

IFC Economics Notes
Note 1
The impact of infrastructure on growth
in developing countries

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Since Aschauer's seminal work (1989a) on the USA, there has been almost 25 years of academic research on the impact of infrastructure on growth.¹ Understanding these long lasting debates is essential to have a balanced quantitative view on the relevance of infrastructure for growth. Some of the issues have indeed been settled, others not quite yet.

That infrastructure matters to growth is now relatively well recognized and widely understood among practitioners and policy makers. There is, indeed, a plethora of anecdotal and more technical evidence that better quantity and quality of infrastructure can directly raise the productivity of human and physical capital and hence growth (e.g. by providing access, roads can: (i) improve education and markets for farmers' outputs and others by cutting costs, (ii) facilitate private investment, (iii) improve jobs and income levels for many).

How much, specifically, and which infrastructure matters when to output levels and their growth in developing and transition economies is not as clearly settled. The research available on these questions is the main focus of this note.

(Settled?) Academic debates on *how much* infrastructure matters

Debates on the proper econometric modeling have tended to dominate the disagreements among academics and other researchers on how much infrastructure matters. The discussion covered poor choice of explained variable (GDP level, or growth, measured in physical or in monetary terms,...), functional forms (Cobb-Douglas, translog, log, linear, or log-

linear,...), data stationarity issues and untreated endogeneity (i.e. how certain are we that the model accounted for the two-way causality between growth and infrastructure). Part of the challenge, when interpreting this literature, is to make sure that results are really comparable.

The upshot is that it is easy to understand why there still are so many debates as to the level of the impact of infrastructure on the level of GDP and its longer term impact on the growth potential of the economy. Among the many debates, the discussions on the specific definition of infrastructure may matter the more directly to practitioners.

In general, infrastructure is defined as electricity, gas, telecoms, transport and water supply, sanitation and sewerage. However, because data on the physical stocks of these sectors, or their valuation, tends to be scarce, authors have often relied on stocks of public capital or specific subsectors as proxies for infrastructure.

Public capital seems to be attractive because it is somewhat easier to identify in many countries. But it is a broader concept that is itself quite unclear. For instance, it can include all public buildings, including often hospitals, schools or public housing and office stocks, or police and fire stations. Thus the extent of its relevance to assess the impact of infrastructure on growth is at best unclear. It is in fact worsening since, pointed out by Straub (2011), the relative importance of the private sector in infrastructure has increased a lot more than in other activities.

For the reader convinced that public capital is a reasonable proxy, two recent surveys show that it has a positive effect on growth. Romp & de Haan (2007) conclude that "there is more consensus than in the past that public capital positively affects economic growth, but the impact seems to

¹ This note represents the views of the authors and these should not be attributed to any of the organizations we are affiliated with, nor to IFC, the World Bank or any of its members countries or agencies. Any mistake or misinterpretation is ours and ours only.

be lower than previously thought." Bom & Lighthart (2009) also point out that early estimates had the right (positive) sign but may have been too optimistic. Focusing on research on the output elasticity of public capital, they conduct a meta-analysis of all comparable studies and find it to average across studies at around 0.08—i.e. a 1% increase in the stock of public capital would lead to a 0.08% increase in GDP, keeping in mind that this is an average that hides much higher sector specific payoffs achieved in some of the subsectors, in particular in infrastructure as seen in the appendix; the appendix table shows that for a few key representative studies focusing on infrastructure only, the elasticity of growth is 2.5 times what it averages out to be for total public capital.

For anyone interested more specifically on infrastructure, it is easy to argue that the impact of public capital on growth underestimates the impact of infrastructure. This is what Straub (2008) argues. His case is a bit technical but it implies that the use of public capital underestimates the statistical strength of the evidence on the real GDP and growth payoffs of infrastructure. The evidence seems to validate this view. When the data allows a measure of infrastructure, the impact of asset expansion in the sector on both GDP and growth is indeed statistically more significant. However, somewhat surprisingly, the order of magnitude remains similar. It is simply statistically more credible. This is also the conclusion reached by Estache and Garsous (2011).

