Journal of Infrastructure, Policy and Development (2017) Volume 1 Issue 2, pp.x-x.
doi: 10.24294/jipd.v1i2.55

POLICY INSIGHT

The economics of infrastructure in a globalized world: Issues, lessons and future challenges

Timo Henckel[1] and Warwick J. McKibbin[2*]

[1] Research School of Economics & Centre for Applied Macroeconomic Analysis, Australian National University
[2] Centre for Applied Macroeconomic Analysis, Crawford School of Public Policy, Australian National University & The Brookings Institution

ABSTRACT

Although infrastructure is widely recognized as a key ingredient in a country's economic success, many issues surrounding infrastructure spending are not well understood. This paper explores six themes: the returns to infrastructure; the role of the private sector; the evaluation and delivery of infrastructure in practice; the nature of network industries, pricing and regulation; political economy considerations of infrastructure provision; and infrastructure in developing countries.

This paper aims to provide insights into many of these questions, drawing on the existing literature.

Keywords*: infrastrusture; pricing; regulation; evaluation*

1. Introduction

The massive fiscal stimulus in the wake of the global financial crisis has refocused the international community onto the nature and role of infrastructure spending. Although this type of spending can provide a short-term demand stimulus to an economy, in the medium to longer term it can form a critical part of a successful economic growth strategy. Well-designed infrastructure facilitates economies of scale, reduces costs of trade, and is thus central to specialization and the efficient production and consumption of goods and services. It is a vital ingredient to economic growth and development, which is the key to raising living standards.

Although infrastructure is widely recognized as a key ingredient in a country's economic success, many issues surrounding infrastructure spending are not well understood. This paper explores six themes: the returns to infrastructure; the role of the private sector; the evaluation and delivery of infrastructure in practice; the nature of network industries, pricing and regulation; political economy considerations of infrastructure provision; and infrastructure in developing countries.

In particular, we ask the following fundamental questions:

1. What is the nature of infrastructure? What are its salient features that distinguish it from other factors of production?

ARTICLE INFO
Received: June 5, 2017
Accepted: July 24, 2017
Available online: August 8, 2017

***CORRESPONDING AUTHOR**
McKibbin Warwick J, Crawford School of Public Policy, Australian National University, Acton ACT 2601, Australia
Warwick.mckibbin@anu.edu.au

CITATION
Henckel T and McKibbin WJ (2017). "The economics of infrastructure in a globalized world: Issues, lessons and future challenges". *Journal of Infrastructure and Policy Development*, 1(2): x–x. doi: 10.24294/jipd.v1i2.55.

COPYRIGHT
Copyright © 2017 by author(s) and EnPress Publisher LLC. This work is licensed under the Creative Commons Attribution-NonCommercial 4.0 International License (CC BY-NC 4.0). http://creativecommons.org/licenses/by/4.0/

2. What are the returns to infrastructure investment? How is infrastructure investment evaluated and delivered? How does infrastructure affect an economy's growth rate?

3. How should infrastructure be provided? Should it be provided by the government, by the private sector under strict government regulation, or by the private sector with little, if any, government regulation?

4. Should infrastructure provision be affected by the stage of a country's economic development?

The first issue is pivotal to understanding the subsequent three issues. What are the main characteristics of infrastructure that make it special to a country's economy? Is it scope, scale or longevity? What is its role as a collective, if not pure, public good? What is the significance of network externalities? Different types of infrastructure—internet, telephone (fixed line and mobile), rail, air, sea and road transport, energy and water—each pose its own challenges.

The second issue is central to boosting overall productivity and to raising living standards. Just how important is infrastructure to the economy? Can this be reliably measured? How are new technologies adopted and how can infrastructure services be made more efficient? How do countries, in practice, evaluate and deliver existing and new infrastructure?

The third issue is central to the policy debate about infrastructure investment, with a long and growing list of open questions: What is the most efficient way to finance infrastructure spending? What are the optimal infrastructure pricing, maintenance and investment policies? What have proven to be the respective strengths and weaknesses of the public and private sectors in infrastructure provision and management, and what shapes those strengths and weaknesses? What are the distributional consequences of infrastructure policies? How do political forces impact the efficiency of public sector provision? What framework deals best with monopoly providers of infrastructure?

The final issue relates to developing countries, whose infrastructure is typically less sophisticated and extensive than industrialized countries' infrastructure and additionally often more poorly managed and less efficiently used. Developing countries' legal systems are weaker, making regulation and enforcement more difficult. They are fiscally weaker and their borrowing costs higher. Given these challenges, it is natural to envisage a greater private sector role in infrastructure in developing countries, but that too poses complex challenges. What have proven to be the major gains from, and difficulties caused by, the expansion of private sector infrastructure provision in developing countries? What lessons can be drawn for the future, especially for policy and regulatory frameworks?

This paper aims to provide insights into many of these questions, drawing on the existing literature.

2. The returns to infrastructure (infrastructure and development)

Most economists agree that infrastructure investment is necessary for a country to industrialize. From a development perspective, infrastructure offers two benefits: 1) it raises productivity and reduces the cost of production, and 2) it has a disproportionate effect on the incomes and welfare of the poor by reducing costs to access markets, raising returns on existing assets, facilitating

human capital accumulation, and facilitating agglomeration economies and the dissemination of knowledge.[1] Measuring the returns of infrastructure investment is a challenging exercise that has dogged economists for centuries.

A recent revival in measuring the returns to infrastructure was pioneered by Aschauer (1989) who empirically found very high rates of return on public capital in the U.S.—between 70 and 100 percent. This and other studies suffered from serious methodological flaws, such as relying on expenditure as a measure of infrastructure investment or failing to account for reverse causality between income and infrastructure. Also, the use of aggregate time series data and the lack of microeconomic foundations have been criticized. A large literature has followed Aschauer's contribution.

Calderón, Moral-Benito and Servén (2015) present new estimates of returns to infrastructure that are very robust and address many of the methodological shortcomings of previous studies. Their estimates of the output elasticity of infrastructure, which rely on a multi-dimensional measure of the physical stock of infrastructure as opposed to infrastructure spending, lie between 0.07 and 0.10. In other words, a 10 percent rise in infrastructure assets directly increases GDP per capita by 0.7 to 1 percent. These estimates are in line with recent estimates from meta-studies.

