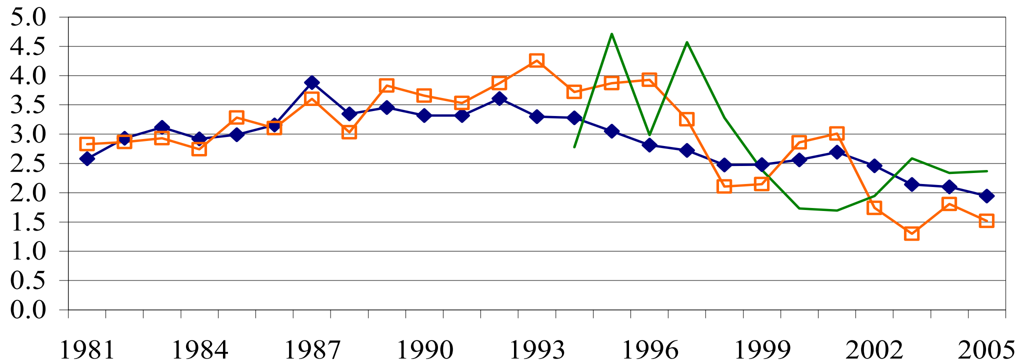
Data source: Calderón, Odawara, and Servén (2008).

Figure 7-1. Infrastructure Investment across Countries
(percentage of GDP)

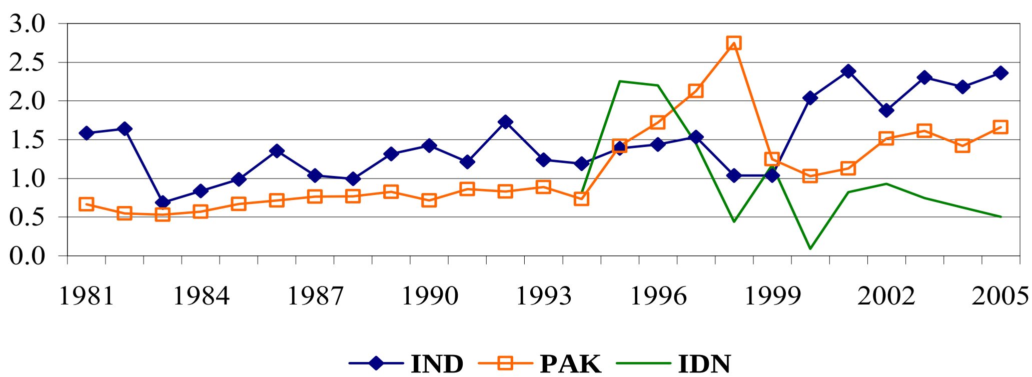
(a) Total Investment



(b) Public Investment



(c) Private Investment

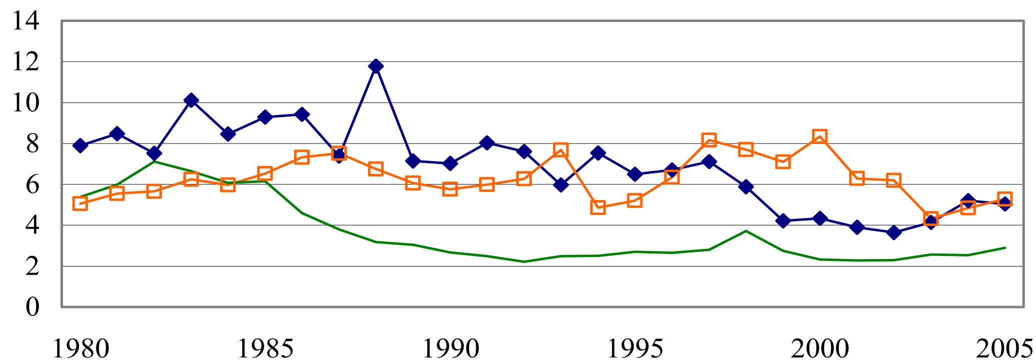


Data source: Calderón, Odawara, and Servén (2008).

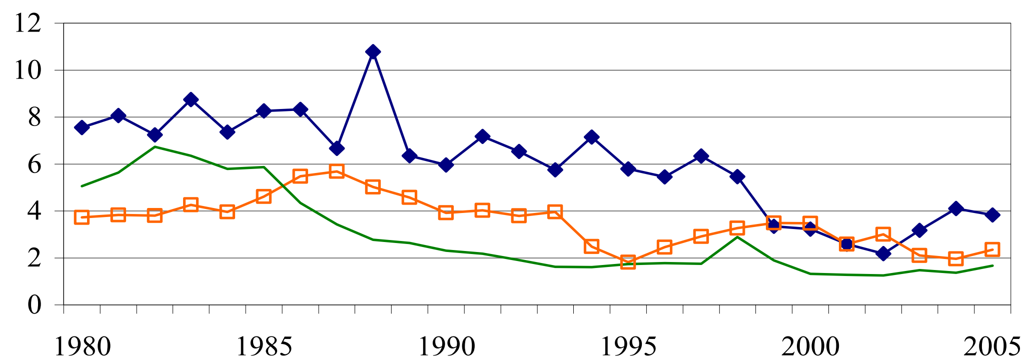
Figure 7-2. Infrastructure Investment across Countries

(percentage of GDP)

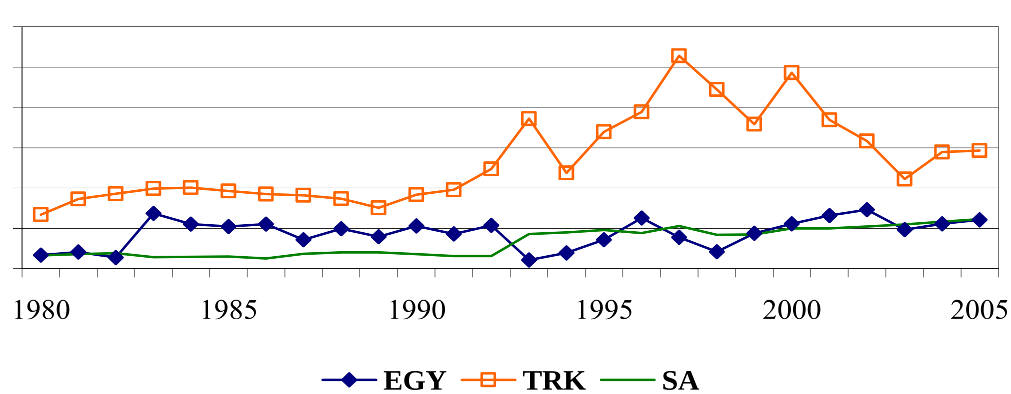
(a) Total Investment



(b) Public Investment



(c) Private Investment



Data source Calderón, Odawara, and Servén (2008).

C. Infrastructure Investment Expenditures and Infrastructure Improvement

The final objective of the paper is to link infrastructure investment expenditures with economic growth in Egypt. To accomplish this objective, we need the estimation of the growth effect of improvements in the infrastructure indices, obtained in section IV above. In addition, we need information concerning the connection between infrastructure investment expenditures and improvement in the infrastructure indices for Egypt. This is the goal of this subsection. For this purpose, we use historical Egyptian data to answer the question: how much improvement in an infrastructure index is obtained for given expenditure in the corresponding area of infrastructure?

Table 6. Electricity Expenditure and Improvement

Electricity
Estimation Method: Quantile regression

	Dependent variable: Change in Electricity Infrastructure Index			
	[1]	[2]	[3]	[4]
Ratio of expenditure to labor force	0.006 ***			
(expenditure on electricity per 100,000 workers)	[5.00]			
Ratio of expenditure to labor force		0.051 ***		
(expenditure on electricity per 100,000 workers, in logs)		[5.04]		
Ratio of expenditure to GDP			0.005 ***	
(expenditure on electricity / 1,000 GDP)			[6.84]	
Ratio of expenditure to GDP				0.079 ***
(expenditure on electricity / 1,000 GDP, in logs)				[8.02]
Constant	-0.056 ***	-0.094 ***	-0.084 ***	-0.206 ***
	[3.57]	[3.89]	[5.32]	[7.39]
Observations	34	34	34	34
R-squared	0.37	0.32	0.41	0.37

Notes:
The dependent variable is smoothed by using the Hodrik Prescott filter.
All the expenditure variables are the moving average of expenditures in the last three years.
Numbers in brackets are the corresponding t-statistics.

** significant at 10%; ** significant at 5%; *** significant at 1%*

We run a series of regressions for which the dependent variable is the change in a given infrastructure index and the explanatory variable is the corresponding investment expenditure in average for the previous three years. Investment expenditure is normalized in different ways. We consider, in turn, the ratio of expenditure to the labor force and the ratio of expenditures to GDP; and in addition, we consider the logarithm of each of these two ratios. As mentioned above, publicly available Egyptian historical data has not (until recently) disaggregated between the transportation and telecommunication sectors;[28] therefore, we use the infrastructure index that combines those two sectors. For electricity, on the other hand, there is sector specific expenditure data; and therefore, we use its own infrastructure index. The results are presented in Table 6 for electricity and Table 7 for transport and telecommunications.[29]

Table 7. Transportation and Telecommunication Expenditures and Improvement

Transportation and Telecommunication
Estimation Method: Quantile regression

	Dependent variable: Change in Transportation & Telecommunication Infrastructure Index			
	[1]	**[2]**	**[3]**	**[4]**
Ratio of expenditure to labor force (expenditure on transportation & telecommunication per 100,000 workers)	0.002 *** [14.22]			
Ratio of expenditure to labor force (expenditure on transportation & telecommunication per 100,000 workers, in logs)		0.038 *** [9.46]		
Ratio of expenditure to GDP (expenditure on transportation & telecommunication / 1,000 GDP)			0.002 *** [5.08]	
Ratio of expenditure to GDP (expenditure on transportation & telecommunication / 1,000 GDP, in logs)				0.061 *** [3.96]
Constant	-0.016 *** [3.84]	-0.076 *** [6.16]	-0.036 ** [2.08]	-0.18 *** [3.16]
Observations	45	45	45	45
R-squared	0.47	0.44	0.19	0.22

Notes:
All the expenditure variables are the moving average of expenditures in the last three years.
Numbers in brackets are the corresponding t-statistics.

** significant at 10%; ** significant at 5%; *** significant at 1%*

[28] As stated in footnote 24, disaggregated investment data for transportation and telecommunication has recently become available for the period 1983-2007. It is not used here, however, because of its limited time coverage and because it has not undergone the necessary quality controls.

