INFRASTRUCTURE AND DEVELOPMENT¹

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ABSTRACT

The notion of infrastructure is presented as a subset of the notion of capital. Several definitional characteristics of infrastructure are identified and discussed. Curiously, for two centuries, infrastructure as an analytic concept has been practically absent from the economist’s tool box.

By contrast, during the 1990ies, a vast body of literature introduced infrastructure as a determinant of production functions, with a view to estimate its contribution to economic growth. The paper reviews the difficulties associated with this enterprise, and the not too clear conclusions that emerge from it. The heterogeneity of the concept is emphasized. Unlike productive capital which is homogenized by market forces, politically-driven infrastructure may—and often does—consist of white elephants as well as of highly useful roads.

Why and how does infrastructure contribute to development? It is a space-shrinker, it enlarges markets, and operates like the lowering of trade barriers. In urban areas, it can be shown that infrastructure contributes to enlarge the effective size of the labor market and of the goods or ideas markets, thus increasing productivity and output.

Institutional and financial regimes have a direct impact upon the socio-economic efficiency of infrastructure. Because infrastructure always has a government dimension and can also have a private dimension, the menu of institutional options available is quite large: from direct government provision (with or without tolls and prices) to unsubsidized concessions, with various forms of public-private partnerships, such as subsidized concessions or shadow tolls. Three mechanisms have to be taken into account: (i) the welfare loss often (not always) associated with tolls and prices, which implies that in such cases, all other things equal, non tolled infrastructure is better than tolled ones, (ii) the cost-advantage usually associated with private production, which implies that, all other things equal, privately managed infrastructure is better, and (iii) the distortionary impact of taxes, which implies that, all other things equal, toll-financed infrastructure is better than tax-financed one. A small model combining these three mechanisms is developed. A simulation, using reasonable values for the main parameters, is presented. It suggests that the more private options, in particular the shadow toll option, are economically superior to the more government-oriented
options. The problem is complicated, however, when one takes into consideration the public finance dimension of the various options.

Forecasting errors and associated risks are characteristic of infrastructure projects. Costs are generally underestimated and patronage overestimated, by large amounts. Errors of 50% or more seem to be the rule rather than the exception. An understanding of the various reasons that explain such errors is useful to allocate the related risks between government bodies and private partners. Substantive risks (risks linked to changes in project design) as well as pure economic risks (risks associated with the macro-economic environment), which are not insurable, should be borne by the public entity. Technical risks (errors in forecasting costs and usage) should be borne by private enterprises. But institutional errors resulting from a strategic behavior of public and even private agents can only be reduced by changes in institutional design and contracts.
“Infrastructure” are many and diverse: roads, tunnels, bridges, railways, airports, harbors, canals, subways and tramways, dams, irrigation networks, water pipes, water purification plants, sewers, water treatment plants, dumps and incinerators, power plants, power lines and distribution networks, oil and gas pipelines, telephone exchanges and networks, district heating equipment, etc.

Infrastructure and infrastructure-related services have always been with us, but the word itself is relatively recent, particularly in English. Although The American Heritage Dictionary of the English Language writes that “the term infrastructure has been used since 1927 to refer collectively to […] roads, bridges rail lines, and similar public works”, it does not appear in the 1952 Concise Oxford Dictionary, nor in the 1950 Real Academia Espanola Diccionario. The word does not appear in the works of the “pioneers in development” (Meier & Seers 1984) writing in the post-war period. It is, for instance, absent from the standard treatises of Lewis (1955), Higgins (1959) or Bauer (1957). It was just not used then.

This contrasts with the formidable success of the word in the 1980ies and 1990ies, when it invaded UN institutions, World Bank organization charts, academic journals, and daily newspapers. The process has clearly been inflationary. The meaning of the word has been extended so much that it no longer means much. As the American Heritage Dictionary puts it: “Today, we may hear that conservatism has an infrastructure of think tanks […] or that terrorists organizations have an infrastructure of people sympathetic to their cause”. In this

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1 As late as 1973, the editors of Urban Studies eliminated “infrastructure” from a paper this writer was contributing to this well-written British journal, and replace it with “social overhead capital”.

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presentation, we will use the word to describe objects like the ones listed above, that have in common all or most of the following attributes.