There is little evidence that output elasticities with respect to the inputs of the aggregate production functions differ across countries. In particular, the output elasticity of infrastructure does not seem to vary with countries' level of per capita income, their infrastructure endowment, or the size of their population. Hence, the marginal productivity of infrastructure is higher in countries with relatively lower infrastructure endowments.

Before identifying the optimal amount and type of infrastructure spending, the benefits to infrastructure investment must be compared to the opportunity costs of infrastructure spending. Moreover, there exists only a weak link between infrastructure spending, on the one hand, and the stock of assets and quality of services, on the other. This reflects big cross-country differences in efficiency and quality of governance.

To the extent that infrastructure is vital for a country's economic development, it is also crucial in improving the quality of life for the poor (see Straub, 2011.) Newly connected poor customers generally enjoy large welfare gains from new infrastructure, especially if they involve improvements to water and sanitary services as well as electricity.

A key benefit of infrastructure, in particular transport infrastructure, is the reduction of transport costs, which helps to create new markets and realize the returns to agglomeration. This in turn fosters competition, spurs innovation, lowers prices and raises productivity, leading to an increase in living standards.

Powerful evidence in favor of this benefit is supplied by Li (2010) for the case of China, where the current level of transport costs is still the most significant trade friction (approximately half of total sales costs), and by Brooks (2010) for Asia more generally. China's investment intensity has increased dramatically since 1990, with highway investment constituting the largest share. By looking at the price wedge of the same products in different cities, from which trade costs

1. See Jones and Romer (2010) who argue that knowledge spillovers are a key determinant of economic growth.

can be inferred, Li studies the impact of the Lanzhou-Xinjiang railroad. Within three years of the railroad's completion, eastbound trade volume increased by over 40 percent and eastbound trade costs decreased by about 30 percent, implying a social return to the investment of approximately 30 percent per year.

Brooks and Ferrarini (2010) also find that in China and India, declining trade costs account for a large and increasing portion of trade growth, explaining approximately 75 percent of trade expansion since the early 1990s. Hummels (2001) argues that for the period 1950–1998 faster transport—air shipping and faster ocean vessels—was equivalent to reducing tariffs on manufactured goods from 32 percent to 9 percent. The use of containers in ocean transport has led to massive efficiency gains in long-distance transport of goods and commodities. According to Limão and Venables (2001), lowering trade costs by 10 percent through infrastructure investment and can increase exports by more than 20 percent. Thus, infrastructure is a key ingredient in a country's ability to capture the gains from trade possible through the process of globalization.

In a national study covering 36 major Chinese cities, Li (2010) finds that infrastructure investment since the mid-1980s led to a dramatic reduction in inventories from an inventory:sales ratio of 0.8 to approximately 0.15. Road investments alone reduced raw materials inventories in the period 1998–2007 by 25 percent. Thus, one dollar of road spending caused 1–2 cents of inventory decline, similar in magnitude to the estimates for the U.S. prior to the 1980s.

Recent work by Donaldson (2014) underscores the importance of transport infrastructure in fostering trade. He estimates the economic impact of the railroads in colonial India and finds that they decrease trade costs and interregional price gaps significantly, increase interregional and international trade, and increase real incomes by about 16%. Similarly, Donaldson and Hornbeck (2016), examining the historical impact of railroads on the US economy, particularly on agriculture, estimate that removing all railroads in 1890 would have decreased the total value of U.S. agricultural land by 60%. Costinot and Donaldson (2016) calculate the benefits of economic integration and estimate that, between 1880 and 1920, integration lifted real output per worker by 79% and that, between 1880 and 1997, integration added as much to American agricultural output as did growth in its productivity. These findings suggest that infrastructure, when it increases market access and reduces market regional segregation, generates large economic returns.

Therefore, transport infrastructure investment contributes significantly to the economic efficiency of an economy by reducing transport costs (direct effect) and lowering inventories (indirect effect). However, benefits are likely to be nonlinear. Once an efficient, reliable and uncongested transport network is in place, direct benefits to building yet another highway are limited.

Infrastructure investment influences a country's absolute and comparative advantage by mitigating the constraints of factor endowments and promoting intra- and inter-regional integration.[2] This leads to a complex interdependent process in which infrastructure determines the patterns of trade, and the patterns of trade determine the level and type of infrastructure.

As a country develops, its economy typically moves up the value chain. This process is reinforced by sound infrastructure, a crucial factor in attracting overseas investment and thereby

2. For a recent survey on the gains from market integration, see Donaldson (2015).

contributing to the knowledge transfer. As the economy moves up the value chain, its infrastructure needs to adapt to reflect the changes in production structures and the ever-changing patterns of movements in goods and people.

In many regions such as Asia, infrastructure remains fragile and cross-border facilities are limited. Due to trade-related externalities, there remains considerable scope for regional cooperation in infrastructure planning and provision. However, the market places continuously changing demands on existing infrastructure, which may be extremely difficult for governments to anticipate and respond to. New trade patterns alter the weight/value composition of merchandise, change the demand for timeliness, increase production fragmentation and generate further demand for transport services. Such changes require a more efficient mix of transport modes (which may be either substitutive or complementary), new connections and nodes in the transport network and more sophisticated transport technology. The challenge for governments is to listen to the demands of the market while acknowledging the spillovers inherent in much of infrastructure investment and acknowledging the potential inefficiencies caused by interest groups that seek to realize rents from public expenditures.

In many cases, economic growth occurs within regional clusters; countries do well when their neighbors do well and vice versa. Cross-country growth spillovers might be localized because spillovers of knowledge between countries are also localized, for example, if knowledge is embodied in those goods which are heavily traded among geographically proximate countries. There are also agglomeration economies. Growth theory suggests that these trading partners form convergence clubs with economic growth correlated across neighboring countries, which explains why economic development tends to be restricted to relatively well-defined geographic regions.

Since growth is typically associated with an expansion in infrastructure, a key question is whether infrastructure itself is co-responsible for promoting regional neighborhood effects. If so, then positive spillovers are likely to lead to underinvestment as total regional returns exceed local returns.

