Infrastructure and Growth
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Economists have viewed infrastructure as a key ingredient for productivity and growth since at least Adam Smith. Conceptually, infrastructure may affect aggregate output in two main ways: first, directly because infrastructure services enter production as an additional input; and second, because they raise total factor productivity by reducing transaction and other costs thus allowing a more efficient use of conventional productive inputs.¹

How big is the contribution of infrastructure to aggregate economic performance – e.g., the level and/or growth rate of GDP? The answer is critical for many policy decisions – for example, to gauge the growth effects of fiscal interventions in the form of public investment changes, or to assess if public infrastructure investments can be self-financing. The empirical literature aimed to offer such quantitative assessments took off with the seminal work of Aschauer (1989) on the effects of public infrastructure capital on U.S. total factor productivity (TFP). Using time-series data, he found an extremely (and, for most observers, implausibly) large effect.

Subsequent empirical research has employed a variety of data, empirical methods and infrastructure measures.² The approaches most frequently used involve the estimation of (i) a production function (or its dual, the cost function) defined at a suitable level of aggregation (national, regional, etc), including measures of infrastructure along with conventional productive inputs, and (ii) empirical growth equations, relating output or productivity growth to different indicators of infrastructure performance together with other controls, typically in a cross-country (or cross-state or province) setting. For these exercises, infrastructure is variously measured in terms of physical stocks (e.g., km of roads or number of telephone lines) or pecuniary stocks constructed by accumulating spending flows. The underlying assumption is that the flow of productive infrastructure services is directly related to the size of the stock of infrastructure assets, analogously to what is routinely assumed about the services of human and physical capital.

For the most part, this literature focuses on quantifying the impact of infrastructure on aggregate performance, and is silent about the specific channels through which the impact occurs.³ Its findings are far from unanimous, but a majority of studies reports a significant positive effect of infrastructure on output, productivity, or their growth rate. This is mostly the case with studies using physical measures of infrastructure stocks; in contrast, results are less conclusive among studies using pecuniary measures such as public investment flows or their accumulation into public capital. There is a good reason for this; namely the lack of a close correspondence between public capital expenditure and the accumulation of public infrastructure assets or the provision of infrastructure

¹ See e.g., Gramlich (1994), Romp and de Haan (2007) and Straub (2008).
² Surveys of this literature include Estache (2006), Romp and de Haan (2007), Straub (2008), and Bom and Ligthart (2009). Related literature examines other development effects of infrastructure – e.g., on poverty and inequality, health, rural incomes, etc. For reasons of space it is not discussed here.
³ Indeed, the ubiquitous Cobb-Douglas specification employed by most production-function studies prevents explicit separation of the direct and TFP channels mentioned above.
services, owing to inefficiencies in public procurement and outright corruption – issues that are likely more important in developing economies than in more advanced ones (Pritchett 2000).

Empirical estimates of the magnitude of infrastructure’s contribution display considerable variation across studies. Overall, however, the recent literature tends to find smaller (and more plausible) effects than those reported in the earlier studies (Romp and de Haan 2007), likely as a result – at least in part – of improved methodological approaches. Thus, in a production-function setting, the mid-point estimate from recent studies of the elasticity of GDP with respect to infrastructure capital lies around 0.15 for developed countries (Bom and Ligthart 2009). This means that a doubling of infrastructure capital raises GDP by roughly 10 percent. Estimates from recent studies using broader country samples are not very different. However, this captures only the direct effect of infrastructure on output, given the use of other productive inputs; there may be additional indirect effects accruing through changes in the usage of the other inputs due to complementarities with infrastructure.

In turn, the findings from reduced-form growth regressions are somewhat harder to summarize, because different studies condition on very different sets of non-infrastructure variables. Nevertheless, estimates from recent studies based on panel data combining industrial and developing countries suggest that a 1-percent increase in physical infrastructure stocks, given other variables, temporarily raises GDP growth by as much as 1-2 percentage points, although the growth acceleration gradually tapers off as the economy approaches its long-run per capita income.

Moreover, a number of empirical studies using various approaches also find that the output contribution of infrastructure exceeds that of conventional capital, which suggests the presence of externalities associated with infrastructure services, in line with theoretical presumptions. These results are subject to some caveats, however. Two in particular are worth stressing. The first one is reverse causation. The output (or growth) impact of infrastructure supply that empirical studies aim to capture may be confounded with the (positive) impact of higher incomes on the demand for infrastructure services. Failure to take this feedback effect into account likely results in an overestimation of the output contribution of infrastructure. Yet relatively few studies address this issue.