[29] These regressions are estimated using the Quantile (Median) estimator, rather than the simpler and more common Ordinary Least Squares procedure. Although the results from both methods are similar to each other, in this case we prefer the Quantile estimator given its lower sensitivity to outlier observations.

The results are qualitatively similar for both electricity and transportation/telecommunications. The coefficients on the four measures of investment expenditure are positive and statistically significant, implying that there is a relevant connection between investments and improvement in infrastructure. However, the small size of the coefficients, as well as the low R^2s, reveals that any economically important improvement in the infrastructure indices would take a relatively long time if investment expenditures are maintained at moderate levels. A rapid improvement in the indices would occur only under quite sizable investment. Since most public expenditure planning is done relative to GDP, in what follows we only use the estimated coefficient in Column 3 of each table.

In addition, we conduct a more complex regression analysis of infrastructure improvement by linking it not only to investment expenditures but also to the current stock of infrastructure. This extension may be necessary to take into account the infrastructure "product cycle," that is, the different investment needs at different stages of infrastructure development. In most infrastructure cases, larger investment is needed when infrastructure is incipient, as when it depends on expensive plants to initiate production. This is known in the economics literature as "non-convex investment," characterized by large fixed costs and low marginal costs. In other cases, initial infrastructure improvements may be obtained relatively easily; but as development occurs, further progress is increasingly costly.

We conduct this extended empirical analysis by estimating a regression of the change in infrastructure index on past investment expenditure, the current infrastructure index, and the interaction between the two. The results are presented in Appendix 5. For electricity, the three explanatory variables are statistically significant, carrying the following pattern of signs. The respective coefficient on investment expenditure is positive, on current infrastructure index is negative, and on the interaction is positive. The positive coefficients on both investment expenditure and its interaction with the current infrastructure level indicate that electricity-related infrastructure behaves as "non-convex" investment, that is, electricity improvements are more costly in the early stages of this type of infrastructure, when large plants and generators have to be constructed. As electricity infrastructure develops, there is a larger expansion in infrastructure for given amount of expenditures. For transport and telecommunications, the pattern of signs is the same, although only the investment expenditure and, in one case, its interaction with current infrastructure level are statistically significant. Given that both of these variables carry positive coefficients, the results indicate that the transport and telecommunications sector is also characterized by necessary large outlays at incipient levels of progress, with lower costs afterwards.[30]

Notwithstanding their insightfulness, the results on the complex specification of the infrastructure regression are more tentative than those of the simple specification presented above because of data constraints and robustness concerns. Since the simple specification implies constant costs to infrastructure improvement (rather than declining ones, as in the complex specification), using the simple specification results entails a more conservative approach to growth projections. We use the simple specification results in order to produce more conservative projections and because we are more confident in the quality of its estimates.

D. Growth Projections

We are now ready to produce the main projections of the paper; that is, the projections on growth improvement given an increase in public infrastructure expenditures. For this purpose, we need three pieces of information. The first relates to the determinants of economic growth. From this analysis, the most important element to consider is the effect of the infrastructure indices on economic growth. We also need to consider that a rise in infrastructure entails an increase in investment expenditures, which may involve a corresponding increase in the government burden (through distortionary taxation, public debt overhang, or bureaucratic red tape). Lastly, we must take into account that improving growth becomes more difficult as per capita GDP gets larger (the convergence effect). These effects are measured through the estimated coefficients on, respectively, the two infrastructure indices, the proxy of government burden, and the initial level of per capita GDP, which we take from Table 5, Col. 2.

[30] The negative coefficient on current infrastructure stock (attenuated by the positive coefficient on the interaction) can be interpreted as an indication of capital depreciation.

The second piece of information is the effect of infrastructure expenditure on improvements in the infrastructure indices in Egypt. These parameters are obtained from the analysis on electricity and transportation/telecommunication improvements; specifically, we use the estimated coefficients reported in Tables 6 and 7, Col. 3. The third piece of information is the projected new level of infrastructure expenditure. In recent years, total infrastructure expenditures in Egypt are about 5% of GDP, allocated around 1.3% to electricity and 3.7% to transportation and telecommunication. For projected expenditures, we consider three scenarios. In the first, we allow total infrastructure expenditures to increase from 5% to 6% of GDP permanently. In the second one, the increase is substantially larger, from 5% to 8% of GDP permanently. In the third scenario, we consider a large initial increase that gradually diminishes over time. Specifically, infrastructure expenditures rise from 5% to 7% of GDP for the first twenty years, then decline to 6.5% of GDP for the following 20 years, and thereafter converge to 6% of GDP forever. In all cases, the increase is allocated proportionally to expenditures for electricity and transportation/telecommunication.

Figure 8: Projected Growth Improvement from Higher Infrastructure Investment

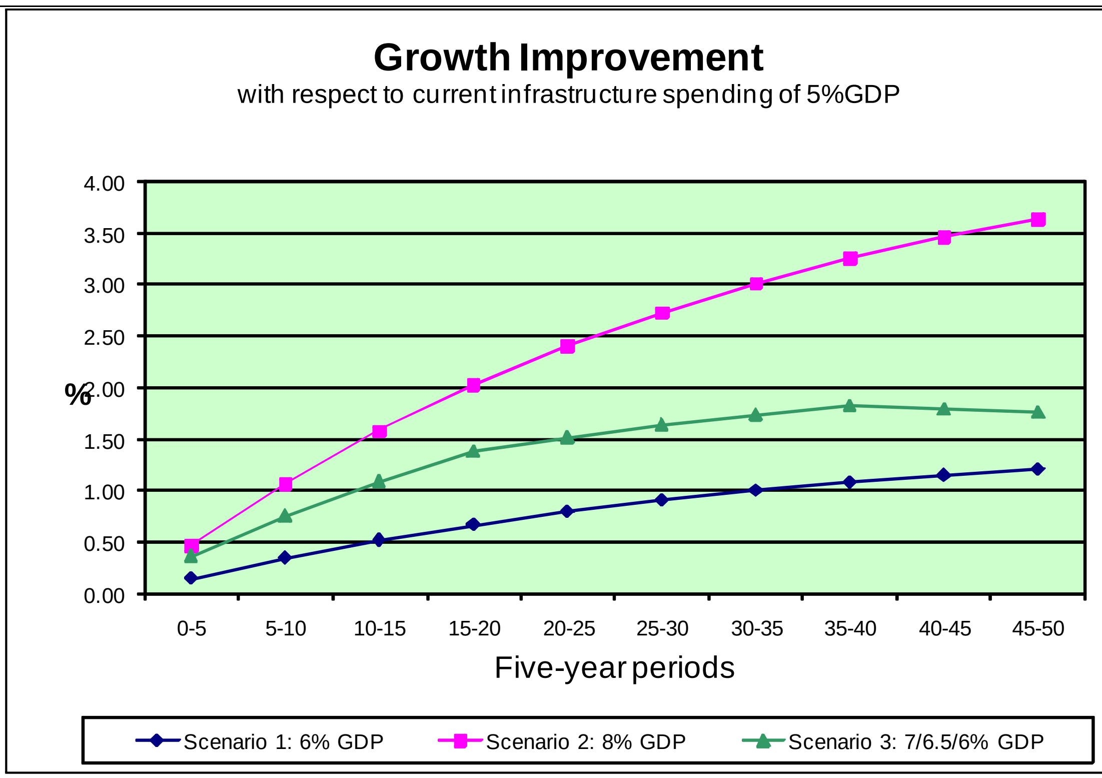
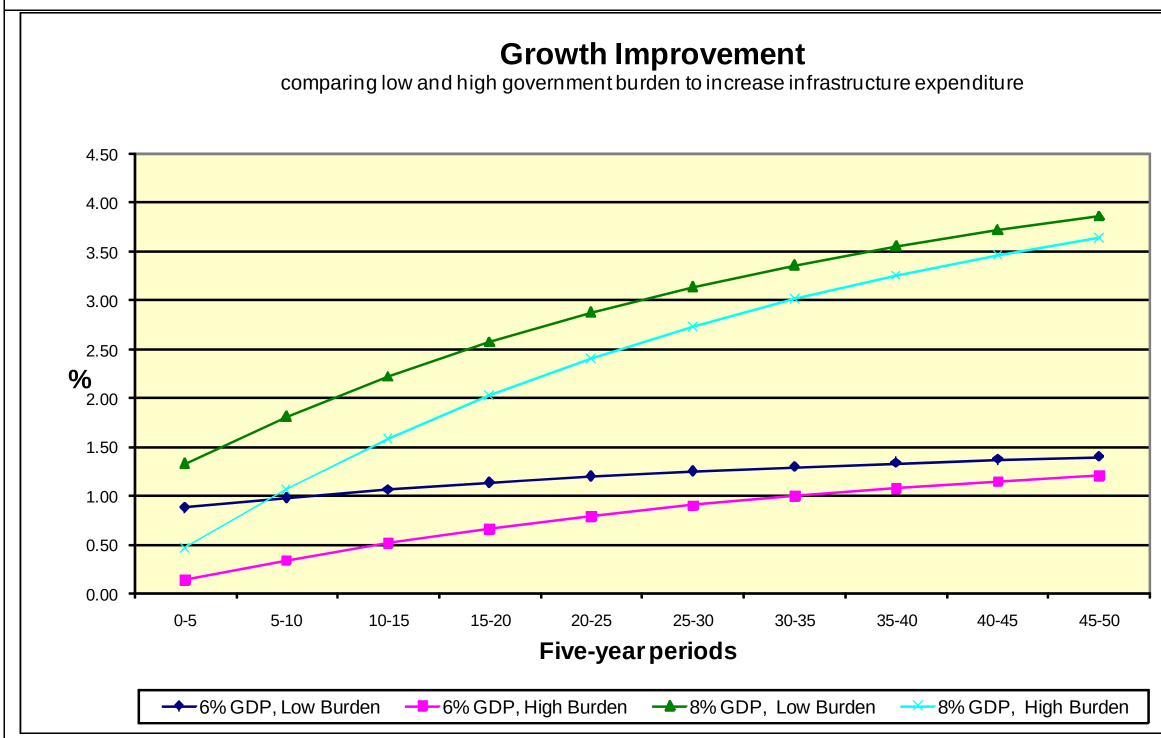


Figure 8 presents the growth projections under the three scenarios for the next 50 years. They represent the change in growth with respect to the path corresponding to the current infrastructure investment of 5% of GDP. The growth improvement is not constant over time because, first, as the infrastructure stock builds up, it renders higher growth; and, second, as per capita GDP rises, it becomes more difficult to grow further. In addition, the government burden of increased expenditures reduces the growth improvement. These three forces play against each other dynamically to render the projected growth path. The effect of higher infrastructure investment dominates over time, and that's why the growth improvement path rises gradually.