Easterly and Levine (1998) and Collier and O'Connell (2007) find that a 1 percent increase in neighbors' growth increases a country's own growth rate by 0.4 to 0.7 percent. Similar findings exist in the United States where research suggests city-level spillovers from infrastructure investments. These growth spillovers are even stronger for resource-poor, landlocked countries, with the exception of sub-Saharan Africa. Econometric evidence by Roberts and Deichmann (2011) confirms the heterogeneity in the strength of growth spillovers across regions. The authors find that transport and telecommunications infrastructure play a significant role in promoting spillovers when it interacts with regional trade integration. Their results show that the importance of infrastructure lies not in its direct contribution to economic growth, but in the benefits it brings to landlocked countries to absorb beneficial growth spillovers from neighboring countries. Hence, it is investment in infrastructure which, along with more formalized trading agreements, has helped countries such as Switzerland and Austria to thrive. The results are consistent with Collier and O'Connell's (2007) hypothesis that, globally, landlocked countries depend more on the growth of their neighbors than coastal countries, with the exception of sub-Saharan Africa where regional integration is low.

3. The role of the private sector

Historically, most infrastructure investment was undertaken by the private sector. Heavy government involvement is a more recent, 20th century phenomenon. However, the performance of public infrastructure—airports, highways, waterways and public railways—has been far from exemplary, with commonplace cost blowouts, planning and construction delays as well as safety problems and a lack of innovation and technological advance. Since the 1980s, there has been a renewed push to involve the private sector in infrastructure, either exclusively or in partnership with the public sector.

Infrastructure projects typically exhibit economies of scale, possibly leading to natural monopolies—they may be socially desirable but not privately profitable. To correct these failures, governments may regulate private service providers or provide the services themselves. Unfortunately, government policies tend to be inefficient and subject to rent-seeking pressures, discussed in more detail below. These government failures may actually exceed the market failures, favoring private provision as argued by Winston (2006).

Winston only sees a weak justification for government intervention based on the available empirical evidence. Private failures are often the result of poor government regulation and lack of assistance during severe crises such as the Great Depression. Examples of public inefficiencies abound from inefficient pricing policies (*e.g.* the failure to charge users for their contribution to highway and airport congestion) and inefficient investment (*e.g.* an inefficient allocation of the Highway Trust Fund that puts a large weight on the size of a state) to inefficient spending (*e.g.* misallocation of Highway Trust Fund) and lack of technical and managerial innovation (*e.g.* slow adoption of navigational aids to ease congestion).

In theory, there remains a strong case for privatization as it puts in place the correct incentives for cost reduction and for innovation to reduce dynamic X-inefficiency. However, in practice, privatization of infrastructure is proving very difficult in the instances that it has been tried in various countries.[3] New private firms must overcome inefficiencies accumulated for decades by the public sector, and large efficiency gains often result from old firms exiting and young innovative firms entering. The benefits of privatization therefore are not immediately apparent; it takes years for old inefficiencies to be purged and for new technologies and managerial processes to transform the industry.

Moreover, the political forces favoring government intervention are powerful and there exists a strong status quo bias, and bungled privatization attempts in some countries (*e.g.* intercity passenger rail in the U.K.) has lessened the public's willingness to experiment with alternative funding and provision arrangements.

Winston advocates a clear solution to the discrepancy between the long-run economic benefits of privatization and the short-run political costs: carefully planned privatization experiments for selected cities or regions. Experiments provide evidence that may be used to make privatization more acceptable to the skeptical public, enabling gradual adjustment. The optimal mix of private and public involvement will vary from country to country and may change over time as technology

3. For a collection of articles critical of privatization attempts in a wide range of industries see von Weizsäcker *et al*. (2005).

and competitive circumstances evolve. Policies governing the degree of private/public involvement in infrastructure projects should not be pursued on ideological grounds but on hard empirical evidence.

A more recent organizational form to capture both the benefits of private and public infrastructure provision are public-private partnerships (PPPs). They have increased sevenfold in developing countries from 1990–1992 to 2006–2008 and sixfold in Europe during the same period. In a PPP, assets are temporarily owned by a private firm and the public, and private sectors are the joint residual claimants for construction, maintenance and demand risk over time. The planning is still largely undertaken by the public sector. The advantages of PPPs include bundling of building, maintenance and operations, easier implementation of efficient user fees, relief of public budgets, and fewer politically motivated white elephants. They may also be a necessary first step toward complete privatization. However, there are also potential drawbacks including high contracting costs, inefficient competitive arrangements leading to bilateral monopolies, exploitation of soft budget constraints, and problems resulting from asymmetric information between the contract partners. Moreover, the motives of PPPs may not be aligned with social welfare maximization. For example, governments want cash to reduce their deficits and private companies want to earn a high rate of return.

Bundling is an essential feature of PPPs, as the private partner minimizes lifetime costs for all aspects of the operation. The risk is that service quality deteriorates, which makes contracting of service standards all the more important.

Hoppe and Schmitz (2013) provide additional theoretical insight. Bundling provides strong incentives to develop flexible and efficient infrastructure design but also exhibits an important disadvantage: it may provide incentives for the private contractor to gather private information about future costs of adaptations. If these adaptations are known to be *ex post* efficient, then the information-gathering costs can be socially wasteful. In other words, in a world in which contracts are necessarily incomplete, there exist information rents which the private contractor will attempt to appropriate at the expense of the public contractor. It is possible that the government may gain experience in this repeated game and design better contracts. As of yet, the evidence does not appear to support that possibility.

Whether PPPs relieve public budgets is unclear. The government saves on upfront capital expenditures and ongoing maintenance costs but forgoes a stream of future revenues. If PPP contracts are poorly specified, the incentive structure is often skewed in favor of the private sector, with profits privatized and potentially large losses socialized. Overall budgetary benefits must ultimately come from efficiency gains, which would need to be appraised on a case-by-case basis. Social gains may come from innovations that are performed by the private sector but would not have been performed by the public sector.

Fischer (2010) and Engel *et al*. (2014a, 2014b) provide comprehensive overviews of the theory and experience associated with PPPs. While being largely sympathetic to PPPs, they also lay out in detail the problems of this organizational form. First, PPPs allow off-budget spending, which is naturally attractive to politicians. In the U.K., only 14 percent of 599 PPP projects up to April 2009 were on-balance sheet. This accounting trickery provides an incentive for governments to pursue excessive and inefficient infrastructure projects.

Second, the complexity of infrastructure operations often requires renegotiation, which itself is a source of significant inefficiencies. It opens doors to further pork barreling, and the lack of competition and informational asymmetries at such a stage of a project can lead to considerable increases in cost and reductions in service quality. The evidence suggests that the costliness of renegotiation depends critically on the quality of industry regulation, on the presence and specificity of service and quality clauses, and on the presence of minimum income guarantees. Renegotiation may enable a firm to earn monopoly rents that were denied to it in the bidding process.