Calderon et al. (2011) provide an additional insight that reinforces the sense of robustness of the impact of infrastructure. Focusing on elasticity of GDP *per worker* with respect to a synthetic infrastructure index leads to a similar elasticity level similar to those focusing on GDP *per se*.

All this research can be translated into an assessment of the infrastructure investment requirements to achieve the growth needed to reach the reductions in poverty demanded by the MDGs. How much infrastructure depends on each region.

For SSA, according to the research conducted collectively by the donors' community, the estimated spending needs are \$93 billion a year or 15% of the region's GDP, about 10% in investment and 5% in operation and maintenance.² The spending needs in the poorest countries are as high as 25% of their GDP, even more for fragile states. Over 40% of the expenditure needed is in the power sector—to finance the 7,000 megawatts of new generation capacity needed each year just to keep pace with demand. Slightly more than 20% is needed for water supply and sanitation and a further 20% for the transport sector to achieve a reasonable level of regional, national, rural, and urban connectivity and to maintain existing assets. The rest is for irrigation and telecommunications.

Asia needs annually about US\$750 billion in infrastructure investment to 2020, around 68% for new investments and the rest for maintenance or replacement of existing assets. This implies an annual commitment of about 6.5% of its GDP. Of the total, about half is for energy infrastructure, a third for transport, 13% for ITC, and 3% for W&S (Bhattacharyay (2010)). East and Southeast Asia together account for more than 50% of the total required investment. In Central, East and Southeast Asia, investment needs are the highest in the electricity sector whereas in South Asia the highest need is in transport.

For Latin America, annual needs are around 4% of GDP to support most growth scenarios—from conservative to optimists. (Kolhi and Basil (2011)). This is also the working order of magnitude used by the main donors. In this region, however, many governments have also released their own estimates and they tend to be 1-2% higher than the estimates based on multi-country assessments.

For MENA, these needs are around 3% of GDP but roughly an extra 4% is needed for operations and maintenance (Yepes and Estache (2011)). This adds up to around US\$106 billion/year. There is however a

² www.infrastructureafrica.org/

huge variance in the region, with oil exporting countries needing to spend around 11%, about the double of what oil importing and GCC countries need to spend. Energy and transport each need around 40% and ICT around 10% of the total needs.

For ECA, the total needs are around 6.6%. What stands out in this region is that the highway interconnections are poor and sources of bottlenecks. This is why road transport (2.7% of GDP) is the subsector with the highest needs, followed by energy (2%). ICT comes third with needs of around 0.9% of GDP (Estache (2011))

Ongoing debates on “which infrastructure matters when?”

While there is a reasonable agreement on how much infrastructure matters to growth, there is much less convergence on which infrastructure subsector matters the most under which circumstance. This can be seen in the differences in estimates of investment needs across regions and within regions. The challenge is thus to sort the drivers of these differences.

One way of organizing the assessment of the drivers of infrastructure priorities is suggested by Estache and Garsous (2011). Infrastructure could depend on:

- the development stage of the countries covered by the sample analyzed,
- the time period over which the impact is assessed, and
- the type of infrastructure.

Building on that suggestion, Garsous (2012) conducts a meta-analysis of studies focused exclusively on infrastructure rather than on public capital. His synthesis and a few related papers offer the insights summarized next.

a. On the stage of development

Intuitively, it should make sense to assume that the more developed a country is, the higher its infrastructure stock and hence the lower the payoff from additional investment, unless it aims at addressing a

major bottleneck or introducing a major technological improvement. Yet, empirical research so far has not really provided a definitive answer. For instance, Calderon et al. (2011), relying on very aggregate approach, find that the stage of development does not seem to matter.

However, Garsous (2012) points out that their conclusion has to be qualified. Indeed, the answer to the question depends on the weight of developing countries in the sample analyzed. The larger the number of developing countries in the sample, the more likely a positive impact of infrastructure on output/growth is likely to be observed. This would allow the conclusion that the less developed the country, the more likely infrastructure to matter. The more developed a country is, the more other dimensions such as bottlenecks, diseconomies of scale, network effects, or technological lags tend to matter more than the aggregate infrastructure stock.