In the first years of larger infrastructure investment, the growth returns are rather small. However, towards the end of the first decade, the per capita GDP growth improvement is already considerable, reaching almost 0.5 pp, 1.5 pp, and 1 pp for three scenarios, respectively. By the third decade, the growth improvement continues to rise, amounting to 1 pp, 3 pp, and 1.75 pp, correspondingly for the three scenarios. Note that, by the design of the third scenario, its growth improvement tends to flatten by the fifth decade. As time goes on, the infrastructure stock continues to increase, promoting larger growth; however, due to decreasing returns (manifested through conditional convergence in the growth regression), these growth improvements are increasingly harder to obtain. The combination of these two forces makes the growth improvement converge to a steady value. Specifically, in the long run, the growth gains from the three scenarios are, respectively, 1.6 pp, 4.7 pp, and 1.6 pp. The first and third scenarios render the same long run increase because in both cases infrastructure expenditure eventually stays at 6% of GDP.

The projections just presented assume, realistically, that the increase in infrastructure investment may involve a heavier government burden (through higher government expenditures). However, if the rise in infrastructure investment occurs in the context of public expenditure reform, entailing a redistribution of funds from less to more efficient uses and a co-participation of the private sector in the investment process, then the growth improvement could become substantial even in the first years of the program. Figure 9 compares the results for the first two scenarios (i.e., a permanent increase of infrastructure investment to 6% and 8% of GDP, respectively) between low and high government burden. High government burden corresponds to the projections analyzed above (and presented in Figure 8). Low government burden corresponds to the case when the increase in infrastructure investment does not imply an increase in government expenditures (setting the corresponding coefficient to zero). The results are remarkable. Having a low government burden is crucial to increase the growth improvement from higher infrastructure investment particularly in the early stages of the program. Even when the increase in infrastructure investment is modest (from 5% to 6% of GDP), the per capita GDP growth improvement can reach 1 pp by the end of the first decade provided the government burden is low (this rise is twice as high as under high government burden). If government burden is a big concern, it may be better to increase infrastructure investment by a modest amount, particularly in the first years. An implication from this analysis is that the merits of increasing infrastructure investment have to be weighed against the costs of an expansion in government size. One way to deal with this challenge is to increase the quality of infrastructure investment by giving the private sector a more active role in the provision of infrastructure.

Figure 9: Projected Growth Improvement under Different Fiscal Burden



The simulations can be used to inform three critical values used in public policy analysis. The first is the measure of the fiscal multiplier. This is the impact on per capita GDP of a given increase in public expenditures. The simulations show that the fiscal multiplier that applies to *infrastructure expenditures* gradually rises over time. A permanent increase in public infrastructure expenditures of 1 percentage point of GDP leads to a positive but small change in per capita GDP in the first few years of implementation. The low short-term impact is explained by the fact that infrastructure takes time to build, while the negative impact of government burden is rather immediate. As the stock of infrastructure grows, so does the positive effect on per capita GDP. Thus, the fiscal multiplier reaches 1 percentage point of per capita GDP about three decades after implementation, gradually converging to a long-run fiscal multiplier of 1.6 percentage points.

The second is the analysis of financial fiscal sustainability. Specifically the issue is whether the improvement in infrastructure can render a sufficient increase in government revenues to fully finance infrastructure investment. In layman's terms: does public infrastructure pay for itself? According to our simulations, if the proceeds derived from the new infrastructure projects are limited to general government revenues, public infrastructure investment will not pay for itself. In Egypt, government revenues amount to 25-30% of GDP. Applying this range of rates, the rise in government revenues given by the increase in GDP will only cover a fraction of the increase in infrastructure expenditure. This fraction would be rising given the increasing impact of infrastructure investment on GDP growth. Thus, assuming a government revenue rate of 30% of GDP, the fraction of self-finance infrastructure investment would be about 35% during the first five years, 50% by the end of the second decade, and 75% in the long run. (Correspondingly, the revenue rates needed for infrastructure investment to break even would be 85%, 60%, and 40% for the respective time horizons.)

The third, and most important, is the analysis from a social perspective. This considers the value of the increase in per capita GDP (or income) for society as a whole. The calculation should take into account the time value of money and, therefore, discount the future stream of income with an appropriate rate. Assuming a discount rate of 5% over the per capita GDP growth rate, an increase in infrastructure expenditure of 1 percentage point of GDP leads to a *net present value* gain of 6 percentage points of per capita GDP for the first 25 years of implementation and 10.5 percentage points of per capita GDP for the first 50 years.[31] This is a sizable yet reasonable improvement, and it can be further increased if the program's financing and implementation are less burdensome to the economy. Finally, we must note that this improvement is only a fraction of the total effect of infrastructure on social welfare. A complete evaluation would also take into account the direct benefit of infrastructure on the health, comfort, and happiness of its recipients.

VI. Summary and Conclusion

In the last half century, Egypt has experienced remarkable progress in the provision of infrastructure, which is the result of decades of purposeful and costly investment. In the past 15 years, however, a worrisome trend has emerged: Infrastructure investment has suffered a substantial decline. To be sure, some of this decrease is to be expected as infrastructure projects mature and demand less costly outlays. Nevertheless, the investment decline should be of concern for two reasons. The first is that the rate of progress in the measures of infrastructure, particularly road networks and power generation, has slowed down. A developing country like Egypt cannot afford such stagnation. The second reason is that, although acceptable at Egypt's current income level, infrastructure in the country has much room to improve to be consistent with its goals of future economic growth.

The study first reviews the current state of several infrastructure indicators in Egypt compared with the rest of the world. For this purpose, a dataset for 150 countries was collected containing different indicators of quantity and quality of services for four major sectors of infrastructure: transport, telecommunications, electricity, and water and sanitation. The overall results suggest that Egypt has attained a level of infrastructure

[31] The first-order condition for consumer welfare maximization implies, $r = \rho + \sigma g$, where r is the real interest rate, ρ is the subjective rate of time preference, σ is the inverse of the coefficient of intertemporal substitution, and g represents the per capita GDP growth rate. It is customarily assumed that the coefficient of intertemporal substitution is equal to 1 and the subjective rate of time preference is 0.05. This would entail a real interest rate equal to 0.05 over the growth rate, which is our working assumption here. Thus, if the per capita GDP growth rate were around 5%, the real interest used as discount rate in the NPV calculations would be 10%.

performance consistent with what is expected given its level of economic development. In particular, Egypt performs as well as or better than other countries of similar per capita GDP regarding the following infrastructure indicators. For transportation: road network length, paved roads, quality of railroads, and quality of air transport. For telecommunication: main telephone lines, telephone faults, and waiting list of mainline installation. For power generation and water: access to electricity, quality of electricity supply, access to improved water source, and access to sanitation facilities.

Then, the study examines the trends in infrastructure spending in Egypt from 1960 to 2007, disaggregated by sector of origin (public and private) and by two main sectors, transportation (including Suez Canal) and communications, and electricity. Relative to GDP, total infrastructure expenditure in Egypt fell after reaching its peak in the late 1980s, mainly due to a decline in public spending. Private investment took off in the mid-1980s, and its magnitude has been growing since then. In recent years, the rise in private investment is clear in transportation and telecommunications, with the private sector becoming a principal player in telecommunications since 2005. Rising private investment in the last two decades, however, has not entirely offset the decline in public spending.

In comparison with other developing countries, the share of public in total infrastructure spending in Egypt is larger than what would be expected according to the country's income level. In contrast, by the same standard its private infrastructure spending is considerably smaller. The trends of infrastructure expenditure across countries also reveal declining public spending and a clear upward trend in private investment. Thus, not only Egypt but countries such as India, Indonesia, Pakistan, South Africa, and Turkey have experienced a composition shift from public to private infrastructure spending. In some cases, such as India and Turkey, private investment has increased sufficiently to offset the decline in public spending in infrastructure.

A large body of literature has found that improving infrastructure has a statistically significant and economically substantial positive effect on economic growth. Using data for 78 countries for the period 1960-2005, this study confirms the result on the beneficial growth impact of infrastructure in telecommunication, transport, and power generation. This impact is found to be larger if infrastructure development does not involve an increase in government burden on the economy. Moreover, using Egypt-specific data, the study finds a positive and significant link between infrastructure expenditures and infrastructure development. Based on these results, this study concludes that improving infrastructure in Egypt will have a beneficial effect on economic growth and that, in turn, improving infrastructure will require a combination of larger infrastructure expenditures and more efficient investment.

The analysis provided in this study suggests that a permanent increase in infrastructure expenditures has a gradually rising effect on per capita GDP growth. As the infrastructure stock builds up, it renders higher growth; on the other hand, as per capita GDP rises, it becomes more difficult to grow (due to diminishing capital returns). In addition, the government burden of increased expenditures may reduce any growth improvement. These three forces play against each other dynamically to render the projected growth path of a permanent rise in infrastructure expenditure. The effect of higher infrastructure investment dominates over time, and, thus, economic growth rises gradually to converge to a positive value.

The quantitative estimates obtained in this study allow some tentative growth projections. If infrastructure expenditure in Egypt rose permanently from its current level of 5% of GDP to 6%, the growth returns would be rather small in the first years but would gradually rise. Towards the end of the first decade, the gain in per capita GDP growth would reach almost 0.5 percentage points, by the third decade it would amount to 1 percentage point, and eventually it would converge to 1.6 percentage points. If the increase in infrastructure expenditures were more pronounced, from 5% to 8%, the rise in per capita GDP growth would amount to 1.5, 3, 4.7 percentage points in the corresponding time horizons.

These quantitative estimates can be used to elucidate questions of fiscal sustainability and social welfare. First, on financial fiscal sustainability, the issue is whether the improvement in infrastructure can render a sufficient increase in government revenues to fully finance infrastructure investment. According to the simulations presented in the study, if the proceeds derived from the new infrastructure projects were limited to general government revenues, public infrastructure investment would not pay for itself. Considering the rates of government revenues prevailing in Egypt (25-30% of

GDP), the rise in government revenues given by the increase in GDP would only cover a fraction of the increase in infrastructure expenditure. This fraction would be rising given the increasing impact of infrastructure investment on GDP growth. Thus, the fraction of self-finance infrastructure expenditure would be about 35% during the first five years, 50% by the end of the second decade, and 75% in the long run. Second, on social welfare, the estimates can be used to quantify the gains from an expansion in infrastructure in terms of per capita GDP. The calculation should take into account the time value of money and, therefore, discount the future stream of income with an appropriate rate. Assuming a discount rate of 5% over the per capita GDP growth rate, an increase in infrastructure expenditure of 1 percentage point of GDP would lead to a *net present value* gain of 6 percentage points of per capita GDP for the first 25 years of implementation and 10.5 percentage points of per capita GDP for the first 50 years.