Success of PPPs therefore depends on good governance of the renegotiation process and on the initial contract design. Fischer and Engel *et al*. argue that improvements to the former require the following: referral to an independent specialized agency that reviews and approves projects so as to minimize the terms of renegotiation; use of service, not input, standards in the contract; public tendering of additional works to break the monopoly power of the private partner; guarantees that contract values will not change after renegotiation; and better and more sophisticated accounting standards with respect to future capital costs and demand guarantees. It is also important to award the job based on quality, expertise and cost. Many awards tend to be given to the lowest-cost bidder regardless of expertise. Then the low-cost bidder finds that it cannot make a profit and tries to renegotiate or cut corners.

Improvements to contract design center on flexible-term contracts to reduce demand risk and the need for guarantees and renegotiations. There is no turnkey solution; individual circumstances will have to determine the optimal contract specifications. Experience with flexible contracts such as in Chile and Portugal (toll roads) has been favorable overall. Marcelo *et al*. (2017), focusing on the prevalence of contract cancellations, finds that countries learn very quickly from only a little PPP experience: after a country closes a relatively small number of PPP contracts, the probability of contract cancellation declines rapidly. However, this learning effect is much more pronounced in the energy and transport sectors than in the water sector.

Public-private partnerships involve a risk transfer from the public to the private sector. Little attention has been given to addressing key questions associated with this risk transfer. Is PPP risk transfer *ex ante* or *ex post* efficient? What are the risks being transferred and is total risk reduced as a result of the PPP?

Blanc-Brude (2010) studied the determinants of risk transfer for construction risk in European road projects where the price of construction works is on average 24 percent higher for PPPs than for traditional public procurement, implying that there exists a hefty risk premium on construction risk. When only considering risk, a PPP appears to be suboptimal for the government since the government is paying a premium for a cost which it can probably bear more efficiently than the private sector. Thus, using risk transfer contracts must reduce expected procurement costs, which in turn implies that risk in infrastructure is endogenous to the type of procurement contract used. Indeed, Blanc-Brude concludes that information asymmetry and endogeneity are the justification for risk transfers in PPPs. This information asymmetry however causes a problem since the principal (the public partner) and the agent (the private partner) may have different views and sensitivities to certain risks, making the discovery of the efficient price for risk difficult.

In order to make the efficient firm choose the risk transfer contract, the principal needs to pay an information rent, as witnessed by the sizeable risk premia in European road projects. Entering into

a PPP with full risk transfer to the agent—namely at a fixed price—is therefore *ex ante* efficient (at the procurement stage) but *ex post* inefficient (during the service period). The rent accruing to the private partner in the form of the risk premium is an essential feature of the PPP contract that ensures incentive-compatibility. However, little effort has gone into finding ways to minimize this rent, for example through *ex post* economic regulation of PPP contracts.

4. Evaluation and delivery of infrastructure in practice

Infrastructure is expensive. Small inefficiencies can put to waste billions of dollars. Given the sums of money involved, the nonchalance and arbitrariness of some infrastructure investment decisions is baffling. If countries demand value for money and strive for productive efficiency, first-rate evaluation of infrastructure projects is necessary to separate the good projects from the bad ones.

Even if infrastructure is provided by the private sector, the decision to pursue a project and the planning is undertaken by government. In Australia, line agencies have been responsible for submitting budgets and programs for individual infrastructure projects. Since 2008, most projects and submissions are centralized and coordinated by a new agency called Infrastructure Australia. This body advises governments, investors and operators on infrastructure issues, audits and evaluates individual projects, and recommends priorities and agendas. It picks up recommendations from the OECD's "Infrastructure to 2030" report, which calls for: long-term strategic planning to coordinate infrastructure development; rigorous evaluation of infrastructure at the national level (large-scale models capturing allocation among broad infrastructure categories), the city/state level (land use and transport studies, micro-economic evaluation models) and the project level (cost-benefit analyses, incidence analyses, feasibility and risk appraisals); and improved governance to reduce the complexity and lags between planning and implementation. However, even if a process is in place, it does not mean that it will work in practice.

The two major evaluation tools available are computable general equilibrium (CGE) models and the more common cost-benefit analysis (CBA). If properly specified, both methods should yield the same answer about costs and benefits of a particular project but both techniques have limitations. As Forsyth (2010) points out, CGE models are frequently used to evaluate large infrastructure projects whereas CBAs are applied to large and small projects. The key benefit of CBA is that it can incorporate all costs and benefits of a project and uses a clearly defined welfare metric. CBE models are useful in understanding and quantifying linkages between different sectors of the economy, but the specificity of the model constrains the overall analysis and a good welfare metric is lacking. As usually implemented, CBA is typically partial equilibrium while CGE models rarely capture non-pecuniary externalities. Hence, both approaches are useful and theoretically sound, whereas other approaches such as input/output impact analyses are not. The latter guarantee big "benefits" and are increasingly used to "sell" projects. The solution in many cases is to employ CGE models and CBA jointly.

Citing recent projects in Australia—the proposed national broadband network and the East West Rail in Victoria—Ergas and Robson (2009) argue that governments systematically overstate the benefits and understate the costs of infrastructure projects. Even when a formal cost-benefit analysis (CBA) is undertaken, it typically constitutes only a small part of a multi-criteria evaluation approach

that gives the evaluator and ultimate decision-maker wide discretion (scores, weights and evaluation approach are arbitrary). Moreover, CBAs are often erroneous with double-counting on the benefit side and underappreciated opportunity costs.

Project evaluation must not only feed into the decision about whether or not to approve the project but also into the choice about the most efficient form of delivery. According to Lyneham (2010), project management contracts (PMCs) offer the most effective way of delivering large-scale projects by aligning government and project objectives, ensuring high quality health, safety and environmental standards, and minimizing uncertainty about cost and the delivery schedule.

No matter which evaluation tool is used, its truthfulness and hence usefulness hinges on the government's commitment to sound, evidence-based policy. Otherwise these tools act as fig leaves for politically motivated investment decisions. Fostering a culture of analytical rigor and disinterested infrastructure policy should be high on the agenda for every government seeking to maximize social welfare.

