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1550 Metro Manila, Philippines
www.adb.org/economics
ISSN: 1655-5252
Publication Stock No.

Printed in the Philippines

ADB

ERD Working Paper SERIES No. 91

ECONOMICS AND RESEARCH DEPARTMENT

Infrastructure as a Catalyst for Regional Integration, Growth, and Economic Convergence: Scenario Analysis for Asia

David Roland-Holst

December 2006

Asian Development Bank

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The author thanks ADB colleagues for productive discussion.

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ISSN 1655-5252

FOREWORD

The ERD Working Paper Series is a forum for ongoing and recently completed research and policy studies undertaken in the Asian Development Bank or on its behalf. The Series is a quick-disseminating, informal publication meant to stimulate discussion and elicit feedback. Papers published under this Series could subsequently be revised for publication as articles in professional journals or chapters in books.

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ABSTRACT

As Asia's economic growth process matures, regional integration offers important opportunities to sustain and extend the achievements of the more dynamic economies. Benefits from this process will include geographic diversification, often toward superior growth rates, as well as structural differentiation and more rapid evolution from established north–south patterns of trade and specialization. Propagation of growth linkages across this diverse region will also facilitate more inclusive growth and economic convergence. Infrastructure commitments can be an essential guarantor of the entire process, and this paper examines their potential to contribute to more sustained and broadly based Asian growth.

I. INTRODUCTION

Recent research at the Asian Development Bank (ADB) on Asian regional integration has highlighted the importance of structural barriers to trade (Brooks et al. 2005). Indeed, it now appears that overcoming geographic and institutional obstacles that increase trade and transport margins are much more important to regional trade expansion and sustained growth. In its flagship study of infrastructure requirements for Asia (ADB 2005), the ADB (in collaboration with Japan Bank for International Cooperation and the World Bank), presents a comprehensive review of the region's infrastructure needs. These needs are very substantial and particularly so in relative terms, i.e., the need is relatively most acute in the poorest countries. In a region that enjoys unprecedented external and domestic savings reserves, at a time when real interest rates are as low as they have been in generations, it is surely an auspicious opportunity to consider how large-scale regional investment could help Asia more fully realize its vast economic potential. The goal of the present study is to link the two, using rigorous empirical methods to show how more determined commitments to regional infrastructure can act as a catalyst for Asian integration, facilitating more sustained and comprehensive economic growth.

In a vast literature on trade facilitation, it is doubly unfortunate that investment in infrastructure has received only scant attention. Infrastructure is one of the oldest and most decisive determinants of trade patterns.Public infrastructure also confers some of the most desirable benefits of trade facilitation, including open market access and pro-poor growth and income effects. By lowering costs of market participation in a relatively nondiscriminatory manner, improvements in infrastructure broaden the basis for growth and directly contribute to its sustainability. By reducing trade and transport margins, infrastructure promises a neat reconciliation of private interests, increasing producer prices while reducing purchaser prices.

In the Asian context, the parallel emergence of the People's Republic of China (PRC) and India portend dramatic change in the economic landscape. Because of geographic realities, however, the full growth potential of these large economies for the region and beyond will depend critically on infrastructure. Although their boundaries are proximate in some areas, the Himalayan plateau is unlikely to sustain more than a small fraction of their bilateral trade in the foreseeable future. A much more attractive bridge between the emerging giants is Southeast Asia, already a robust trading environment and one that could capture many of the indirect benefits of intensified trade linkages with the PRC and India. For these reasons, the entire Asian region has an important stake in expanded Southeast Asian trade infrastructure. This is particularly true of many of the region's poorest economies, which would be directly in the path of many new transport axes under consideration. Cambodia, Laos, Myanmar, and (to a lesser extent) Viet Nam have long been at the margins of the more dynamic East and South Asian growth experience, yet they could become central pillars of any comprehensive bridging infrastructure between the PRC and India.

The research reported here is based on applications of a multicountry dynamic model that captures detailed trade and domestic market interactions between and within Asia and in its relationship

to the rest of the world. This kind of computable general equilibrium (CGE) modelling has already established itself as the preferred tool for empirical research on trade policy, and is ideally suited in the present context to demonstrate how infrastructure changes neoclassical fundamentals (market access costs) to amplify gains from trade and accelerate growth. There are relatively few examples of economywide simulation modelling being used for infrastructure assessment, an unfortunate, missed opportunity because this approach is well suited to capturing the kinds of neoclassical cost–price effects and extensive indirect linkages that make up infrastructure's main contribution to economic activity.[1]

Because the paper studies one of the world's most dynamic multilateral trading regions, this is also an ideal application of the Global Trade Analysis Project dataset. Preliminary results indicate that determined commitments to infrastructure investment can sharply expand economic participation, and leverage the superior growth rates of Asia's largest countries for the benefit of the entire region, with large proportionate gains for the poorest countries. In this way, integration will accelerate as regional supply chains are consolidated, and growth externalities can be substantial for all participants. In the absence of more determined infrastructure commitments, trade will simply be intensified along established channels and its benefits diverted over more distant trade routes to traditional markets.