These projections assume, realistically, that the increase in infrastructure expenditure may involve a heavier government burden (through higher government expenditures). However, if the rise in infrastructure expenditure occurs in the context of public expenditure reform, entailing a redistribution of funds from less to more efficient uses and a co-participation of the private sector in the investment process, then the growth improvement could become substantial even in the first years of the program. If infrastructure expenditure rose permanently from 5% to 6% of GDP without entailing more government burden, the per capita GDP growth improvement could reach 1 percentage point by the end of the first decade. If government burden is a big concern, it may be better to increase infrastructure investment by a modest amount, particularly in the first years.

One implication from this analysis is that the merits of increasing infrastructure investment have to be weighed against the costs of an expansion in government size. A second implication is that renewed infrastructure investment should be considered in the larger context of public sector reform. Rationalizing public expenditures can release resources to be used in the generation of infrastructure. Moreover, an improvement in the quality of infrastructure investments can result in faster progress at lower costs. In this regard, Egypt would do well in considering the experience of other countries where stronger participation of the private sector in the provision of infrastructure has led to significant productivity gains.

Finally, a limitation of this study should be acknowledged. It has focused on the economic growth impact and corresponding income improvement obtained from higher infrastructure investment. This is, however, only one of the positive effects of infrastructure on social welfare. A complete evaluation would also take into account the *direct* benefit of infrastructure on people's health, accessibility, comfort, and, ultimately, happiness.

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APPENDIX 1: Data sources

- Investment in infrastructure data for Egypt is obtained from Ministry of Economic Development, Egypt. (http://www.mop.gov.eg/English/Economic%20Indicators.html). The unit is in local currency unit, millions, at current prices.

- Investment in infrastructure data used for Figure 6 and 7 are obtained from César Calderón, Rei Odawara and Luis Servén (2008).

- Real per capita GDP, PPP adjusted 2005 international dollars from WDI database, The World Bank.

- Labor force from WDI database, The World Bank.

- Arable land from WDI database, The World Bank.

- Surface area from WDI database, The World Bank.

APPENDIX 2: Additional Cross-Country Comparisons

Figure 1-A. Sub-sample: countries with real per capita growth>0.019
Correlations between infrastructure indicators and per capita GDP, PPP (constant 2005 int'l $)

(a) Transport

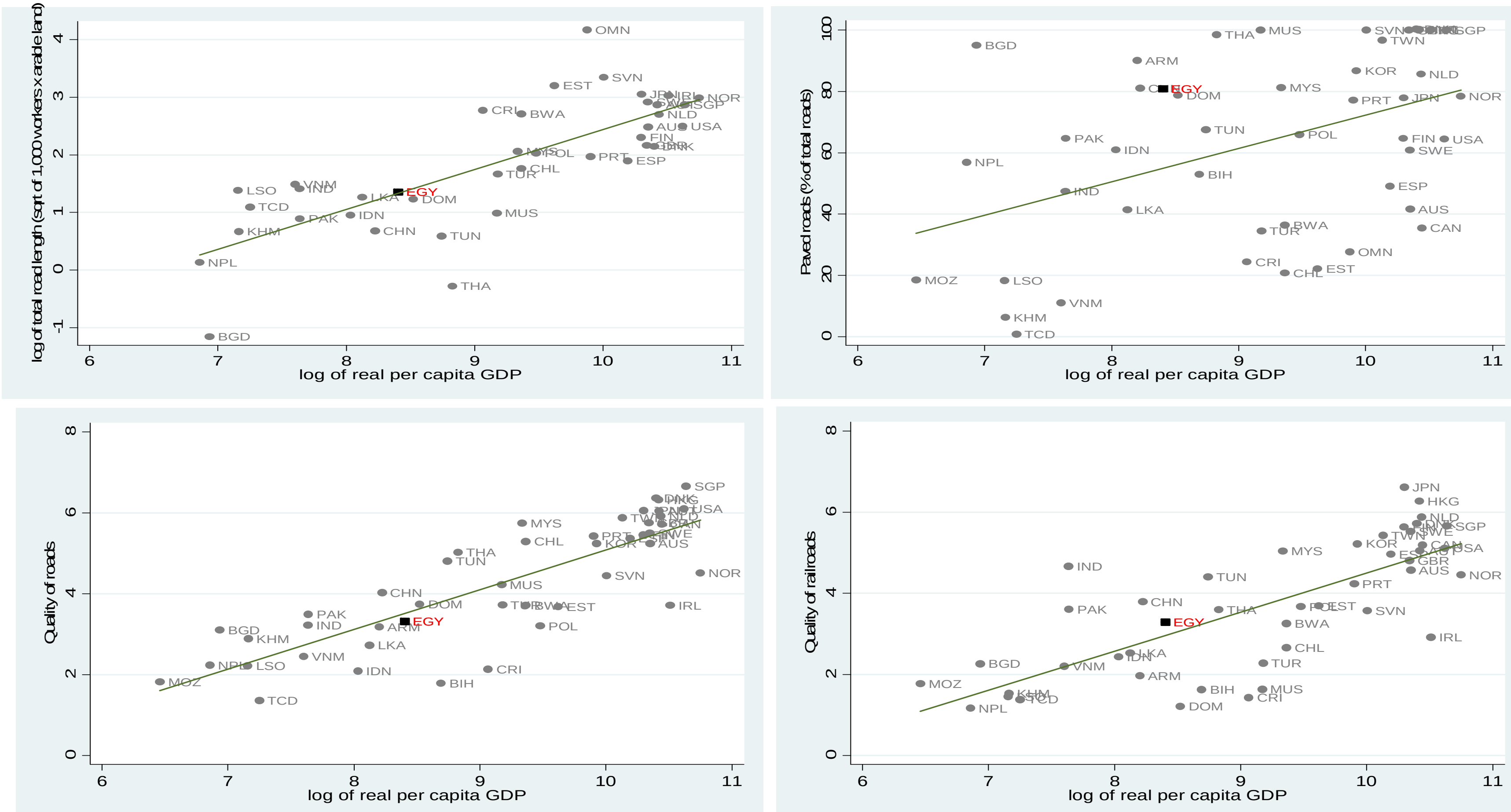


Figure 1-A (continued). Sub-sample: countries with real per capita growth>0.019
Correlations between infrastructure indicators and per capita GDP, PPP (constant 2005 int'l $)