5. Network industries, pricing and regulation

Large fixed costs and increasing returns-to-scale are common to many infrastructure industries, as are public good qualities and the presence of network externalities. These features tend to endow incumbent firms with market power due to large fixed capital costs that act as a barrier to entry. From society's viewpoint, this is inefficient. As a consequence, government intervention—direct ownership or regulation of privately owned enterprises—is near-universal.

There are three possible solutions to the inefficiencies described above. First, governments may own and operate a monopoly firm. However, absence of competition and bureaucratic failures lead to inefficiency, characterized by poor quality and high prices. Second, private monopolies can be subjected to rate-of-return regulation, restricting profits to 'reasonable' levels. While this approach imposes greater operational discipline, there exist dynamic efficiency problems leading to delays in investment in new technologies and underinvestment in R&D. Third, governments can adopt incentive regulation with the objective to emulate incentives found in a competitive market. This approach shifts costs of investment and R&D risk onto the private sector, while safeguarding liberal access to the market for potential new entrants.

The third solution, incentive regulation, is desirable in theory but difficult to implement. Moreover, it exposes infrastructure operators to risks they have limited ability to influence, including demand-side uncertainties (*e.g.* changing consumer valuations of products and services), supply-side uncertainties (*e.g.* technological change) and regulatory uncertainty (in particular, regulation tends to increase in response to highly profitable investments, implying that regulatory constraints are asymmetric). As the pace of technological innovation increases, so do all three uncertainties.

One regulatory instrument, namely access regulation, tends to exacerbate incentive problems. Entrants into the market are allowed to buy from incumbents at regulated prices. This offers essentially risk-free entry and exit into and out of the market, but punishes incumbents who are not compensated for bearing all the risk in the sector. In the telecommunications industry, total investment by both incumbents and entrants is smaller in heavily access-regulated EU countries than in less regulated countries such as the U.S. Structural separation further exacerbates the

incentive problems stemming from access regulation since risks are unduly shifted from retailers to infrastructure providers and the latter are forced to meet all forward orders. As a result, there are too many retailers and infrastructure providers inefficiently overinvest.

Howell (2010) concludes that the current regulatory theory was developed for times and places with slow technological change. As the pace of change increases, so does the risk of "getting regulation wrong". As a consequence, regulators ought to learn the lessons from the theory of investment under uncertainty and refrain from regulating until more information is collected. However, "unregulated" does not mean uncompetitive behavior should be tolerated; antitrust laws remain as important as ever.

Not only does regulation respond to inefficiencies associated with infrastructure provision, but price regulation in turn affects investment in infrastructure. Two types of price regulation are common: cost-of-service (COS) regulation and price-cap (PC) regulation. The former is based on average-cost pricing. It emerged as a solution to asymmetric information problems, but it requires explicit use of detailed accounting data. COS regulation leads to moral hazard and fosters inefficiencies since regulatory requirements tend to be based on historical data. Recently, popular PC regulation addresses the moral hazard problem and does not make explicit use of accounting data: the regulator fixes ceiling prices which may be indexed to reflect changes in the economic environment. In practice, price caps are periodically reviewed, which reintroduces the asymmetric information problem. The general experience seems to be that declining prices are followed by claims of underinvestment and subsequent higher regulated prices.

Menezes (2010) considers two issues related to price regulation: first, to what extent PC regulation affects the timing of investment and, second, how price regulation affects the cost of capital. Any investment involves a considerable degree of risk (or even uncertainty, in the sense of unquantifiable risk) about future demand, cost, market structure, *etc*. Delaying investment resolves some or all of the uncertainty before investment takes place, lowering the required price for the firm. The downside is that consumers have to wait longer to enjoy the service. Hence, there exists a trade-off between how early consumers are served and the price they have to pay to compensate the investing firm for taking on risk. The optimal regulated price will depend on the nature of demand, the firm's cost structure and the degree of uncertainty.

When studying the relationship between price regulation and the cost of capital, information and uncertainty are once again the salient factors. In general, under COS regulation, society bears the full extent of moral hazard but the cost of capital is the risk-free rate. Under PC regulation, the opposite is true, namely the cost of capital might increase due to the possibility of bankruptcy created by the mandated price ceiling. The optimal choice of regulation will depend on the comparison between the extent of moral hazard and the increase in the cost of capital resulting from price-cap regulation. This comparison is, unfortunately, a difficult exercise in practice.

In many developing countries, effective demand for infrastructure services at current prices exceeds current supply, that is, infrastructure services are rationed. In the case of private network industries or industries with increasing returns to scale, a firm's pricing policy must account for a trade-off between current and future profits. Setting low prices today reduces current profits but enables a more aggressive expansion of the network with higher profits in the future. A firm's optimal price balances these two effects; it will be lower the less heavily the firm discounts future

revenues and profits, and the smaller the adjustment costs associated with a rapid expansion of its network.

Further complication arises from the positive relationship between the price charged by the private firm and the probability of retaliatory government intervention. A firm's optimal price will be lower the more sensitive the likelihood of government intervention to the price charged is and the more severe the punishment imposed by such government action. Kessides (2010) concludes that in many developing countries—where coverage ratios are low, with significant opportunities for network expansion, and government retaliation is common—pricing restraint during the early stages of network development is profit-maximizing for the infrastructure providers.

For governments, optimal price regulation is challenging because of the amount of information required. Firms are likely to have better information about cost and demand conditions, suggesting that heavy-handed price controls are likely to be grossly inefficient. Furthermore, regulatory stability is vital to reduce uncertainty in the firms' investment decisions and to extend their planning horizons.

Ng (2009, 2010) argues that the improvement in transaction efficiency from infrastructure investment may generate benefits in excess of the direct private benefits through the promotion of higher degrees of specialization. In other words, infrastructure significantly alters production factor allocations, which allow for a greater degree of specialization and hence higher productivity. These benefits cannot be solved through exclusion, as the producers of the products are typically different from the infrastructure operator, and they provide possible grounds for the "encouragement in lumpy improvements in transaction efficiency, including the provision of infrastructure."

6. Political economy considerations of infrastructure provision

U.S. House Transportation Committee Chair Bud Shuster said, "Angels in heaven don't decide where highways will be built. This is a political process." (quoted in Knight, 2000). Indeed, the importance, scale and public good nature of infrastructure causes most governments to become involved in the planning, regulation, provision or maintenance of infrastructure projects. While there is an opportunity for governments to correct some of the market failures associated with big investment projects, they often generate their own failures. The lack of hard profit objectives means governments tend to run projects inefficiently, and rent-seeking and lobbying pressure often proves too strong to resist, leading to inefficient political logrolling, pork barreling and corruption.