The second caveat concerns heterogeneity. The output contribution of infrastructure may well vary across countries and time periods depending on many factors – starting with the heterogeneous quality of infrastructure assets themselves. However, few studies take into account the quality dimension – in large part perhaps due to measurement problems. Those that do find that the quality of infrastructure is no less important than its quantity for aggregate performance.

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4 Also, public investment and public capital are poor proxies for infrastructure accumulation if the private sector plays a significant role in infrastructure provision, as is the case in an increasing number of developing countries.
5 For example, Bom and Ligthart (2009) report that estimates of the output elasticity of public capital range from −0.175 to +0.917 in a large set of empirical studies using industrial-country data in a production-function setting.
6 Much of the earlier literature was plagued by spurious regression and other forms of misspecification; see Gramlich (1994).
7 For example, there is evidence that better infrastructure reduces the cost of human capital accumulation.
8 See for example Easterly and Servén (2003, Chapter 3).
9 See, e.g., Calderón and Servén (2010a, b) and Loayza and Odawara (2010). These studies feature conditional convergence, hence the growth acceleration is only temporary.
10 See for example Kamps (2005) and Calderón, Moral-Benito and Servén (2010).
11 The problem is similar to that encountered in the empirical estimation of fiscal multipliers. To deal with reverse causation, the literature has resorted to the use of instrumental variables, and (less commonly) to explicit modeling of infrastructure demand.
12 The classic reference is Hulten (1996). Among the recent literature, the studies listed in fn.9 all control for infrastructure quality.
implication is that adequate maintenance of existing assets deserves at least as high a priority as the acquisition of new ones, a lesson often forgotten, especially in developing countries.

Aside from asset quality, variation in the effects of infrastructure could arise from many other sources – e.g., network effects that create nonlinearities in the output contribution of infrastructure; institutional factors that constrain the efficient use of infrastructure assets. Still, formal tests reported in some recent studies fail to yield much evidence of heterogeneity in the cross-country dimension.\(^{13}\) While these tests may lack power, due to the poor precision of country-specific estimates, they imply that – other things equal – the percentage increase in real GDP (or its growth rate) that results from a given percentage increase in the availability of infrastructure is roughly similar across countries irrespective of size, income level, or infrastructure endowment. Hence the marginal productivity of infrastructure is higher, other things equal, where the (relative) stock of infrastructure is lower – e.g., if the ratio of infrastructure capital to GDP doubles, the marginal productivity of infrastructure is halved.

However, before taking this conclusion as a basis to determine infrastructure spending, it is important to keep in mind that the bulk of the empirical literature summarized here is concerned with measuring the returns on infrastructure assets (in terms of output), but has much less to say about the cost of acquiring and operating them. Assessing the latter is necessary to reach conclusions about the optimal level of infrastructure provision, achieved by equating marginal social return and cost, and to determine accordingly whether infrastructure is under- or over-provided. Intuitively, if infrastructure is close to its optimal level, the general-equilibrium growth effect of a marginal addition to the infrastructure stock should be zero, as the direct output impact of increased assets would cancel out with the negative impact of diverting more resources towards infrastructure accumulation.

Very few studies have followed this route, typically using simple growth models that take explicit account of the resource cost of public infrastructure. Cross-country studies unsurprisingly conclude that infrastructure is over- (under-) provided in some countries, but not in other countries, and the verdict shows no clear correlation with countries’ per capita income.\(^{14}\) These conclusions may well be model-dependent, and their robustness has yet to be established. But the implication is that there is no evidence of a ‘generalized’ infrastructure shortage, so that country and sector-specific studies are necessary to identify suitable policy actions.

\(^{13}\) Calderón, Moral-Benito and Servén (2010) report various tests of general and parametric heterogeneity. See also Calderón and Servén (2010a, b).

\(^{14}\) Further, for a given country, the situation may be different across different types of infrastructure capital (e.g., roads vs power). See Canning and Pedroni (2008) and Kamps (2005). Loayza and Odawara (2010) use a related approach for the case of Egypt.
References