First, they are capital goods. They are not consumed directly. Rather, in combination with labor, and possibly other inputs, they provide services. Table 1 shows the relationship between infrastructure and the associated services.

<table>
<thead>
<tr>
<th>Service</th>
<th>Associated infrastructure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation</td>
<td>Roads, bridges, tunnels, rail tracks, harbors, etc.</td>
</tr>
<tr>
<td>Water supply</td>
<td>Dams, reservoirs, pipes, treatment plants, etc.</td>
</tr>
<tr>
<td>Water disposal</td>
<td>Sewers, used water treatment plants, etc.</td>
</tr>
<tr>
<td>Irrigation</td>
<td>Dams, canals</td>
</tr>
<tr>
<td>Garbage disposal</td>
<td>Dumps, incinerators, compost units</td>
</tr>
<tr>
<td>District heating</td>
<td>Plant, network</td>
</tr>
<tr>
<td>Telecommunication</td>
<td>Telephone exchanges, telephone lines, etc.</td>
</tr>
<tr>
<td>Power</td>
<td>Power plants, transmission &amp; distribution lines</td>
</tr>
</tbody>
</table>

Indeed, what matters is the service, much more than the infrastructure used or needed to produce it. Policies should focus on the end, service provision, not on the means, infrastructure endowment. The confusion often made between the two reflects the fact that, in many cases, the role of the infrastructure is predominant in the production of the service, or, to put it otherwise, that these services are very capital intensive.

Second, infrastructure is often very lumpy, as opposed to incremental. The usefulness of dam or a bridge which is eight-tenth built is zero. Since the demand for infrastructure services usually increases gradually, adjusting supply and demand over the course of time is difficult, not to say impossible. Lumpiness also implies that siting and construction often take years.

Third, infrastructure is usually very long lasting. Its life is often measured in decades, if not in centuries. In Europe, there are still in use roads and sewers dating from the Roman empire. Infrastructure are not the only long lasting goods: housing, and some ordinary capital goods,
can also have very long lives. Nevertheless, this characteristic has major implications, in terms of financing or maintenance, for instance.

Fourth, infrastructure is space-specific. Unlike most goods, it is generally immobile. A pair of shoes in A is very much like a pair of shoes in B, because it can easily be moved (at a small transportation cost) from A to B. It is therefore quite meaningful to add up the total production of shoes in a country. However, a sewer in A can in no way render services in B. Adding sewers in a country can be misleading if sewers have not been located optimally. In addition, the combination of immobility with long life duration means that infrastructure investments will shape the economic geography, or regional policy, of a country for decades.

A fifth characteristics is that infrastructure, or rather the service it renders, is associated with market failures, in the traditional forms of public goods, externalities (including network externalities), decreasing costs (leading to natural monopolies), or merit goods, as shown in Table 2.

<table>
<thead>
<tr>
<th>Infrastructure-related service</th>
<th>Alleged market failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power, gas</td>
<td>Natural monopolies</td>
</tr>
<tr>
<td>Water supply &amp; treatment</td>
<td>Natural monopolies, externalities</td>
</tr>
<tr>
<td>Telephone</td>
<td>Natural monopolies, externalities</td>
</tr>
<tr>
<td>Rail transport</td>
<td>Natural monopoly, merit good</td>
</tr>
<tr>
<td>District heating</td>
<td>Natural monopoly</td>
</tr>
<tr>
<td>Garbage collection &amp; disposal</td>
<td>Pure public good, externalities</td>
</tr>
<tr>
<td>Cable</td>
<td>Natural monopoly, merit good</td>
</tr>
<tr>
<td>Roads</td>
<td>Quasi public good, externality</td>
</tr>
</tbody>
</table>

This is usually considered to imply some form of public intervention. Infrastructure, and infrastructure services cannot be left to pure market forces only. This important policy conclusion, which is generally true, must be handled with caution, however.

1 It has been noted that in some cases, such as harbors, re-use might be an alternative to mobility.
Many market failures are not as clear cut as is often claimed. The notion of decreasing costs leading to natural monopolies, for instance, might make sense for some parts of a service and not for other. In the case of power, for instance, it makes more sense for transportation or distribution that it does for production. In the case of telephone, this notion is wiped out by technological progress.