Ghosh and Meagher (2008) investigate the theoretical links between the market environment and infrastructure provision, with the latter determined by the political process. They show that the political economy matters and interacts with private markets in subtle ways. Even in environments where there theoretically exists a positive level of welfare-improving infrastructure capital, the political process may prevent this level from being achieved if costs and benefits are unequally distributed. This may lead to infrastructure traps in which no infrastructure is provided (even though it would be beneficial) and infrastructure thresholds which imply that only sufficiently large projects are politically feasible. A lack of competition in product markets and poor initial conditions (unequal coverage of infrastructure services) makes such traps more likely.

A key insight from Ghosh and Meagher's analysis is that promotion of competition in private markets can generate support for additional infrastructure provision. Consumers, in their role as voters, are given the chance to choose the "rules of the game," generating a complex interdependency between the political process and the marketplace. This interdependency is still poorly understood and awaits further investigation, both theoretical and empirical.

Obtaining good data on how governments evaluate and decide on infrastructure projects is hard to obtain, reflecting the arbitrariness and occasional secrecy of government policy. Ergas and Robson (2009) conclude that project evaluation is only as good as the governments for which it is done: it is only sustained if governments see value in it. Several factors have led to a lack of appreciation of high quality project evaluation including: a) strong revenue growth during good times, b) disregard for quality concerns in favor of timeliness during recessions, c) blurred funding responsibilities between the state and federal governments, and d) partnerships with the private sector, often on opaque and deliberately misleading terms. Together these factors have reduced the perceived budget constraints and opened the door to non-transparent policies and processes.

Redressing this type of Gresham's Law, in which low quality evaluation drives out high quality evaluation, is very difficult as long as governments view infrastructure spending as a benefit as opposed to a cost and as an ends as opposed to a means. Improvements will require a cultural shift as well as institutional change. These might include mandatory full disclosure of all aspects of the project, compulsory independent auditing at various stages of the project, and referral to an independent entity that acts as a champion of good project evaluation.

7. Infrastructure in developing countries

With infrastructure a key driver of economic growth, developing countries are particularly aware of their infrastructure needs. For low-income countries, infrastructure investment providing access to energy, clean water and basic transport may mean the difference between life and death. Basic infrastructure helps alleviate poverty directly and provides the poor with the environment in which they can grow their way out of poverty.

Not only is the stock of infrastructure capital in advanced countries much greater than in developing countries (by a factor of up to 50), but there also exist large disparities within the developing world. For example, whereas electricity consumption in 2005 was approximately 4,000 kWh per capita in East Asia, it was less than 200 kWh per capita in South Asia. (OECD countries consumed on average more than 11,000 kWh per capita in the same year; see Lee, 2010.)

The Asian Development Bank (ADB), one of Asia's main aid and development agencies, estimates that on average Asia needs to invest about US$750 billion per year in infrastructure, especially energy and transport, during 2010–2020 to create the Bank's vision of a "Seamless Asia", a well-integrated, equitable and fast-growing economy. Earlier this year the Bank bumped up its estimate of the investment gap to a whopping US$26 trillion, or US$1.7 trillion per year, for the period 2016–2030. The ADB argues that the region's vast domestic savings can be the main source of financing for Asia's infrastructure with the private sector taking on a major role in funding and delivery.

The experience of private sector participation, seen as a crucial path to help meet the growing investment needs in many countries, is mixed. This may be in part due to a lack of experience and expertise. For example, in 2003, private financing in water supply and sanitation accounted for less than 10 percent of total infrastructure investments in developing countries, and more than 70 percent of this financing was in the form of concessions (see Gunatilake, 2010).

The benefits of private participation such as increased competition and greater productive efficiency are not always evident, according to studies conducted by the ADB. Poor regulation tends to give private suppliers excessive monopoly power; markets are thin, offering incumbent firms ample opportunity to collude; and technology is not sufficiently varied to allow new entrants to shake up the market. Furthermore, at least in the water sector, there is no statistically significant difference between the efficiency of public and private operations.

The poor tend to be extremely sensitive to prices of necessary goods; a significant increase in water prices will be met with stiff opposition and possibly even social unrest. This constrains how profit-maximizing firms can run their business.

Coverage is rarely better with private sector participation as private investments tend to benefit middle-income countries or regions. The ADB identifies several ingredients for successful private sector participation in theory. On the supply side, there must exist mature institutions and effective regulation to foster sound business practice, contract enforcement, innovation and product market competition. On the demand side, there must exist a willingness to pay for improved services, metering must be feasible to enable efficient pricing, and services must be allowed to be context-specific. Private sector participation in some sectors has not lived up to its promise because the projects were often undertaken without sufficient forethought, analysis and public consultation. Success occurred in countries with good capital markets, strong legal systems and well-developed business ethics. Thus, mere transfer of ownership from the public to the private sector will rarely lead to appreciable improvements.

Developing countries face a host of challenges going forward. First, the public sector faces severe budget constraints and so can only be expected to fund a small proportion of investments. Second, the private sector in many countries is still not very resilient—it took 10 years for private sector infrastructure investment to recover from the 1997–1998 Asian crisis. Third, public-private partnerships offer a promising solution to the financing needs, but there are considerable risks associated with inefficient procurement policies and inadequate contracting arrangements. Sound legal frameworks are vital, especially if countries wish to attract foreign investment. Fourth, donors and aid agencies need to provide better financial and technical support, with an improved understanding of investment priorities and local needs. Finally, many developing countries would benefit from greater cross-country coordination to fully capture the spillovers of infrastructure services, especially in transport.

8. Conclusion

There is a tendency in political discourse to assume that all spending labeled “infrastructure” is necessarily good and that in many countries the government is best placed to deliver these projects. It is clear from the academic literature that this is far from the consensus view. Indeed,

although there are potentially large theoretical gains from infrastructure investment for economic growth, the efficacy of infrastructure spending in practice is at best mixed. In order to improve the returns to infrastructure investment, there is a variety of issues in both developed and developing economies that need to be addressed, including: the measurement of the returns to infrastructure; the way in which projects should be evaluated; the delivery mechanisms and the ongoing regulatory environment. Rigorous analysis around all aspects of infrastructure spending is needed to improve the disappointing performance to date. Perhaps the worst time to relieve under-provision of infrastructure is during a crisis, especially when evaluation and delivery have not been thought through well in advance. A more transparent process of evaluation and delivery, as well as an improved understanding of the complexities of infrastructure, are investments in *policy infrastructure* well worth making.