(b) Telecommunications

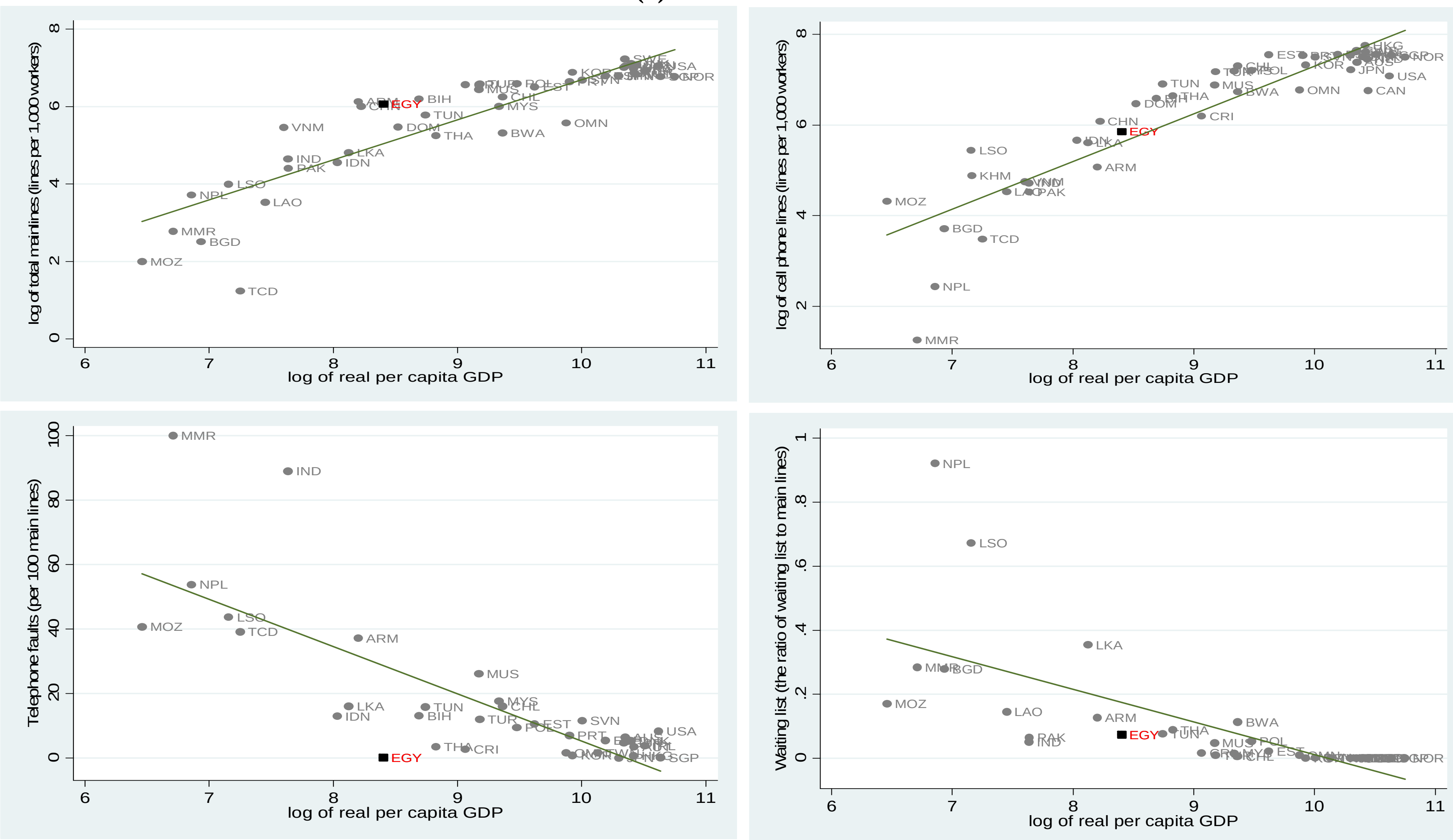
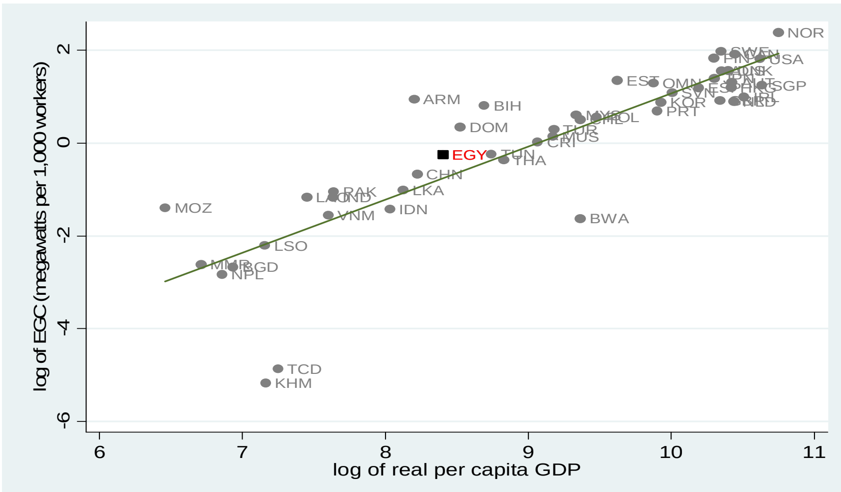
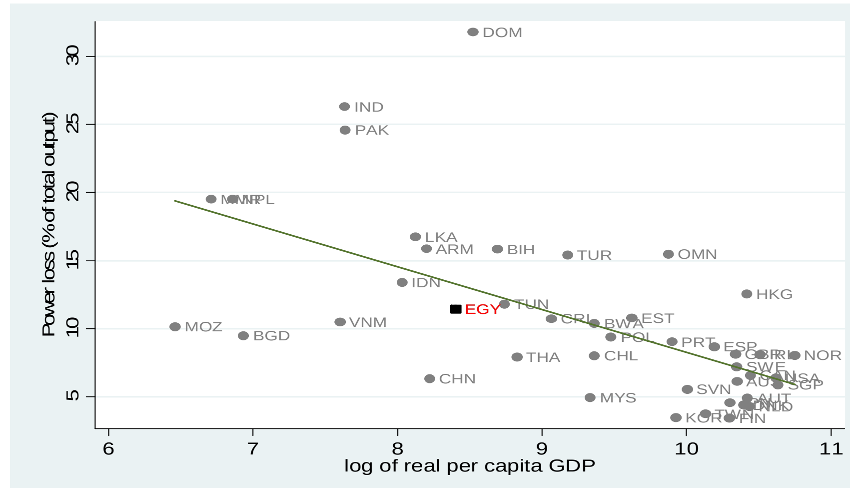
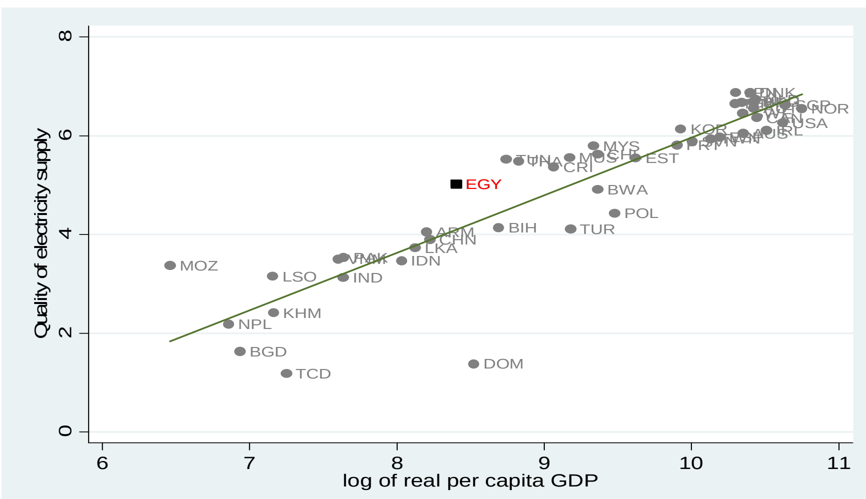


Figure 1-A (continued). Sub-sample: countries with real per capita growth>0.019
Correlations between infrastructure indicators and per capita GDP, PPP (constant 2005 int'l $)

(c) Electricity







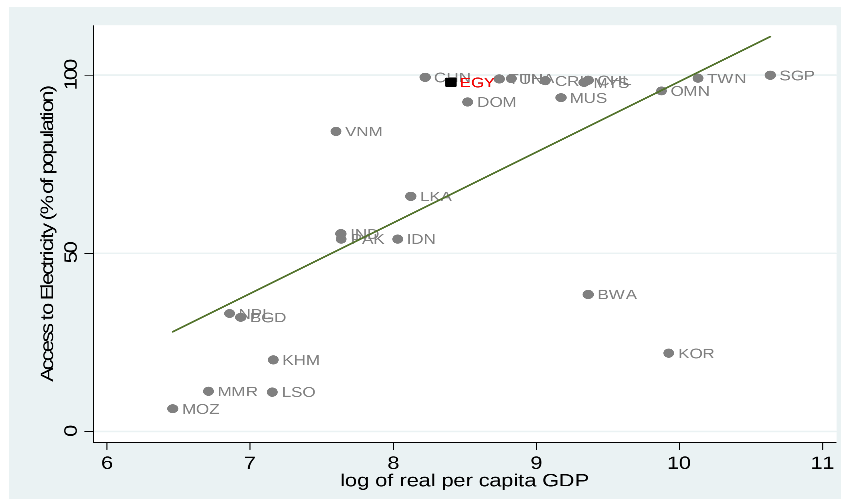


Figure 1-A (continued). Sub-sample: countries with real per capita growth>0.019
Correlations between infrastructure indicators and per capita GDP, PPP (constant 2005 int'l $)

(d) Water and Sanitation

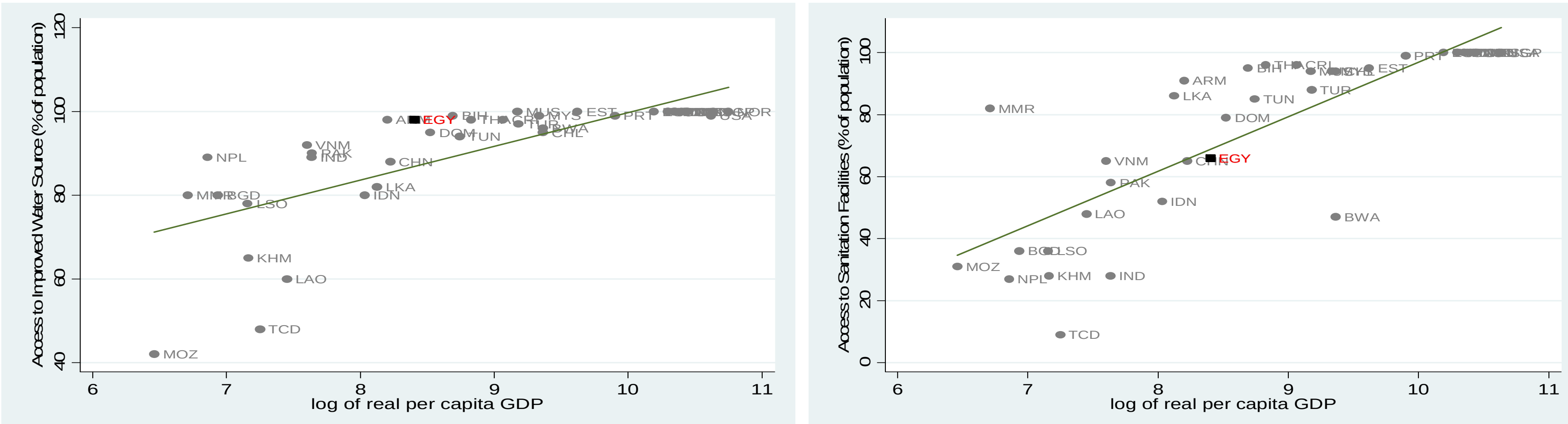


Figure 1-B. Full-sample, correlations between infrastructure indicators and average per capita GDP growth (1995-2007), PPP