Then, the existence of market failures is not an automatic justification of government intervention. The opposite view—which has long been dominant—is akin to the attitude of the jury of a beauty contest who would look at the first candidate, and declare the other candidate a winner. The existence of market failures only provides a presumption of the need for government intervention. But in practice, one has to take into account possible government failures, and compare the costs and benefits of both options.

Finally, of course, government intervention, when it is required or desirable, can take many forms. Direct public provision is only one of them, and not necessarily the best one.

Sixth, infrastructure, or the service it provides, is usually consumed by both households and enterprises. It is at the same time a final consumption item, and an intermediate consumption item. It increases welfare (directly), and it increases output. The relative importance of these two types of consumption varies with each infrastructure, and over space and time, but in general, the consumption of enterprises seems to be somewhat greater than that of households.

These attributes might be used to define, albeit loosely, the notion of infrastructure. They exclude the so-called “social infrastructure”, such as schools, universities, clinics, hospitals,

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1 For France, input-output tables data showed that, in 2001, households consumption of infrastructure-related services was exactly one third of the total.
etc. It does not mean that schools and clinics are not important, but rather that they do not share some of the characteristics mentioned. They are not always very long-lasting, and the service they provide owes generally more to labor input than to infrastructure input.

It is not easy to assess the relative importance of infrastructure capital in our economies. This is in part because of the uncertainties attached to the notion, and in part because data on the value of capital stock (as opposed to data on flows) is difficult to estimate everywhere and scarce in many countries. Easterly and Rebelo (1993) produced estimates of “public investment” in a large number of countries and for 1960, 1970, 1980 decades averages. Consolidated public investment, consisting of investments by governments and by public enterprises, represented 43% of total investments (and 9% of GDP). Because the life length of such public investments is likely longer that that of private investments, this would suggest that the stock of “public investments”, thus defined, represents around half the total capital stock.

Some countries, like France, publish estimates of the capital stock by type. Government capital stock in 2002 represented 15% of total capital stock, and 47% of GDP. Government capital stock is different from infrastructure. It includes administrative buildings, schools and hospitals, but it ignores the capital stock of public enterprises, in many cases a component of infrastructure. Assuming that these two items cancel each other, this gives us an idea of the relative importance of infrastructure in France, which appears to be much smaller than the Easterly and Rebelo estimates. Table 3 presents this data, and extends it to Brazil and Mexico. The ratio of flow to stock calculated for France has been applied to flow data in order to produce stock data for Brazil and Mexico. The methodology is very crude, but it produces estimates of the relative importance of infrastructure which are for Brazil similar to French numbers (15% of total stock of capital, 50% of GDP), and for Mexico much smaller (9% of total stock of capital, 7% of GDP).
The concept of infrastructure, and not only the word, has largely, and surprisingly, been absent from the history of economic analysis. Infrastructure, particularly transport infrastructure, play a key role in Adam Smith’s vision of economic development. No roads, no transport, no trade, no specialization, no economies of scale, no productivity progress, and no development. Yet, during the 19th century, and much of the 20th century, infrastructure virtually disappears from economics. In Marx, in Walras, in Marshall, in Keynes, in Domar, output is produced only by labor and capital, and the capital these economists have in mind is mostly or only the so-called “productive” capital of private enterprises. This is strange, because in the 19th century, governments in the then developing countries —to-day’s developed economies— did invest heavily in infrastructure, particularly in urban areas. This, somehow, largely escaped the attention of dominant, mainstream, macro-economists.

Even in the post world war II period, when development economics appeared as a branch of economics, reference to infrastructure and their role are scarce. “Capital” plays a key role in most growth theories and analysis, but “capital” is undifferentiated. Roads and factories are lumped together in the common concept of capital. The obvious differences outlined above were ignored. And because factories weighted heavier than roads, the discussion of “capital” turned out to be a discussion of factories. Some pioneers, like Rosenstein-Rodan or Singer,
were more perceptive than others, and made timid references to infrastructure. Thus, Rosenstein-Rodan, discussing in 1984 his war time views writes: “The third new idea was that before building consumer goods factories, a major indivisible block of social overhead capital or infrastructure must be built and sponsored because private market initiatives will not create it in time” (Meiers and Seers 1984 p. 208). But this is an exception. Until the 1970ies, infrastructure, even under a different name, hardly existed as an analytic concept or category in economic theory and policy.