In the first decade of this century there was a renewed effort to research the economics of infrastructure. Ironically, since the global financial crisis, a time when interest rates are low and public investment is relatively cheap, this research effort has waned noticeably. This is unfortunate as there remain a number of important open questions.

As highlighted above, while infrastructure is the key ingredient in a country's ability to capture gains from trade, the benefits are typically highly non-linear due to the presence of network externalities. Once an efficient transport network is in place, direct benefits to building yet another highway are limited. This leads to a complex interdependent process in which infrastructure determines the patterns of trade, and the patterns of trade, in turn, determine the level and type of infrastructure.

Understanding, measuring and predicting the non-linear effects of infrastructure investment is very difficult and requires sophisticated technical tools. Expanding this toolkit and applying it widely should be at the top of the to-do list. Thankfully, the theoretical literature on the economics of networks has progressed substantially in the past 10-15 years (see, for example, the 2016 Oxford Handbook edited by Bramoullé et al.) and the empirical tools are following, but these have yet to be widely employed in the economics of infrastructure. This should be an important priority.

Nonlinearities and complexity prevent economists from generating accurate forecasts about the economy more generally and about the likely outcome of economic policy. Most economic policies have unintended consequences, sometimes large ones. Recently, Treasuries and economic planning units in several countries---for example in Australia and the UK---have started to conduct randomized controlled trials (RCTs) of government policies in order to better gauge their likely side-effects. While RCTs are no panacea and their systematic use is not practical in the evaluation of infrastructure investment, especially for large-scale projects, the "RCT way of thinking" may serve as a useful guide. Some of the techniques used to identify spillover effects in RCTs, such as cluster-level analysis with variational cluster-level intensity (e.g. Baird et al., 2014), could prove useful in identifying network externalities, and limited controlled trials could be used to assess different financing models, in particular PPPs.

Closely related to the issue of financing structures is the one of governance. Poor governance wastes scarce public and private resources, opening doors for rent-seeking, contractual inefficiencies and downright corruption. Repeatedly, economists have advocated the establishment of 'infrastructure banks' to depoliticize the choice of infrastructure projects, improve their

implementation, monitoring and evaluation, reduce financing costs through the issuance of safe long-term infrastructure bonds and better leverage private capital. (See Agénor 2013.) This is a concept worth investigating further, both in academia and in practice.

The list of open questions continues: what are the distributional consequences of infrastructure projects? What welfare function should be used when evaluating infrastructure investment? What discount rate? Which political structures are most suitable for efficient infrastructure investment and delivery? And many more…

We have summarized the current state of infrastructure economics and identified the salient issues. Public policy lags behind in embracing the insights from recent research; there are likely to be substantial benefits from better communication, in both directions, between academia and the policy world. But many more open questions remain and so this survey is also a clarion call to our academic colleagues to redouble their research efforts in the important field of infrastructure economics.

References

Agénor PR (2013). *Public Capital, Growth and Welfare: Analytical Foundations for Public* Policy. Princeton: Princeton University Press.

Aschauer D (1989). "Is public expenditure productive?". *Journal of Monetary Economics,* 23(2): 177–200. doi: 10.1016/0304-3932(89)90047-0.

Sarah B, Bohren JA, McIntosh C, and *et al*. (2014). "Designing experiments to measure spillover effects". *Policy Research Working Paper No. 6824*. Washington, DC, USA: World Bank.

Bramoullé Y, Galeotti A and Rogers BW (eds.) (2016). *The Oxford Handbook of the Economics of Networks*. New York, NY, USA: Oxford University Press.

Blanc-Brude F (2010). "Risk transfer in long-term public-private contracts". Conference on the Economics of Infrastructure in a Globalised World: Issues, Lessons and Future Challenges; 2010 March 18–19; Sydney, Australia. https://web.archive.org/web/20110217220419/http://cama.anu.edu.au/Infrastructure_Conference.asp.

Brooks DH (2010). "Asia's infrastructure and trade". Conference on the Economics of Infrastructure in a Globalised World: Issues, Lessons and Future Challenges, 2010 March 18–19; Sydney, Australia. https://web.archive.org/web/20110217220419/http://cama.anu.edu.au/Infrastructure_Conference.asp.

Brooks DH and Ferrarini B (2010). "Changing trade costs between people's republic of China and India". *ADB Economics Working Paper Series No. 203*. Manila, Philippines: Asian Development Bank.

Calderón C, Moral-Benito E and Servén L (2015). "Is infrastructure capital productive? A dynamic heterogeneous approach". *Journal of Applied Econometrics*, 30(2): 177–198. doi: 10.1002/jae.2373.

Collier P and O'Connell SA (2007). "Opportunities and choices". In: Ndulu BJ, O'Connell SA, Azam JP, *et al*. (eds.) *The Political Economy of Economic Growth in Africa 1960–2000.* Cambridge, UK: Cambridge University Press. doi: 10.1017/CBO9780511492648.003.

Costinot A and Donaldson D (2016). "How large are the gains from economic integration? Theory and evidence from U.S. agriculture, 1880–1997". *NBER Working Paper No. 22946*. Cambridge, MA, USA: National Bureau Of Economic Research. doi: 10.3386/w22946.

Donaldson D (2014) (Forthcoming). "Railroads of the Raj: Estimating the impact of transportation infrastructure," *American Economic Review*. doi: 10.3386/w16487.

_____ (2015). "The gains from market integration". *Annual Review of Economics*, 7: 619–647. doi: 10.1146/annurev-economics-080213-041015.

Donaldson D and Hornbeck R (2016). "Railroads and American economic growth: A "Market Access" Approach". *The Quarterly Journal of Economics*, 131(2): 799–858. doi: 10.1093/qje/qjw002.

Easterly W and Levine R (1998). "Troubles with the neighbours: Africa's problem, Africa's opportunity". *Journal of African Economies*, 7(1): 120–142. doi: 10.1093/oxfordjournals.jae.a020941.