II. MOTIVATION AND BACKGROUND

In economics, both the theoretical and policy literature recognize the importance of infrastructure. In this section, this issue is reviewed from both perspectives. The next subsection provides a conceptual framework for understanding infrastructure's primary economic effects. This is followed by an overview of the available empirical literature on estimating the real impacts of infrastructure investments. In both contexts, macroeconomic and microeconomic analyses are included.

A. Conceptual Framework

There is broad agreement on what constitutes infrastructure, yet its economic agency is quite diverse. A convenient way to understand its role is by decomposition into three functional economic categories:

(i) *Keynesian*. This refers to the pure expenditure component of infrastructure, as reflected in national, regional, and local aggregate demand and employment stimulus.

(ii) *Ricardian*. This component refers to infrastructure's effect on the cost of transport and distribution. Reducing trade margins can have a potent effect on prices and competitiveness, intensifying comparative advantage and increasing both domestic and international trade flows.

(iii) *Neoclassical*. Modern economic theory recognizes infrastructure's contribution to increasing productivity, as technology embodied in transport, communication, and distribution systems increases the efficiency of search, transactions, and shipments. These are generally termed endogenous growth benefits, and are considered among the most important economic contributions of modern infrastructure investments.

[1] One exception is Agénor, et al. (2005) who apply a different but related approach.

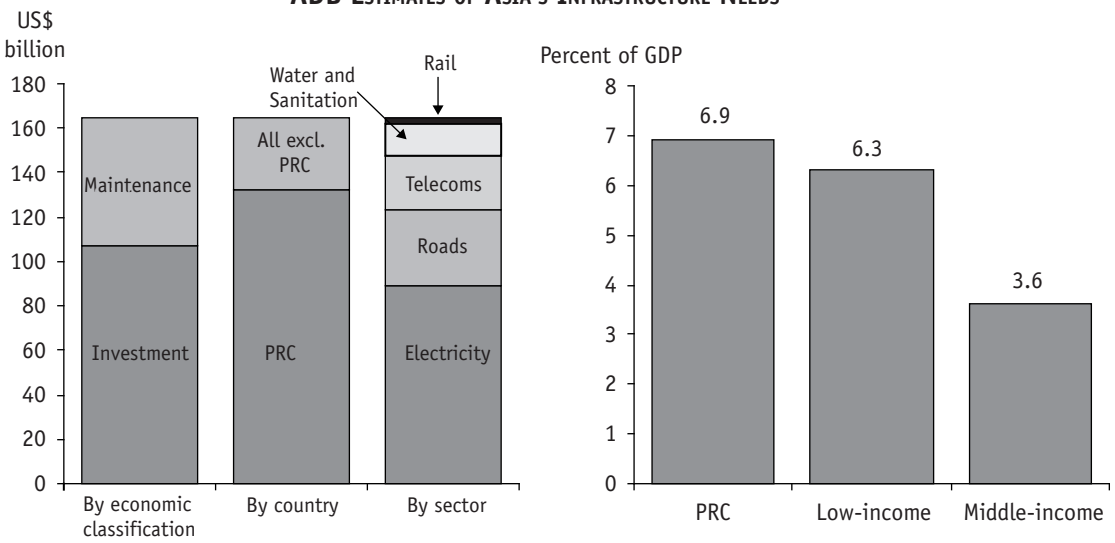
1. Keynesian Stimulus

The direct macroeconomic benefits of public investment have long been recognized, and infrastructure spending itself is a popular means of direct medium-term or transitory employment stimulus. In many economies, programs like the United States's (US) Worker Protection Act and work relief (the PRC), and Japan with its heavy countercyclical and recurrent fiscal commitments to public works) often have employment as their primary goal and downstream benefits as a secondary one.

Because of its generality, this kind of spending can be targeted across a wide spectrum of regions and socioeconomic groups conducted at the national, regional, or local level, and timed to coincide with cyclical economic events. In the case of real public goods infrastructure, multiplier effects from both direct employment and downstream use can be substantial. Obviously, the latter benefits will be greater if more investment can be focused on real public goods and widely used infrastructure capacity. In this study, targeted increases in investment in trade and transport infrastructure for Asian economies that are considered to have the greatest unmet needs are examined.

In its extensive flagship *Asian Development Outlook 2005* report on Asia's infrastructure needs (ADB 2005), the ADB identified several countries that needed to maintain higher long-term infrastructure investments if they were to "catch up" with faster-growing or higher-income countries in the region. As Figure 1 below indicates, ADB estimates that Asia will need US$106 billion in new infrastructure between 2006 and 2010.

Figure 1
ADB Estimates of Asia's Infrastructure Needs



Source: Yepes (2004).