Estache and Wren-Lewis (2011) add that large supranational energy or transport projects can have very significant payoffs at all stages of development. Investments in these sectors can thus make a significant impact in terms of connecting markets. Ignoring this may underestimate the payoffs from infrastructure or some countries.

The case for such projects is just as strong in Europe as it can be in Africa, Asia or Latin America. This point was already made at the US level where spillover effects across states can be important. Fernald (1999) showed a difference in the U.S. interstate highway network productivity before and after its completion. In particular, the massive road-building of the 1950's and 1960's seem to have offered a one-time boost productivity. Fernald (1999) actually argues that Aschauer (1989) high productivity assessments were biased by this one-time increase in productivity. A much broader conclusion is that relying only on past productivity gains from “local or national” investments may underestimate the gains from investing in larger networks for some countries, in

particular when these investments have huge international network externalities.

b. On the time dimension

As too often in economic research, the importance of very basic facts and assumptions for the extent to which a conclusion can be generalized tends to be underestimated. One such characteristic is the relevance of the time period analyzed. The older the studies on a given country or regions, the more like they are to cover time periods in which the stock of infrastructure was lower and hence any improvement would have a higher payoff. This is the case for Spain or the US for instance (Estache-Fay (2010)). But this is just another way of validating the point that the stage of development matters. Indeed, infrastructure mattered a lot more to Spain in the 60s when it was simply trying to catch with the more advanced parts of Europe. This is what the old studies picked up. More recent studies, include time periods as of which, the gap has closed and the payoffs to additional infrastructure are still positive, but simply lower.

Estache (2011) provide a somewhat more subtle argument to explain the relevance of time. *Ceteris paribus*, studies covering a longer period are more likely to find a positive impact of infrastructure on output or growth. This result should not be surprising. Infrastructure has an unusual cash flow profile, with high short-term costs and slow but long income flows. Therefore, for a given project and discount rate, the longer the analysis, the more likely a positive impact assessed on GDP, growth and, in fact, jobs.

Even if these arguments seem robust, the hard evidence continues to raise questions. It is intriguing that many of the studies covering the fifties and eighties were more likely to find a positive impact of infrastructure. The opposite is true for many of the studies covering the sixties and the seventies. Clearly, other factors matter as well. For instance, Albala-Bertrand and Mamatzakis (2004) show for Chile that infrastructure impact became higher after liberalization (see Note 2 for more details).

c. On the type of infrastructure³

Any modern textbook on industrial economics or industrial organization will point out that for industries that enjoy network externalities, the social rate of return has to be higher than the private rate of return in these projects—assuming that the regulation does not allow the network externality to be turned into a private rent. In other words, their impact on GDP and its growth should be high.

This explains for instance why the growth impact of the telecoms sector so often come out to be high. But for specific countries or regions, this could also be true for transport or electricity. In general, however, all infrastructure subsectors can be good examples of sectors in which such network externalities can matter. Their social return will however evolve with time, with stock size and with market size. This section reviews the main lessons available on each subsector on the growth impact of each infrastructure subsector.

i. Energy

The importance of access to electricity to human development has been documented in a large number of case studies and cross-country econometric studies across regions. It is a recurring item in all studies on the impediments to the business environment. (see Dethier et al. (2008 et al.) for instance). Among these studies, those focusing on developing countries all find a positive impact of energy infrastructure on output/growth. In fact, in his survey, Garsous (2012) finds that, *ceteris paribus*, studies focusing on the energy sector are more likely to find a robust positive impact than any other infrastructure sector. In other words, investing in the energy sector may be the safest bet to achieve a high social rate of return. This should not be a surprise, energy is indeed an input into any of the other infrastructure subsectors—for instance, water is often pumped thanks to electric pumps.