In the meantime, however, governments were busy building roads or sewers. They felt the need for principles and tools to improve these infrastructure investments. This led to the development of cost-benefit analysis. The intellectual foundations date back to the mid 19th century, with the seminal article of Dupuit on the utility of a non-tolled bridge, and the concept of “surplus”. But the key role in the development of cost-benefit analysis —which is mostly applied to infrastructure investments— was played by the New Deal and by the World Bank. In the late 1930ies, the US Federal government financed massive infrastructure investments, but the US Congress prescribed that only projects with sufficient social utility could be undertaken. The Keynesian digging and filling of holes would not qualify. The US Corps of Engineers, and economists like Robert Dorfman carried the required studies and tried to give a content to the notion of “sufficient utility”. Similarly, after the war, the World Bank —and with it many other international, bilateral and national institutions— mostly involved in infrastructure financing were required to undertake only projects that would meet the test of a cost-benefit analysis. This led to the development and refinement of project appraisal methodologies, that still continue to date.

The literature on infrastructure, although recent, is enormous. On transportation infrastructure alone, Stough et al. (2002) published a reader supposedly limited to “classics” that comprises 650 pages of fine print. The World Bank itself has published extensively on
this topic (its 1994 World Development Report on *Infrastructure for Development*, prepared under the leadership of Greg Ingram, remains a major contribution). Indeed, financing infrastructure for development could be defined as one of the main business, if not the main business, of the Bank. Presenting a paper on this very topic at the World Bank sounds like bringing coal to Newcastle.

This paper will obviously not attempt to cover all the important dimensions of the subject. It will deal only marginally with the issues of privatization and regulation. It will largely ignore the key question of pricing. Relatively few infrastructure are pure public goods that cannot be priced. Most are chargeable. The World Bank, amongst other, has actively argued in favor of charges, for the sake of replicability. But replicability does not say much about the structure of charges: is marginal social cost pricing really the only and most efficient pricing method? The paper will also neglect the qualitative dimensions of infrastructure supply. Most studies have considered infrastructure endowment in quantitative and dichotomous terms: as present or absent. In reality, in many cases, the problem is not so much to provide the infrastructure as to improve the quality of its service.

Instead, the paper will focus on three issues: the contribution of infrastructure to economic growth; the relationship between financing options for infrastructure investments and economic efficiency; and the magnitude of forecasting errors in infrastructure projects and what they mean in terms of uncertainty and risks.

**Contribution of Infrastructure to Economic Growth**

*How much?*
What is the contribution of infrastructure to economic growth? The topic, which had been largely neglected until the late 1980ies, became suddenly very fashionable after a seminal (although later much criticized) paper by Aschauer (1989). Dozens of contributions were produced in the following decade. Gramlich (1994), in a survey article, goes as far as talking of “research bubbles here” (Ibidem, p. 1189). All of these studies have one point in common: they relate to infrastructure capital, and ignore infrastructure services. The main line of research uses an extended production function, in which output $Y$ is not merely a function of labor $L$ and capital $K$, but also of infrastructure $G$:

$$Y = f(L, K, G)$$

Various functional forms were used, particularly Cobb-Douglas type functions, and translog functions. Various notions of “infrastructure” were utilized, more often dictated by data availability than theoretical arguments. Various data sets were used: time series, cross section data, and panel data. The pitfalls of such analysis, however, are formidable.

First, there is the issue of reverse causality. Even if it appears that infrastructure $G$ and output $Y$ are correlated, it does not mean that more infrastructure necessarily produces more output. It can also be argued that more output makes it possible to finance more infrastructure. There is a chicken and egg problem here.

Second, infrastructure investment is a component of output. An increase in infrastructure investment mechanically raises aggregate demand and output, even if it does not contribute to increase productivity and output.

Third, many infrastructure are decided in order to increase welfare, and welfare is only a relatively distant cousin of output or GDP. Many welfare improvements are not or are very

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1 Even this author added one stone to this monument (Fritsch & Prud’homme 1997).