To accomplish this, it is estimated that low-income countries must sustain infrastructure investment levels at 6.3% of gross domestic product (GDP) over this period and beyond. At the moment, many of these countries have rates below 3% because of low domestic savings, weak fiscal institutions, or both. In the analysis presented below, the detailed growth and structural implications of achieving these investment objectives are examined.

2. Ricardian Stimulus

At the microeconomic level, the role of infrastructure in reducing distribution margins is widely acknowledged in the policy and theoretical literature, but explicit treatments are relatively few and not easy to synthesize into a general treatment. Policy-oriented discussion emphasizes the obvious advantages of increased market participation, as infrastructure commitments reduce distribution margins, expanding the profitable horizon of market-oriented investments, whether private or public. This is particularly the case in emerging economic environments, where distribution costs are an important source of price distortions that significantly limit market access and reduce economic efficiency. Such access barriers are particularly important in countries with rural poor majorities, or between economic zones (e.g., South Asia and East Asia) that are separated by more remote subsistence areas. Not only does infrastructure facilitate integration between active zones, it confers growth externalities across the networks so established. In this way, for example, the parallel emergence of the PRC and India has the potential to confer substantial growth externalities across Southeast Asia, especially among the latter's poorest countries. Cambodia, Laos, and Myanmar are among the areas ideally suited to become "pillars" of a "growth bridge" between Asia's two emergent giants.

Empirical evidence of the significance of distribution margins is more plentiful and also quite diverse. This can generally be divided into four categories. The first deals with traditional and modern issues related to physical geography. Second, a large volume of work relates to direct transport costs, including means as well as distance. Third, institutional economics has examined trade margins arising from administrative, regulatory, and political conditions governing transboundary and international commerce. Finally, there is a special component of international finance that deals with exchange rate and PPP distortions and their influence on underlying commerce.

The large literature on geophysical (spatial, etc.) determinants of transportation costs extends from the transport sector itself to general economic geography. This work has a very long history, going back to the founders of trade theory and microeconomics. Heckscher (1916) himself qualified many of his early arguments about the resource basis for trade with caveats about initial physical conditions that might facilitate or hinder trade relations. These were continued down to the present by a variety of authors (recently Obstfeld and Taylor 1997). Samuelson (1952) made early contributions to economic and trade analysis from a spatial perspective, with many later contributions from regional analysis and location theory (e.g., Bergstrand 1990). Moreover, contributions such as Fujita et al. (1999) have initiated a new era of investigations that expand the understanding of the economics of location.

To be more specific, infrastructure reduces trade margins that in turn have three important structural effects on the economy.

(i) *Intensification of Comparative Advantage*

Classical trade theory states that price differences create incentives for international and inter-regional exchange of goods and specialization that increases aggregate efficiency. Distribution margins serve to undermine these price differences, thus the basis for trade and more efficient specialization. To see this, consider two prices *PH* and *PF* for comparable goods from two different sources (home and foreign), although they could simply be from different regions or even cities in the same country. Given that a trade margin (*M*) is generally symmetric, the ratio of these two prices, with margins taken into account, is given by the following expression, evaluated as *M* rises

without limit. Evidently, the higher the margin, the less the degree of comparative advantage for either good across these markets.

$$\frac{P_H + M}{P_F + M} \xrightarrow[M \to \infty]{} 1$$

(ii) *Improved International Terms of Trade*

A second advantage of falling margins is to improve international terms of trade. Consider now the domestic producer price of exports *PE = PWE - M*, where *PWE* denotes the international price of an export good and *M* the margin that must be debited against the exporter's net revenue (producer) price. Symmetrically, the domestic purchaser price of imports takes the form *PM = PWM + M* where *PWM* is the corresponding international price of imported goods and the margin *M* must be added to purchaser prices. It can be observed that falling margins induce an increase in terms of trade *PE/PM*. Once again the double virtue of falling margins and increasing producer prices while reducing purchaser prices sharpens the incentive for trade.

$$M \downarrow \Rightarrow \frac{PWE - M}{P_D} \uparrow \; and \; \frac{PWM + M}{P_D} \downarrow$$

(iii) *Improved Agricultural Terms of Trade*

Finally, margins are inversely related to the rural terms of trade, and thus investments that reduce distribution margins are pro-poor in most developing countries. Consider the rural terms of trade defined as follows:

$$\rho = \frac{P_R^R}{P_U^R} = \frac{P_D - M}{P_D + M}$$

where rural prices of rural products (or rural household producer prices) must be debited for distribution to the domestic market (at prices *PD*) and rural prices of urban products (or rural household purchaser prices) must include shipping cost from domestic urban markets. Differentiating this ratio of rural producer prices to rural consumer prices,

$$\frac{\partial \rho}{\partial M} = -2 \frac{P_D}{(P_D + M)^2}$$

which reveals that falling margins increase the rural terms of trade. Note also that, because this relationship is quadratic in margins, high initial barriers make it difficult to animate market incentives.