(a) Transport

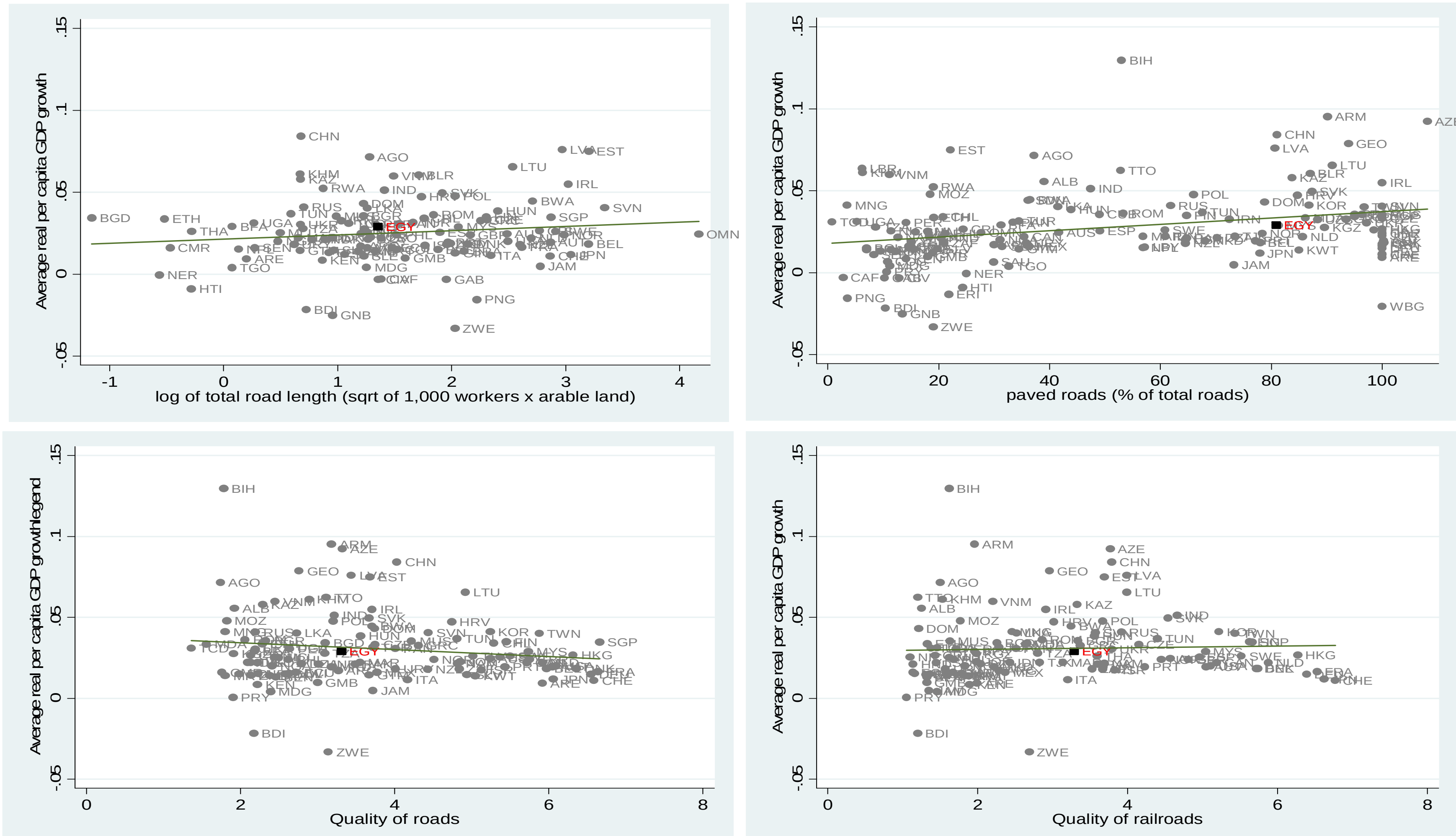
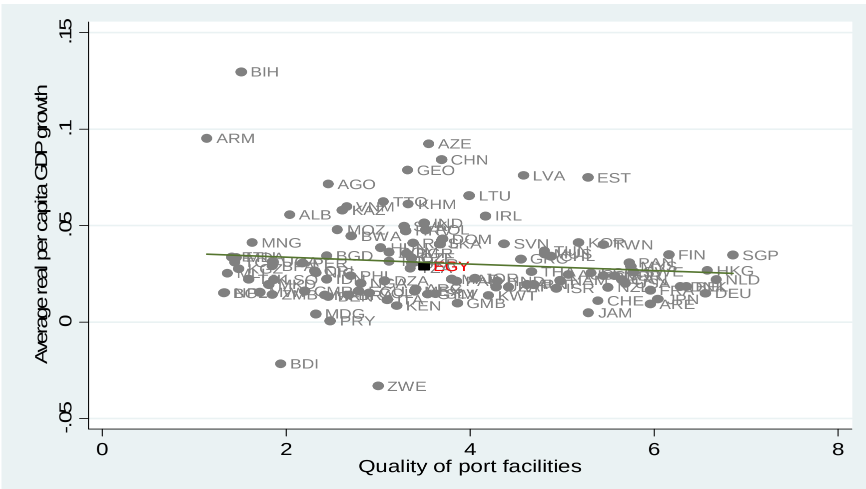


Figure 1-B (continued). Full-sample, correlations between infrastructure indicators and average per capita GDP growth (1995-2007), PPP

(a) Transport (continued)



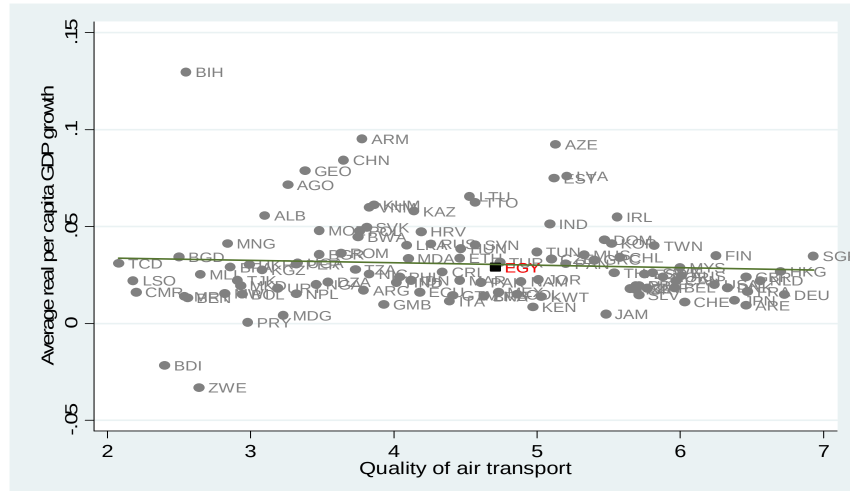


Figure 1-B (continued). Full-sample, correlations between infrastructure indicators and average per capita GDP growth (1995-2007), PPP

(b) Telecommunications

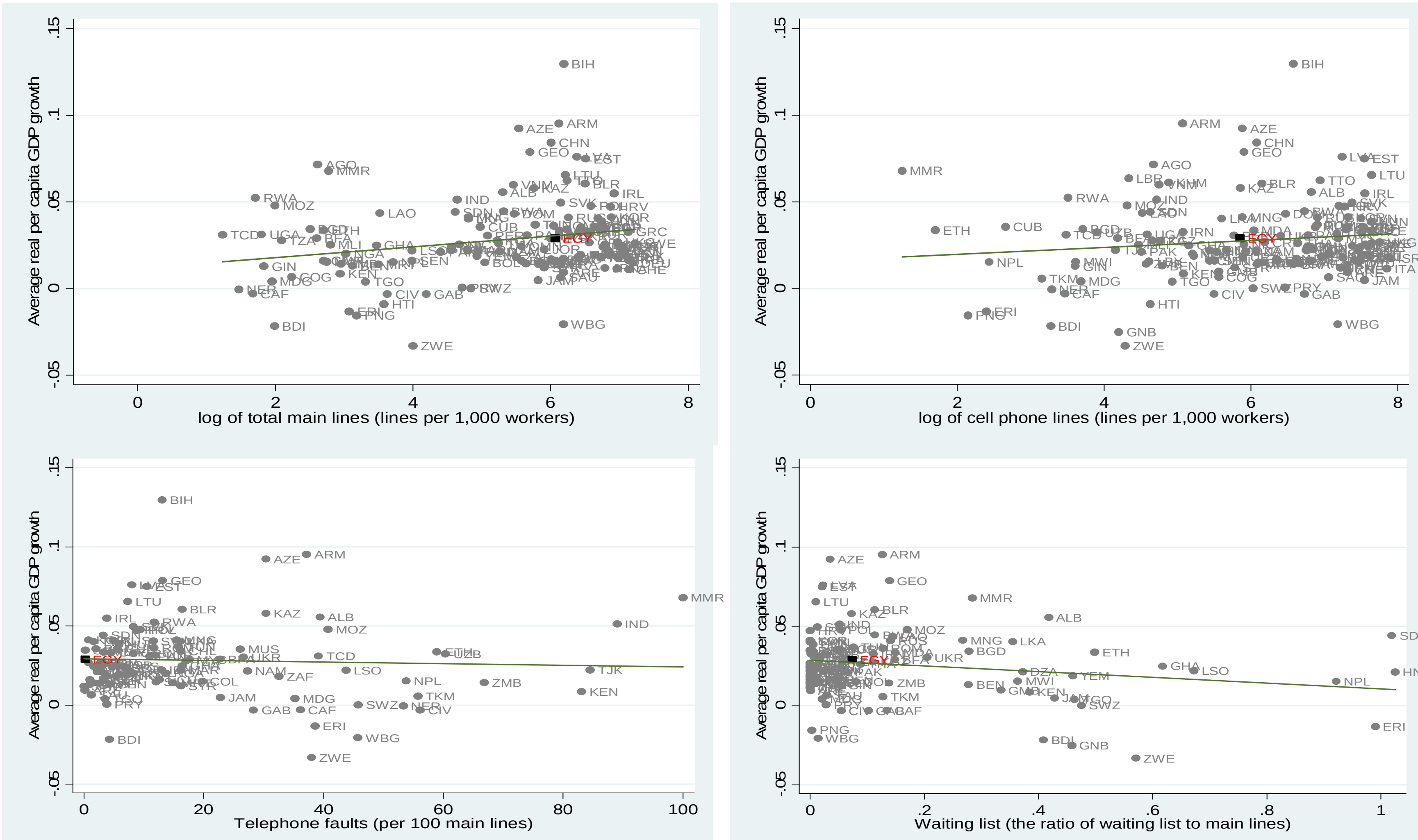


Figure 1-B (continued). Full-sample, correlations between infrastructure indicators and average per capita GDP growth (1995-2007), PPP