Engel E, Fischer RD and Galetovic A (2014a). *The economics of public-private partnerships: A basic guide.* New York, NY, USA: Cambridge University Press. doi: 10.1017/CBO9781139565615.

_____ (2014b). "Finance and public-private partnerships". In: Heath A and Read M (eds.). *Financial flows and infrastructure financing*, p. 193–222. Sydney, Australia: Reserve Bank of Australia.

Ergas Henry and Robson ARW (2009). "The social losses from inefficient infrastructure projects: Recent Australian experience". Conference on the Economics of Infrastructure in a Globalised World: Issues, Lessons and Future Challenges, 2010 March 18–19; Sydney, Australia. https://web.archive.org/web/20110217220419/http://cama.anu.edu.au/Infrastructure_Conference.asp.

Fischer R (2010). "PPP: Conceptual issues and pitfalls". Conference on the Economics of Infrastructure in a Globalised World: Issues, Lessons and Future Challenges, 2010 March 18–19; Sydney, Australia. https://web.archive.org/web/20110217220419/http://cama.anu.edu.au/Infrastructure_Conference.asp.

Forsyth P (2010). "Evaluating Investments—CGE or CBA?" Conference on the Economics of Infrastructure in a Globalised World: Issues, Lessons and Future Challenges, 2010 March 18–19; Sydney, Australia. https://web.archive.org/web/20110217220419/http://cama.anu.edu.au/Infrastructure_Conference.asp.

Ghosh A and Meagher K (2008). "Political economy of infrastructure investment: A spatial approach". Sydney, Australia: University of New South Wales. doi: 10.2139/ssrn.694243.

Gunatilake H (2010). "Lessons from private sector participation in water and energy sectors in developing countries". Conference on the Economics of Infrastructure in a Globalised World: Issues, Lessons and Future Challenges, 2010 March 18–19; Sydney, Australia. https://web.archive.org/web/20110217220419/http://cama.anu.edu.au/Infrastructure_Conference.asp.

Hoppe EI and Schmitz PW (2013). "Public-private partnerships versus traditional procurement: Innovation incentives and information gathering". *The RAND Journal of Economics*, 44(1): 56–74. doi: 10.1111/1756-2171.12010.

Howell B (2010). "Regulation and investment in technologically dynamic infrastructures: Insights from telecommunications". Conference on the Economics of Infrastructure in a Globalised World: Issues, Lessons and Future Challenges, 2010 March 18–19; Sydney, Australia. https://web.archive.org/web/20110217220419/http://cama.anu.edu.au/Infrastructure_Conference.asp.

Hummels D (2001). "Time as a trade barrier". *GTAP Working Paper No. 18.* West Lafayette, IN, USA: Purdue University.

Jones CI and Romer PM (2010). "The New Kaldor facts: Ideas, institutions, population, and human capital". *American Economic Journal: Macroeconomics*, 2(1): 224–245. doi: 10.1257/mac.2.1.224.

Kessides I (2010). "Pricing flexibility in restructured network utilities". Conference on the Economics of Infrastructure in a Globalised World: Issues, Lessons and Future Challenges, 2010 March 18–19; Sydney, Australia. https://web.archive.org/web/20110217220419/http://cama.anu.edu.au/Infrastructure_Conference.asp.

Knight B (2000). "The flypaper effect unstuck: Evidence on endogenous grants from the federal highway aid program". *Finance and Economics Discussion Series.* Washington, DC, USA: Divisions of Research & Statistics and Monetary Affairs, Federal Reserve Board.

Lee JW (2010). "Financing infrastructure investment in Asia: Need and the role of development partners". Conference on the Economics of Infrastructure in a Globalised World: Issues, Lessons and Future Challenges, 2010 March 18–19; Sydney, Australia. https://web.archive.org/web/20110217220419/http://cama.anu.edu.au/Infrastructure_Conference.asp.

Li Z (2010). "Some evidence on the performance of transport infrastructure investment in China". Conference on the Economics of Infrastructure in a Globalised World: Issues, Lessons and Future Challenges, 2010

March 18–19; Sydney, Australia. https://web.archive.org/web/20110217220419/http://cama.anu.edu.au/Infrastructure_Conference.asp.

Limão N and Venables AJ (2001). "Infrastructure, geographical disadvantage, transport costs, and trade". *The World Bank Economic Review*, 15(3): 451–79. doi: 10.1093/wber/15.3.451.

Lyneham S (2010). "Evaluation and delivery of infrastructure in practice—Theory and practice. Conference on the Economics of Infrastructure in a Globalised World: Issues, Lessons and Future Challenges, 2010 March 18–19; Sydney, Australia. https://web.archive.org/web/20110217220419/http://cama.anu.edu.au/Infrastructure_Conference.asp.

Marcelo D, House S, Mandri-Perrott C, *et al*. (2017). "Do countries learn from experience in infrastructure PPP? PPP practice and contract cancellation". *Policy Research Working Paper No. 8054*. Washington, DC, USA: The World Bank.

Menezes F (2010). "Price regulation and infrastructure investment". Conference on the Economics of Infrastructure in a Globalised World: Issues, Lessons and Future Challenges, 2010 March 18–19; Sydney, Australia. https://web.archive.org/web/20110217220419/http://cama.anu.edu.au/Infrastructure_Conference.asp.

Ng YK (2009). *Increasing returns and economic efficiency*. New York, NY, USA: Palgrave Macmillan. doi: 10.1057/9780230236813.

_____ (2010). "Why should governments encourage improvements in infrastructure"? Conference on the Economics of Infrastructure in a Globalised World: Issues, Lessons and Future Challenges, 2010 March 18–19; Sydney, Australia. https://web.archive.org/web/20110217220419/http://cama.anu.edu.au/Infrastructure_Conference.asp.

Roberts M and Deichmann U (2011). "International growth spillovers, geography and infrastructure". *The World Economy*, 34(9): 1507–1533. doi: 10.1111/j.1467-9701.2011.01392.x.

Straub S (2011). "Infrastructure and development: A critical appraisal of the macro-level literature". *The Journal of Development Studies,* 47(5): 683–708. doi: 10.1080/00220388.2010.509785.

Von Weizsäcker EU, Young OR and Finger M (eds.) (2005). *Limits to privatization: How to avoid too much of a good thing.* Sterling, VA, London, UK: Earthscan.

Winston C (2006). *Government failure versus market failure: Microeconomics policy research and government performance.* Washington, DC, USA: The Brookings Institution.