3. Neoclassical Stimulus

Modern economic theory recognizes many so-called "endogenous growth factors", i.e., economic conditions that facilitate readiness for growth and can accelerate it when they are present in an economic setting. Many of these are also facilitated by infrastructure, including (i) productivity enhancement, (ii) technology diffusion, (iii) information diffusion, (iv) supply chain articulation and other network externalities, and (v) human capital development (migration).

Many of these factors are among the most sought after rewards of direct investment, whether domestic or foreign in origin. They are often embodied in new investment, particularly that which

is technology-oriented, and are thought to contribute strongly to economic and institutional modernization, accelerating growth, increasing labor productivity and real wage potential, and ultimately contributing to higher sustainable living standards. While these characteristics are widely acknowledged and increasingly understood, many of them are notoriously difficult to measure. The present study uses counterfactual experiments to appraise their general significance.

B. Empirical Findings on Economic Returns to Investment in Infrastructure

While the intuition about infrastructure's link to economic growth is widely accepted, actual mechanisms of this linkage are so diffuse institutionally, spatially, and temporally that they often defy quantification. Thus it is widely agreed that infrastructure makes an essential economic contribution, but calibrating this for benefit–cost assessment is notoriously difficult. As with many public goods, even directly targeted willingness-to-pay surveys are difficult because individuals cannot or will not accurately measure infrastructure's contribution to their individual balance sheets. Despite these challenges, it is important to advance empirical capacity for appraising infrastructure's role in growth and integration. Before a more extended discussion, the basic issues are nicely summarized in the following excerpt from a World Bank (2003) report (see Box 1).

What follows is a survey of the large literature on private growth benefits of public spending on infrastructure.[2] Much of the empirical research on this issue is confined to Organisation for Economic Co-operation and Development (OECD) countries, where growth rates are low and infrastructure stocks, public and private investment levels, and incomes are relatively high. These characteristics may limit the relevance of these results to emerging economies particularly the poorest Asian countries, where initial commitments to infrastructure have little private opportunity cost and can achieve dramatic gains in private output, income, and productivity growth. For these reasons, the results examined here probably represent very conservative indications of what responsibly targeted investments in infrastructure could accomplish in developing Asia.

[2] The material below draws on surveys sponsored by the US government and the World Bank, neither of which bears any responsibility for representations in the present discussion.

Box 1
Title???

A number of studies have found empirical support for a positive impact of infrastructure on aggregate output, especially in developing countries. Overall, results suggest that the returns to infrastructure investment are probably highest during the early stages of development, when infrastructure is scarce and basic networks have not been completed. Returns on infrastructure investment tend to fall, sometimes sharply, as economies reach maturity, so that some studies of the US have even found negative effects (Briceño-Garmendia et al. 2004).

In a seminal paper, Aschauer (1989) found that the stock of public infrastructure capital is a significant determinant of aggregate total factor productivity. However, the economic significance of his results was deemed implausibly large, and found not to be robust to the use of more sophisticated econometric techniques (Holtz-Eakin 1994, Cashin 1995, Baltagi and Pinnoi 1995). Gramlich (1994) provides an overview of this literature.

A more recent empirical literature, mostly in a cross-country panel data context, has confirmed the significant output contribution of infrastructure. It relies on increasingly sophisticated econometric techniques to address reverse causation (infrastructure may cause growth, but growth also causes firms and people to demand more infrastructure—failure to take this into account would result in the overestimation of the contribution of infrastructure to growth).

Notable papers include Canning (1999) using panel data for a large number of countries, and by Demetriades and Mamuneas (2000) using OECD data. Röller and Waverman (2001) also find large output effects of telecommunications infrastructure in industrial countries in a framework that controls for the possible endogeneity of infrastructure accumulation. Similar results for roads are reported by Fernald (1999) using industry data for the US. Calderón and Servén (2005) present a similar empirical analysis with a focus on Latin America. They find positive and significant output contributions of three types of infrastructure assets—telecommunications, transport, and power.

A few papers go beyond measures of infrastructure spending and infrastructure stocks, and consider the issue of infrastructure efficiency or quality. Hulten (1996) finds that differences in the effective use of infrastructure resources explain one quarter of the growth differential between Africa and East Asia, and more than 40 percent of the growth differential between low- and high-growth countries. Esfahani and Ramirez (2002) report significant growth effects of infrastructure in a large panel data set in which the contribution of infrastructure is affected by institutional factors. Finally, Calderón and Servén (2004b) find a robust impact of both infrastructure quantity and quality on economic growth and income distribution using a large panel data set encompassing over 100 countries and spanning the years 1960–2000. They use a variety of specification tests to ensure these results capture the causal impact of the exogenous component of infrastructure quantity and quality on growth and inequality.