(c) Electricity

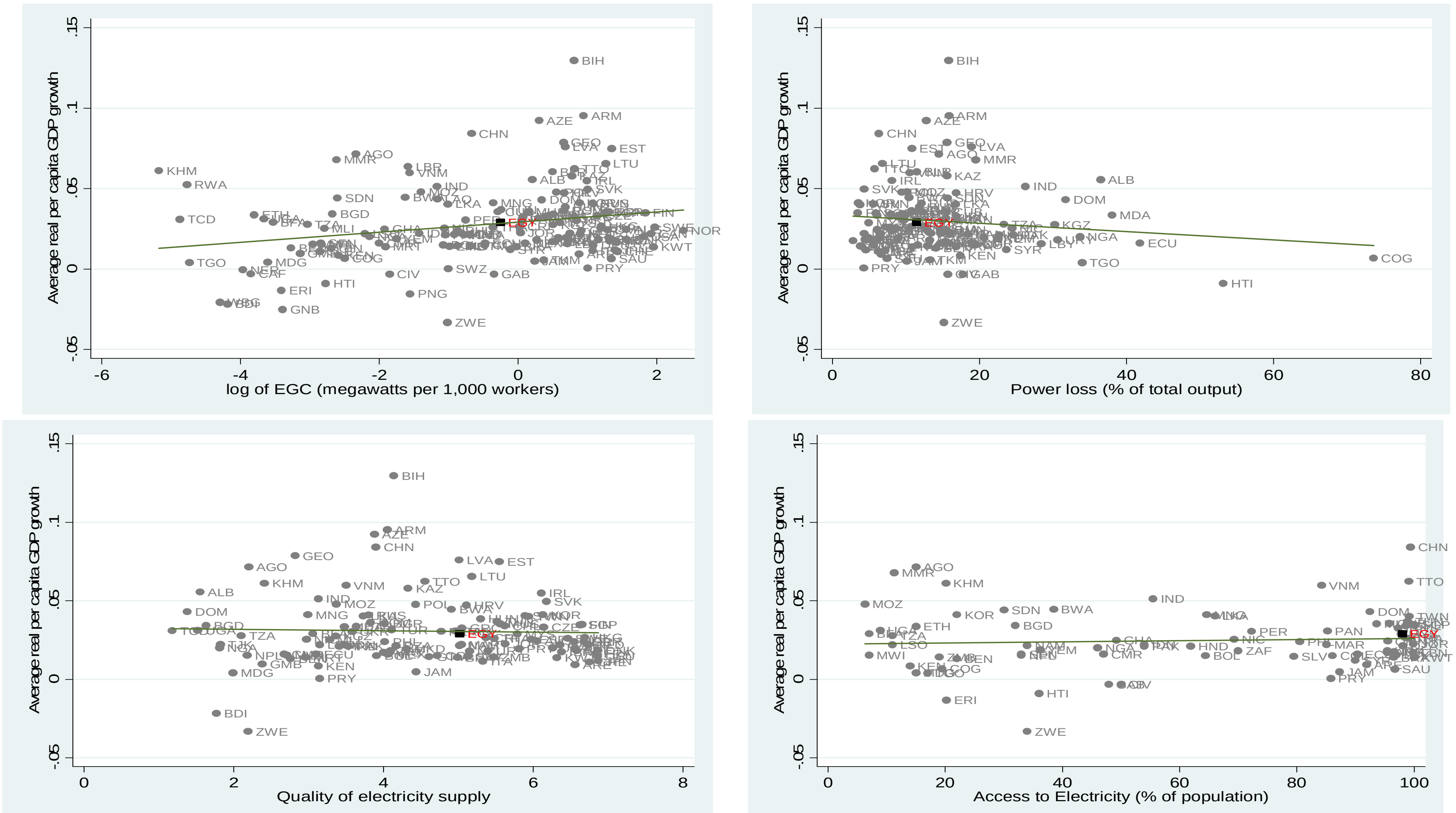
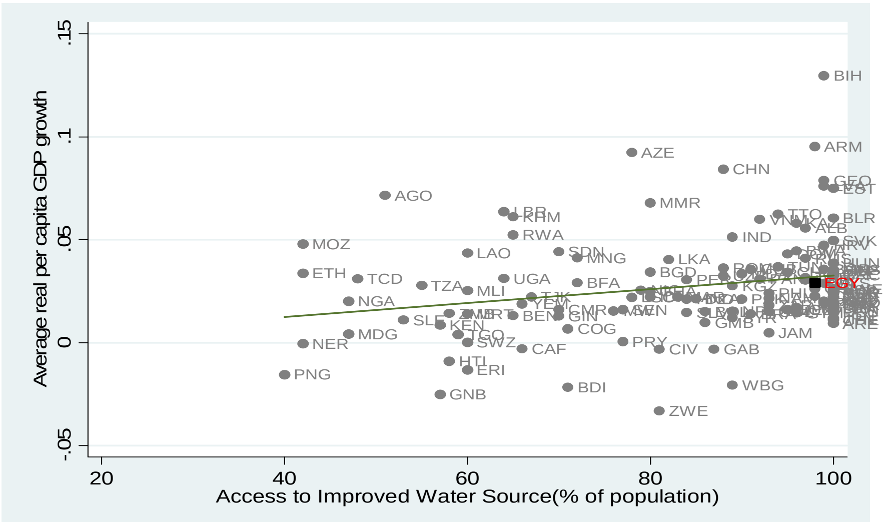
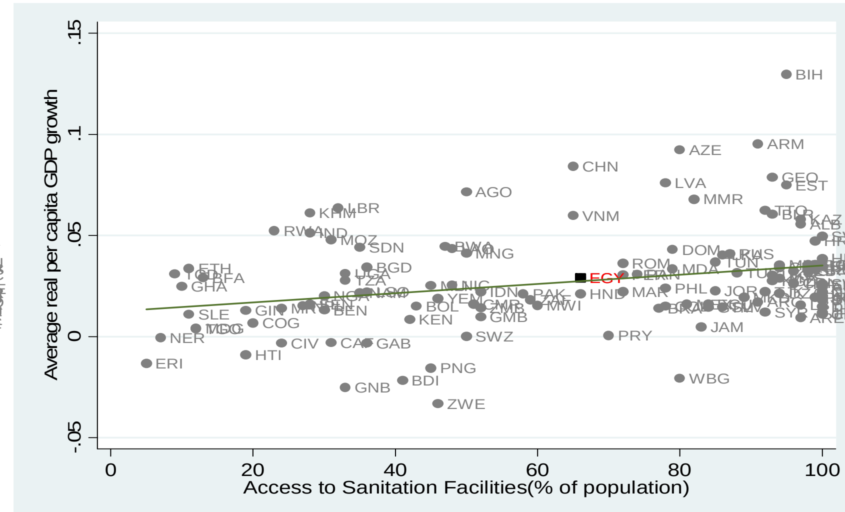


Figure 1-B (continued). Full-sample, correlations between infrastructure indicators and average per capita GDP growth (1995-2007), PPP

(d) Water and Sanitation





APPENDIX 3: Econometric Methodology

Although our focus is on the estimation of the growth effects of public infrastructure, we must make sure that the full growth regression is correctly specified and estimated. Thus, we need to ensure that all relevant variables are included, that their potential endogeneity is controlled for, and that we account for unobserved effects.

The growth regression presented above poses some challenges for estimation. The first is the presence of unobserved period- and country-specific effects. While the inclusion of period-specific dummy variables can account for the time effects, the common methods of dealing with country-specific effects (that is, within-group or difference estimators) are inappropriate given the dynamic nature of the regression. The second challenge is that most explanatory variables, including the public infrastructure indices, are likely to be jointly endogenous with economic growth, so we need to control for the biases resulting from simultaneous or reverse causation. The following outlines the econometric methodology we use to control for country-specific effects and joint endogeneity in a dynamic model of panel data.

We use the generalized method of moments (GMM) estimators developed for dynamic models of panel data that were introduced by Holtz-Eakin, Newey, and Rosen (1988), Arellano and Bond (1991), and Arellano and Bover (1995). These estimators are based, first, on differencing regressions or instruments to control for unobserved effects and, second, on using previous observations of explanatory and lagged-dependent variables as instruments (which are called internal instruments).

After accounting for time-specific effects, we can rewrite equation 4.1:

$$y_{i,t} = \alpha\, y_{i,t-1} + \vec{\beta}' X_{i,t} + \eta_i + \varepsilon_{i,t} \qquad (4.2)$$

To eliminate the country-specific effect, we take first differences of equation 4.2:

$$y_{i,t} - y_{i,t-1} = \alpha\left(y_{i,t-1} - y_{i,t-2}\right) + \beta'\left(X_{i,t} - X_{i,t-1}\right) + \left(\varepsilon_{i,t} - \varepsilon_{i,t-1}\right) \qquad (4.3)$$

The use of instruments is required to deal with the likely endogeneity of the explanatory variables and the problem that, by construction, the new error term, $\varepsilon_{i,t} - \varepsilon_{i,t-1}$, is correlated with the lagged dependent variable, $y_{i,t-1} - y_{i,t-2}$. The instruments take advantage of the panel nature of the data set in that they consist of previous observations of the explanatory and lagged-dependent variables. Conceptually, this assumes that shocks to economic growth (that is, the regression error term) be unpredictable given past values of the explanatory variables. The method does allow, however, for current and future values of the explanatory variables to be affected by growth shocks. It is this type of endogeneity that the method is devised to handle.

Under the assumptions that the error term, ε, is not serially correlated and that the explanatory variables are weakly exogenous (that is, the explanatory variables are assumed to be uncorrelated with future realizations of the error term), our application of the GMM dynamic panel estimator uses the following moment conditions:

$$E\left[y_{i,t-s} \cdot \left(\varepsilon_{i,t} - \varepsilon_{i,t-1}\right)\right] = 0 \quad for\ s \geq 2; t = 3, \ldots, T \quad (4.4)$$

$$E\left[X_{i,t-s} \cdot \left(\varepsilon_{i,t} - \varepsilon_{i,t-1}\right)\right] = 0 \quad for\ s \geq 2; t = 3, \ldots, T \quad (4.5)$$

for $s \geq 2$ and $t = 3,\ldots, T$. Although in theory the number of potential moment conditions is large and growing with the number of time periods, T, when the sample size in the cross-sectional dimension is limited, it is recommended to use a restricted set of moment conditions in order to avoid overfitting bias (we return to this issue below). In our case, we work with the first five acceptable lags as instruments.[32] As mentioned above, the indicator of natural disasters and the measure of external shocks (i.e. growth rate of terms of trade) are treated as exogenous variables.

The GMM estimator based on the conditions in 4.4 and 4.5 is known as the difference estimator. Notwithstanding its advantages with respect to simpler panel data

[32] Specifically, regarding the difference regression corresponding to the periods *t* and *t-1*, we use the following instruments: for the variables measured as period averages --financial depth, government spending, trade openness, inflation, and crisis volatility-- the instrument corresponds to the average of period *t-2;* for the variables measured as initial values --per capita output and secondary school enrollment-- the instrument corresponds to the observation at the start of period *t-1*.

estimators, the difference estimator has important statistical shortcomings. Blundell and Bond (1998) and Alonso-Borrego and Arellano (1999) show that when the explanatory variables are persistent over time, lagged levels of these variables are weak instruments for the regression equation in differences. Instrument weakness influences the asymptotic and small-sample performance of the difference estimator toward inefficient and biased coefficient estimates, respectively.[33]

To reduce the potential biases and imprecision associated with the difference estimator, we use an estimator that combines the regression equation in differences and the regression equation in levels into one system (developed in Arellano and Bover, 1995, and Blundell and Bond, 1998). For the equation in differences, the instruments are those presented above. For the equation in levels (equation 4.2), the instruments are given by the lagged differences of the explanatory variables.[34] These are appropriate instruments under the assumption that the correlation between the explanatory variables and the country-specific effect is the same for all time periods. That is,

$$\begin{aligned} &E[y_{i,t+p} \cdot \eta_i] = E[y_{i,t+q} \cdot \eta_i] \quad \textit{and} \\ &E[X_{i,t+p} \cdot \eta_i] = E[X_{i,t+q} \cdot \eta_i] \quad \textit{for all } p \textit{ and } q \end{aligned} \qquad (4.6)$$

Using this stationarity property and the assumption of exogeneity of future growth shocks, the moment conditions for the second part of the system (the regression in levels) are given by:

$$E[(y_{i,t-1} - y_{i,t-2}) \cdot (\eta_i + \varepsilon_{i,t})] = 0 \qquad (4.7)$$

$$E[(X_{i,t-1} - X_{i,t-2}) \cdot (\eta_i + \varepsilon_{i,t})] = 0 \qquad (4.8)$$

---

[33] An additional problem with the simple difference estimator involves measurement error: differencing may exacerbate the bias stemming from errors in variables by decreasing the signal-to-noise ratio (see Griliches and Hausman, 1986).