³ The few sub-Sector specific elasticities results available from cross country studies are reported in the appendix.

ii. Water and Sanitation

The water and sanitation sector may be the infrastructure subsector for which the econometric evidence of an impact is the less well documented. This reflects the fact that the link with growth is a lot more indirect than for the other subsectors. Although water drives health which in turn drives labor productivity and labor productivity, itself, drives growth, the link between water and growth does not seem to spring to mind to most researchers or at least not as strongly as for the other sectors. It is noteworthy that Calderon and Serven, the World Bank based researchers who may have spent the most time on assessing the impact of infrastructure on growth have left out the water sector of their analysis.

Among the few studies that have analyzed this contribution in developing countries, the evidence is mixed. Binswanger et al. (1992) for instance find that the contribution of canal irrigation infrastructure to crop output is null from a panel of districts in India. Estache et al. (2005) find the contribution of water and sanitary infrastructure to be positive from a panel of sub-Saharan countries.

iii. Telecommunications

The impact of telecoms for growth may be the best documented impact. To a large extent, it is because telecoms data is relatively easy to access, including for developing countries. Zhan-Wei Qiang and Pitt (2009) and Chakraborty and Nandi (2011), more recently, survey this literature. But it continues to grow.⁴ Most studies find a positive impact of telecommunication infrastructure on GDP, on growth—and also on labor productivity. As with other infrastructures, there is a debate on the precise magnitude of its contribution. But this is quite normal, the interdependency between fixed and mobile telephony for instance still requires a significant amount of regulation of access. Its effectiveness strongly drives the social return of return for the sector.

⁴ The IMF has produced a few working papers on the topic. The latest one is by Andrianaivo and Kpodar (2011) focusing on the growth effect of ICT in Africa and it features an interesting focus on the impact of mobile telephony and financial inclusion.

This is quite obvious in the recent growing research on the importance of the access to internet to increase competition in the sector and from there increase the social return to expansions in the sector. Poor regulation hurts the growth payoffs because even when investment takes place, quality does not necessarily follow. We know for instance that the faster the access to high speed internet, the stronger the payoff. Yet many countries fail to manage this, contributing to explain the differences in the macroeconomic and social returns to investment in the sector.

The orders of magnitude of the gains vary across regions and across countries. But the average payoffs are quite impressive—they are usually among the highest when the payoffs to infrastructure are unbundled into its components. For Africa for instance, this is one of the reasons why supranational investments on the backbones are so important.

iv. Transports

For developed countries, the estimated growth effects of transport investments have not been very strong. This has been a common finding in research over the last 20 years or so. This is not surprising since their transport stocks are mature. The main impact at advanced stages of development has to come from quality, from addressing bottlenecks or from capturing new network or supranational effects which have not been internalized in older designs of the transport networks.

For developing countries, the picture looks quite different. Whatever the GDP growth related focus, most cross-country studies find a positive impact. For instance, roads are needed for Africa to catch with the rest of the world (Buys et al. (2006). Roads are essential to reduce differences across regions within countries (Estache–Fay (2010)). Port quality is central to the evidence collected on the gains from trade facilitation for instance. In the case of APEC countries, Wilson et al. (2003) for instance found that increasing port capacity for countries below capacity average could increase APEC average per capita GDP by 4.3%.

It is however important to point out that for country specific studies, the overall results are not always as clear cut. A possible explanation, of course, could be is that econometric methodologies cannot easily fully capture the gains from marginal, or sometimes more significant, redesigns of the transport networks to fully internalize network externalities.⁵ Similarly, these methodologies seldom pick up fully properly at the country level the gains from intermodal interactions from increased competition or improved integration.

iv. So, in which subsector to invest?

There is no simple answer to any question trying to lead to a ranking of sectoral investments. The best standard way to deal with these sorts of questions is still to conduct a good cost-benefit analysis at the project level and to add up the results for all projects to generate the aggregate investment profile for the country. No country really does it like that. Some do it within sectors (the UK, Australia or Finland for instance). Chile is probably the country that comes the closest to following this rational approach.

When trying to see ex-post which sector has tended to help the most, one alternative approach is to look at comparative impact assessments from econometric studies. The approach raises lots of issues, but it seems to suggest quite systematically that energy is the more productive sub-sector in most country specific assessments. However, in general, these papers do not include ICT infrastructure, in particular all the modern developments allowed by the constant technological improvements in the sector.