1. OECD Results

Private returns to public infrastructure investment can be decomposed into two generic categories: top-down and bottom-up studies look at the role of economic returns to public investments in infrastructure. Both approaches have strengths and weaknesses and neither of them offer definitive estimates of the private value of these public investments. Generally, most of these studies suggest limits to the supply of projects with high economic returns, and there are serious limits to growth rate benefits from increases in infrastructure investment, if any. Moreover, some studies recognize a crowding-out effect, where public dollars yield less than a dollar of net investment because some portion would probably have been undertaken in any case by private parties or regional/local

governments. Because local and regional governments can second guess central government initiatives and refrain from spending their own fiscal resources, central government investment might even discourage other investments and reduce reliance on local knowledge for project selection. This trend could undermine project selection quality, reduce the incentive benefits of local ownership, and undermine the long-term sustainability of the services from these public goods.

2. Top-Down Approaches

Top-down approaches begin with macro or large-scale public investments and attempt to identify sector or even firm-level welfare benefits. There are a variety of survey articles that summarize and draw conclusions from the assessment literature for physical infrastructure (see for example, Munnell 1992, Gramlich 1994, Fisher 1997, and Boarnet 1997). Some of this research finds insignificant or even negative net economic effects, while others estimate large positive effects. Having said this, a clear majority of studies present evidence that public capital has a measurably positive but modest impact. In fairness, however, data limitations often preclude definitive conclusions.

Perhaps the most compelling study in this literature were early contributions of Aschauer (1989 a and b). Using a simple production function specification and 1949–1985 data for commercial profitability, public capital, private capital, employment, and output, Aschauer estimates that at the margin, a dollar of public capital investment yields a much higher aggregate return than an additional dollar of private capital. This conclusion is directly adducible to a high correlation between trends in private productivity and the stock of public infrastructure. In the US, these two both grew much faster in the first half of the sample period (to 1970) than afterward.

Aschauer's results inspired extensive critical reaction, mainly because of its reliance on national level time-series data for investment/capital stocks and output. The nature of the data implies that results can be quite sensitive to minor within-sample changes (e.g., beginning the sample not in 1949 but in 1950). This kind of sensitivity means that Aschauer's results might arise from coincidental factors rather than the causality that his interpretation suggests.[3]

The literature growing out of Aschauer has seen increasing sophistication, both in econometric specification and data development. Alternative estimation strategies include first-differencing, which elucidates relationships between growth rates, rather than levels, of the variables of interest. This approach reduces the likelihood of spurious correlations like the one described above (see, for example, Holtz-Eakin and Schwartz 1994). An alternative approach exploits cross-section or panel data for regions, metropolitan areas, or industry groups, all more focused alternatives to time-series or national variables. The basic objective of these approaches is to study smaller and more specialized agents with more discernible sample variance.

Generally, the research using differencing methods are not consistent with those based on national time-series level data. Having said this, however, the differencing studies do not provide clear and convincing estimates of the marginal impact of public investment. Munnell, among others, expressed scepticism about the early differencing approaches because they lack rigorous justification for their own methodology. She argues that growth rate analysis can obscure long-run trend relationships that may in fact be causal, partly because of variable gestation periods and other lag effects. First-difference data also have higher susceptibility to measurement error. Later studies,

[3] For contrast, see Tatom (1993). Studies using industry-level or state-level data, however, have found evidence that infrastructure can indeed lead to gains in productivity.

one each using national and regional level data, respectively, apply specification tests and conclude that first-differencing is justified. What all these studies have in common is a failure to support the Aschauer conclusions. Neither of the latter studies deals effectively with lag issues, however. Other contributions examine such relationships by analyzing data observed at longer intervals (e.g., decadal growth rates), but degrees of freedom undermine the robustness of these findings.

Whether the specification is in level or difference form, more focused data from cross-section or panel samples generally produce smaller estimates of the impact of public capital than those relying on time-series at the national level. One review article in 1997 mentions that eight of 15 studies on regional or local impact of highway investment found positive and statistically significant (reliably different from zero) effects, and seven others yielded either negative or insignificant effects. In other words, aggregating these sectoral results would yield the kind of spurious correlation already discussed at the national level.[4]

A more modern approach to econometric estimation of investment returns and productivity focuses on empirical cost functions, yet this has not been extensively applied to public capital investment issues. In a recent exceptional case, annual regional-level data for the period 1970–1987 is used to analyze effects of highways, water, and waste treatment facilities systems on private manufacturing costs, finding very significant positive effects. The basic finding is that a marginal dollar of this category of infrastructure saved private manufacturers approximately 31 cents per year in operating costs. Comparable estimates for other regions fell between 16–18 cents (Morrison and Schwartz 1996). Such estimated benefits seem quite high, especially when it is acknowledged that manufacturing represents only about 20% of the private economy and hence reflects only a fraction of the total benefit of public capital. Overall, however, these estimates of private savings appear too optimistic to generalize very widely.[5]