[34] The timing of the instruments is analogous to that used for the difference regression: for the variables measured as period averages, the instruments correspond to the difference between *t-1* and *t-2*; and for the variables measured at the start of the period, the instruments correspond to the difference between *t* and *t-1*.

We thus use the moment conditions presented in equations 4.4, 4.5, 4.7, and 4.8 and employ a GMM procedure to generate consistent and efficient estimates of the parameters of interest and their asymptotic variance-covariance (Arellano and Bond 1991; Arellano and Bover 1995). These are given by the following formulas:

$$\hat{\theta} = (\bar{X}' Z \hat{\Omega}^{-1} Z' \bar{X})^{-1} \bar{X}' Z \hat{\Omega}^{-1} Z' \bar{y} \qquad (4.9)$$

$$AVAR(\hat{\theta}) = (\bar{X}' Z \hat{\Omega}^{-1} Z' \bar{X})^{-1} \qquad (4.10)$$

where $\boldsymbol{\theta}$ is the vector of parameters of interest (α, $\boldsymbol{\beta}$); $\bar{\mathbf{y}}$ is the dependent variable stacked first in differences and then in levels; $\bar{\mathbf{X}}$ is the explanatory-variable matrix including the lagged dependent variable (y_{t-1}, $\mathbf{X}$) stacked first in differences and then in levels; $\mathbf{Z}$ is the matrix of instruments derived from the moment conditions; and $\hat{\Omega}$ is a consistent estimate of the variance-covariance matrix of the moment conditions.[35]

Note that we use only a limited set of moment conditions. In theory the potential set of instruments spans all sufficiently lagged observations and, thus, grows with the number of time periods, T. However, when the sample size in the cross-sectional dimension is limited, it is recommended to use a smaller set of moment conditions in order to avoid over-fitting bias (see Arellano and Bond 1998; for a detailed discussion of over-fitting bias in the context of panel-data GMM estimation, see Roodman 2007). This is our case, and therefore we use two steps to limit the moment conditions. First, as described in detail above, we use as instruments only five *appropriate lags* of each endogenous explanatory variable. Second, we use a common variance-covariance of moment conditions across periods. This results from substituting the assumption that the average (across periods) of moment conditions for a particular instrument be equal to zero for the assumption, conventional but more restrictive, that each of the period moment conditions be equal to zero.[36] At the cost of the reduced efficiency, our two

[35] Arellano and Bond (1991) suggest the following two-step procedure to obtain consistent and efficient GMM estimates. First, assume that the residuals, $\varepsilon_{i,t}$, are independent and homoskedastic both across countries and over time; this assumption corresponds to a specific weighting matrix that is used to produce first-step coefficient estimates. Second, construct a consistent estimate of the variance-covariance matrix of the moment conditions with the residuals obtained in the first step, and then use this matrix to re-estimate the parameters of interest (that is, second-step estimates).

[36] This uses the "collapse" option of xtabond2 for STATA.

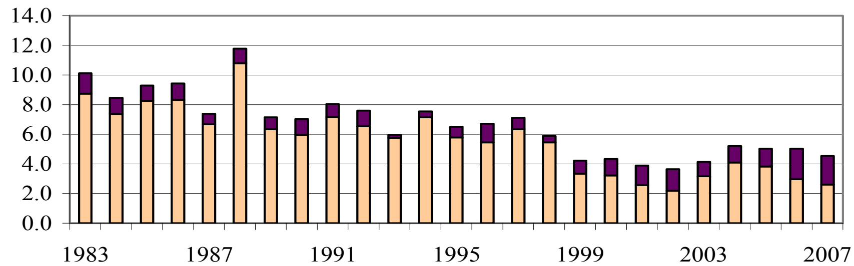
steps decrease over-fitting bias in the presence of small samples by accommodating cases when the unrestricted variance-covariance is too large for estimation and inversion given both a large number of explanatory variables and the presence of several time-series periods.

The consistency of the GMM estimators depends on whether lagged values of the explanatory variables are valid instruments in the growth regression. We address this issue by considering a specification test. This is the Hansen test of overidentifying restrictions, which tests the validity of the instruments by analyzing the sample analog of the moment conditions used in the estimation process. Failure to reject the null hypothesis gives support to the model.

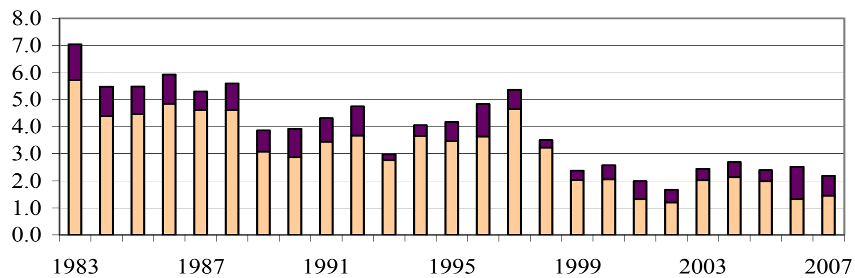
APPENDIX 4: Infrastructure Investment – Recently Published Disaggregation

Figure 4-A. Infrastructure Investment in Egypt (1983-2007) (Percentage of GDP)

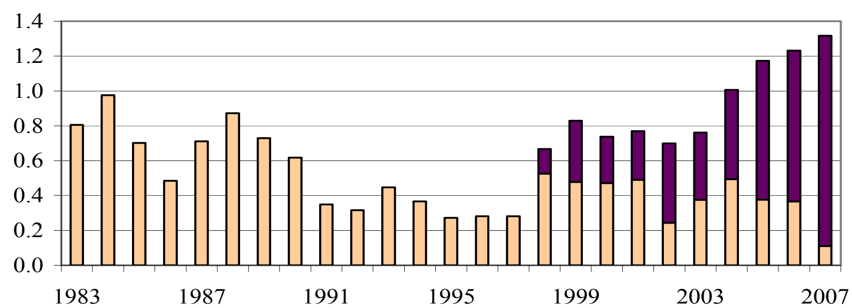
(a) Total Investment



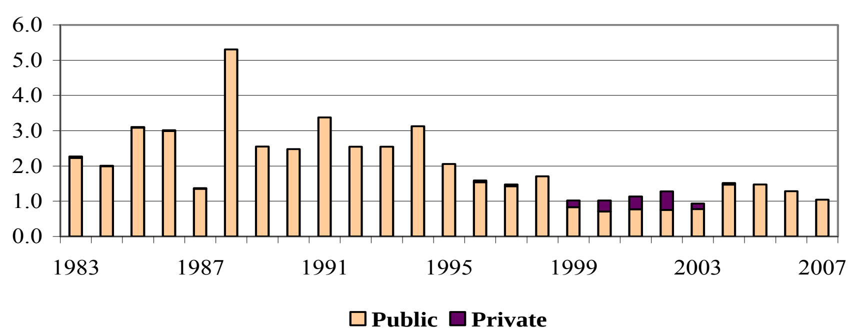
(b) Transportation (incl. SC)



(c) Communications



(d) Electricity



APPENDIX 5: Additional Regression Analysis on Infrastructure Expenditure and Improvement

Table 6-A. Electricity Expenditure and Improvement

Electricity

Estimation Method: Quantile regression

	Dependent variable: Change in Electricity Infrastructure Index			
	[1]	**[2]**	**[3]**	**[4]**
Ratio of expenditure to labor force	0.010 ***			
(expenditure on electricity per 100,000 workers)	[6.02]			
Ratio of expenditure to labor force		0.112 ***		
(expenditure on electricity per 100,000 workers, in logs)		[4.13]		
Ratio of expenditure to GDP			0.007 ***	
(expenditure on electricity / 1,000 GDP)			[6.38]	
Ratio of expenditure to GDP				0.129 ***
(expenditure on electricity / 1,000 GDP, in logs)				[6.24]
Initial value of infrastructure index	-0.232 **	-0.542 **	-0.226 **	-0.687 ***
	[2.43]	[2.06]	[2.22]	[2.76]
Initial value of infrastructure index * Expenditure	0.009	0.184 *	0.010 *	0.219 **
	[1.43]	[1.82]	[1.99]	[2.61]
Constant	-0.135 ***	-0.281 ***	-0.145 ***	-0.372 ***
	[5.05]	[3.87]	[5.83]	[6.11]
Observations	34	34	34	34
R-squared	0.46	0.35	0.47	0.42

Notes:
The dependent variable and initial value of index are smoothed by using the Hodrik Prescott filter.
All the expenditure variables are the moving average of expenditures in the last three years.
Numbers in brackets are the corresponding t-statistics.

** significant at 10%; ** significant at 5%; *** significant at 1%*

Table 7-B. Transportation and Telecommunication Expenditures and Improvement

Transportation and Telecommunication
Estimation Method: Quantile regression

	Dependent variable: Change in Transportation & Telecommunication Infrastructure Index			
	[1]	**[2]**	**[3]**	**[4]**
Ratio of expenditure to labor force	0.002 ***			
(expenditure on transportation & telecommunication per 100,000 wor	[3.04]			
Ratio of expenditure to labor force		0.053 **		
(expenditure on transportation & telecommunication per 100,000 workers, in logs)		[2.65]		
Ratio of expenditure to GDP			0.001 ***	
(expenditure on transportation & telecommunication / 1,000 GDP)			[2.71]	
Ratio of expenditure to GDP				0.052 ***
(expenditure on transportation & telecommunication / 1,000 GDP, in logs)				[3.05]
Initial value of infrastructure index	0.008	-0.082	-0.007	-0.089
	[0.40]	[1.19]	[0.30]	[1.29]
Initial value of infrastructure index * Expenditure	0	0.029	0.001	0.033 *
	[0.26]	[1.36]	[1.62]	[1.71]
Constant	-0.005	-0.132 *	-0.017	-0.149 **
	[0.24]	[1.92]	[0.74]	[2.37]
Observations	45	45	45	45
R-squared	0.50	0.47	0.46	0.45

Notes:
All the expenditure variables are the moving average of expenditures in the last three years.
Numbers in brackets are the corresponding t-statistics.

** significant at 10%; ** significant at 5%; *** significant at 1%*