Although there is no precise answer to the macro-ranking question in the literature, the best general answer is offered by Hulten and Isaksson (2007) when trying to explain differences in income and productivity levels for 112 countries between 1970 and 2000. They

argue that, at different stages of development, different kinds of infrastructure are important to maintain growth and productivity at levels high enough to allow countries to catch up with the countries with the highest growth rates. At a given level of development, however, the growth and productivity payoffs of sector specific investment will not be the same across regions.

There is a lot of ongoing research showing that differences in institutional quality matters to growth and hence to the growth payoffs of sectoral investment decisions (Rodrik (2008), Acemoglu and Robinson (2012)). There is also sound and increasingly popular research on the importance of identifying bottlenecks when deciding where to allocate scarce resources (using firm-level surveys critically—recognizing that complaints are not the same as real constraints). Hausman and various co-authors at Harvard have conducted many such diagnostics—see Hausman et al. (2005) for the intuition and Hausman et al (2008) for a “manual”. This is the research that is starting to provide useful answers to the question “where should investment take place?”. In a nutshell, it all starts with a tedious but much needed growth diagnostic.

Main messages to remember?

Improvements in econometric techniques, and sometimes in data sources, have steadily improved the precision and reliability of our collective understanding and assessment of the contribution of public capital/infrastructure to growth. Our knowledge is still far from perfect as the data available on the sector is still problematic. However, the improvement in the quality of macroeconomic research in the field has generated a few reasonably robust messages for practitioners. They can be summarized as follows:

- **Infrastructure matters to growth and its impact is easy to underestimate;** to avoid underestimating its impact:
 - distinguish between infrastructure and public capital, as public capital

⁵ It is quite widely recognized that the current African networks reflect designs largely inherited from colonial powers and mostly aimed at exporting raw materials to Europe. This reflects of concept of mobility quite far from the current internal needs of the continent.

- tends to underestimate the impact of infrastructure on growth
- take into account the national payoffs that can be achieved from supranational projects, if needed.
- **Infrastructure investment needs to support growth vary across regions:**
 - For SSA, they average 10% of GDP (over 40% for energy and 20% each for water and sanitation and transport) and can reach over 25% for the poorest of the region;
 - Asia and Latin America needs around 4-5% of their GDP for new investment only;
 - The needs in MENA are around 3% but are more than double that amount in oil exporting countries;
 - The needs in ECA are closer to 6.5% including large rehabilitation and replacement needs
- **Subsectoral needs vary across regions;**
 - Across regions, energy is where the largest infrastructure gaps are found (around 40-60% of the investment needs, depending on the country) followed transport—except in ECA and South Asia where the transport needs are the highest
- **On average, the operation and maintenance of the assets adds the equivalent of at least 50% of the investment needs (more in MENA)⁶**
- **Access to physical infrastructure does not drive GDP, growth or the social returns alone.**
 - The poorer a country, the more infrastructure matters on average
 - The weaker the institutions (i.e. more corruption, fewer skills, ...), the lower the growth payoff
 - The more competitive the environment, the higher the payoff
 - The more balanced the residual regulation, the higher the payoffs

⁶ This is based on the information provided by sector specific engineers on how much it costs to operate and maintain a standardized assets. This costs is assessed as a percentage of the per unit value of the asset. This is the foundation of most recent studies of investment and matching operating and maintenance costs.

- **And finally, payoffs are slow to show up in infrastructure—roads are often built on traffic forecast with over 30 years of lead time.**

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Appendix

Authors	Sectors	Estimated output Elasticity to sector investment
Calderon & Serven (2009)	Mixed	0,08
Canning (1999)	Telecoms	0,14
Estache et al. (2005)	Telecoms	0,19
Estache et al. (2005)	Transports	0,34
Estache et al. (2005)	Energy	0,5
Estache et al. (2005)	Water	0,45
Hurlin (2006)	Transports	0,07
Hurlin (2006)	Energy	0,052
Hurlin (2006)	Telecoms	0,104
Sridhar & Sridhar (2009)	Telecoms	0,15
	Average	0,2076