Another cost function study examines highway investment. Commissioned by the US Federal Highway Administration (FHWA), this study examined private savings from highway investment for the period 1950–1989, detailing effects for 35 distinct industry groups (private returns to personal transport were not considered). This study used two metrics for the highway system as a public good: lineal miles of total highway stock (all central government, regional, and local roads), and the same measure covering the "non-local highway system." The importance of this distinction is that the latter variable excludes local government investments. This research indicated that a marginal dollar invested in the nonlocal network yielded an average of about 24 cents annually of private benefit to business across the entire sample period. In terms of productivity/profitability, this translates into an annual average rate of private return on public investments of 16%, compared with 11% for comparable private investment. It is noteworthy, however, that the estimated benefits were highest in the early years, before the advent of the interstate highway system, and these tapered off significantly as the highway network expanded. By the 1980s, it was estimated that

[4] See the comments in Fisher (1997, 59); Gramlich (1994, 1188–89); and Boarnet (1997, 479–80). Some studies use data from multiple countries; they face both the issue of unobserved country-specific factors and the additional problem that the data may be defined differently across countries. Perhaps as a result, the international studies have not yielded clear insights (Gramlich 1994).

[5] After adjusting for inflation in prices of capital goods between 1982 and 1987, gross savings from a marginal dollar of manufacturing capital in 1987 are estimated at 50 cents in the eastern US and 60 cents in the north; net savings after borrowing costs, depreciation, and taxes are 15 cents and 26 cents, respectively. (The 1987 figures reported in the study are somewhat higher, representing nominal dollar savings per unit of real capital, with the unit defined in 1982 prices.) See Morrison and Schwartz (1996, 1095–111).

the overall stock of nonlocal highway capital was only 4% below the size beyond which further increases would cost more than they would return in benefits to business. Moreover, by this time the total road network was yielding only 10 percent on additional investments, below the reference rate of 11% for returns to private capital (Nadiri and Mamuneas 1996).

Aschauer's work stimulated important innovations in estimation methods from the top-down perspective (see, for example, Sturm and de Haan 1995 and Garcia-Mila et al. 1996). Despite this, however, the evidence on private returns to public investment, while generally positive, are neither definitive nor precise enough to support calibrated simulation exercises. It should be noted in passing, however, that the studies considered so far look only at the observed pattern of spending on infrastructure. In particular, none of these studies consider or estimate the impact of shifting funds from low-return projects chosen by other criteria to projects with higher returns.

3. Bottom-Up Approaches

Bottom-up studies of infrastructure generally begin with sectoral or even agent-level profit, efficiency, or some other welfare proxy, then try to associate changes in this with specific or generic public goods or infrastructure investment. For two principal reasons, estimates from these kinds of benefit–cost and rate-of-return studies cannot clearly delineate the private value of public infrastructure. Most importantly, the scope of variation in rates of return, from losses to very high positive profits, makes it extremely difficult to generalize the handful of results from these case studies. There are a small number of broad compilations of estimates for large numbers of projects. Second, the universe of bottom-up studies differs widely in both scope and rigor. Policy conclusions should ideally rest on independent reviews that evaluate a set of studies from different sources. But again, few such independent reviews exist.[6]

The basic challenge of generalizing policy conclusions from bottom-up evidence can be seen in a set of benefit–cost data produced by the US Aviation Administration (FAA) and the FHWA. The FAA data have serious design limitations, as they cover only 18 proposed airport improvement projects evaluated by the agency over a 4-year period (1994–1997). This sample is too restrictive to support conclusions about airports as a category of public investments.

By contrast, the more extensive FHWA data provide estimates of nationwide benefit–cost ratios for all improvements to existing highways that are expected to be efficient (that is, have a B/C ratio of at least 1). However, the data are not derived from detailed analyses of thousands of individual projects but from a set of policy simulation models, reflecting some set of simplifying assumptions rather than observed project performance. The models estimate the benefits and costs of various types of paving, widening, and road alignment projects, based on data for about 123,000 segments covering roughly 30% of the US highway network. By applying standardized formulas and tables, these models estimate essential performance relationships, e.g., the influences of weather and truck traffic on pavement condition, and of pavement condition on travel times and vehicle operating costs. The limited ability of the data to capture specific circumstances of each of the segments modelled limits the accuracy of these FHWA estimates. Moreover, according to experts both inside and outside the agency, evidence for many of the relationships assumed in these models is fragmentary or out of date.

[6] For more on this, see Gramlich (1994) and Florio (1997). The latter compiles data from 200 benefit–cost studies submitted to the European Commission and cites analogous data from the World Bank, but those data have limited relevance for the US.

Overall, the benefit–cost data from these agencies do not offer reliable or precise evidence on the value of investments in airports and highways, respectively, let alone reflect performance of infrastructure as a whole, but they do illustrate some useful qualitative characteristics. Firstly, returns vary considerably across investments, even within a particular category. Of the 18 airport projects in the FAA sample, four had ratios below 1, indicating that their measured benefits would not justify their costs, while three had estimated benefit–cost ratios exceeding 10, including one with a startling ratio of 105. There is no unique relationship to translate benefit–cost ratios into rates of return or vice versa, but a ratio of 10 heuristically suggests annual return of 80% or better. Of the remaining projects, four had estimated ratios between 1 and 2, five had ratios between 2 and 4, and two had ratios between 4 and 10.

Secondly, while some individual projects are estimated to have very high returns, they represent a small share of the universe of investment opportunities. This is evident in the case of the FHWA models, which are used to delineate the set of highway improvement projects expected to be efficient. When searched by project class and road type, the data show a very high average benefit–cost ratio of 12.1 for the set of efficient projects dealing with rural interconnection, yet this set includes relatively few projects, representing only 0.1 percent of total investment allocation for all efficient projects. In contrast, road widening projects of all types account for over 60% of all efficient investment dollars, yet these offer much lower average benefit–cost ratios, averaging 1.8. Similar results for roads are reported by Fernald (1999) using industry data for the US.

Thirdly, variegated returns suggest that, a priori, it can be very difficult to predict returns, yet the same fact makes clear the importance of project selection. Consider the FHWA sample, which evaluates 81 combinations of road type and project type. Among these, the 35 investment categories with the highest benefit–cost ratios averaged B/C=5.89. Moreover, funding these projects would cost just 30 percent of the total required for all efficient projects but yield 70% of total net benefits (benefits minus costs). The other 46 project categories have an average benefit–cost ratio of 1.87.

Fourthly, the FHWA evidence suggests that, beyond a certain point, maintenance and management of existing infrastructure become more attractive than new investment in additional capacity, which tends to be more costly. For example, these data indicate that efficient resurfacing projects not involving shoulder improvements have a benefit–cost ratio of 6.0, averaged over all types of roads, compared with an average ratio of 3.2 for efficient projects that add new lanes.

Some researchers carry this idea a step further, citing low-cost opportunities to make existing infrastructure more productive through efficient pricing and other management improvements. This is a very promising area for policy research, and in some cases, such efforts may yield higher returns than more traditional investment projects, even compared to new investment with attractive benefit–cost ratios. It should be observed, however, that current taxes and fees do not accurately reflect the costs users of airports and roadways impose on others through congestion and wear and tear. Under rules designed to promote efficiency in infrastructure use, motorists and aircraft operators would pay fees (tolls or landing fees) based on their contribution to congestion of a particular facility at a particular time of day; and commercial truckers would pay taxes based on weight per axle (the key determinant of pavement damage). Winston and Bosworth have estimated that efficient pricing of airport and road use would yield annual benefits of $22.2 billion in 1995 dollars. They also find that combining efficiency pricing with efficient investment—building highways

with thicker pavement and adding runways at existing congested airports—would produce additional benefits of $12.7 billion per year, net of the incremental capital cost of $3.0 billion per year.[7]

4. Displacement

The top-down and bottom-up studies discussed above all have the goal of estimating the private value of infrastructure, regardless of how and by whom it is financed. A more complete analysis of a given public infrastructure program should also consider the extent to which it actually increases total infrastructure investment rather than displacing spending by public agents at other (regional, local, central) levels.

Both theory and evidence suggest that significant displacement can occur in higher-income countries. Most evidence supports the widely held notion that regional and local governments have strong incentives to invest in infrastructure, even in the absence of central government assistance, because the majority of benefits accrue to local residents. Moreover, some studies present evidence that regional and local governments will delay infrastructure investments in anticipation of subsequent central government funding. Indeed, displacement manifests itself as a more general phenomenon, extending well beyond infrastructure. In the material surveyed here, six such studies out of nine present evidence of the so-called "flypaper effect", where grants from larger to smaller government jurisdictions significantly reduced the recipients' spending from other sources (estimates suggested displacement as high as 35–75 cents per grant dollar).[8]

5. Non-OECD Evidence

Although evidence outside OECD is of greater relevance to ADB's infrastructure agenda, evidence here is sparse. Despite this fact, however, those studies that have been carried out are positive in their findings for several reasons. Firstly, they make consistent positive links between well-targeted infrastructure and aggregate growth, productivity improvements, and poverty alleviation. Secondly, there is clear evidence from a variety of countries that basic infrastructure has the highest rates of social and private return. Finally, it is apparent from some work that returns to public investment diminish monotonically with respect to aggregate income, a result that means weak effects observed for OECD economies do not imply low returns in low-income countries.

One study of the PRC (Fan, Zhang, and Zhang 2003), for example, finds high GDP multipliers for public investment in road systems. More strikingly, this study finds that the multiples are several times higher for low-quality roads than for high-quality ones. This strongly supports the notion that the earlier the stage of development, the higher the private return to public investment in infrastructure. In contrast, Lin and Song (2002) focused on the urban sector. Using data for 189 PRC cities from 1991 to 1998, they found that an increase in paved roads is positively and significantly related to growth in GDP per capita in urban areas. Benziger (1996) provides interesting evidence on

[7] These estimates are from Winston and Bosworth (1992, 293), converted to 1995 dollars by the US Congressional Budget Office, using the GDP implicit price deflator.

[8] More on this aspect of public finance can be found in Hines and Thaler (1995, 219). Grant providers in the nine studies include the federal and state governments, while recipients include states, municipalities, and school districts. The phrase "flypaper effect" refers to evidence that intergovernmental grants "stick" to recipients' budgets more than they would if recipients treated them the same as increases in local income. The other three studies cited found essentially a dollar-for-dollar flypaper effect, implying no displacement at the level of recipients' overall budgets.

the linkages between the urban and rural sectors, testing whether greater access to urban markets increases the intensity of input use and productivity in the rural sector in the province of Hebei. His econometric results show that road density and distance to the nearest city are positively correlated with the use of fertilizer per unit of land, machinery utilization per worker, and average land and labor productivity.

Many focused studies in developing countries reach similar conclusions. In the case of road investments, for example, positive links to output and productivity are reported by Ahmed and Hossain (1990) for Bangladesh; Khandker et al. (1994) for Morocco; Songco (2002) for Viet Nam; Jacoby (2000) for Nepal; and Riverson et al. (1991) who reviewed 127 World Bank supported road projects and showed the majority stimulated income and productivity growth. Having said this, the effects on poverty may generally be positive, but inequality is often found to increase because of road development.

International comparison studies, mostly in a cross-country panel data context, have confirmed the significant output contribution of infrastructure. For example, Canning (1999) used panel data for a large number of countries and Demetriades and Mamuneas (2000) used OECD data. Röller and Waverman (2001) also find large output effects of telecommunications infrastructure in industrial countries in a framework that controls for the possible endogeneity of infrastructure accumulation.

Among the most comprehensive recent studies is research in the Latin American context by Calderón and Servén (2005). These authors produce generalized method of moments estimates of a hypothetical Cobb-Douglas production technology obtained from a very large (121 country) panel data set, finding positive and significant output contributions by three types of infrastructure assets: telecommunications, transport, and power. The estimated marginal productivity of these assets significantly exceeds that of noninfrastructure capital. On the basis of those estimates, Calderón and Servén infer that a major portion of the per capita output gap that opened between Latin America and East Asia over the 1980s and 1990s can be traced to the slowdown in Latin America's infrastructure accumulation during the same period.

In contrast with the relatively large literature on the output effects of infrastructure, studies of the impact of infrastructure on long-term growth are not numerous. In a study of the growth impact of government spending, Easterly and Rebelo (1993) find that public expenditure on transport and communications significantly raises growth. Also, Sanchez-Robles (1998) presents evidence that summary measures of physical infrastructure are positively and significantly correlated with growth in GDP per capita. Easterly (2001) reports that a measure of telephone density contributes significantly to growth performance of developing countries over the last two decades, but the strict interpretation of this result is one of correlation rather than causality.

A subset of this literature extends the basic analysis of infrastructure stocks and investment to consider quality or efficiency of infrastructure. Prominent among these is Hulten (1996), who finds that differences in the effective use of infrastructure resources explain one quarter of the growth differential between Africa and East Asia, and more than 40% of the growth differential between low- and high-growth countries. In a more generic correlation exercise, Esfahani and Ramirez (2002) find there are significant growth links arising from infrastructure across a large panel data set where explicit account is taken of institutional factors affecting infrastructure's growth performance.

III. OVERVIEW OF THE CGE MODEL

The complexities of today's global economy make it very unlikely that policymakers relying on intuition or rules-of-thumb will achieve anything approaching optimality in either the domestic or international arenas. Market interactions are so pervasive in determining economic outcomes that more sophisticated empirical research tools are needed to improve visibility for both public and private sector decision makers. The preferred tool for detailed empirical analysis of economic policy is now the calibrated general equilibrium (CGE) model. It is well suited to trade analysis because it can detail structural adjustments within national economies and elucidate their interactions in international markets. The model is based on a prototype global trade model developed by the World Bank and is fully documented elsewhere, but a few general comments will facilitate discussion and interpretation of the scenario results that follow.[9]

Technically, a CGE model is a system of simultaneous equations that simulate price-directed interactions between firms and households in commodity and factor markets. The role of government, capital markets, and other trading partners are also specified, with varying degrees of detail and passivity, to close the model and account for economywide resource allocation, production, and income determination.

The role of markets is to mediate exchange, usually with a flexible system of prices, the most important endogenous variables in a typical CGE model. As in a real market economy, commodity and factor price changes induce changes in the level and composition of supply and demand, production and income, and the remaining endogenous variables in the system. In CGE models, an equation system is solved for prices that correspond to equilibrium in markets and satisfy the accounting identities governing economic behavior. If such a system is precisely specified, equilibrium always exists and such a consistent model can be calibrated to a base period data set. The resulting calibrated general equilibrium model is then used to simulate the economywide (and regional) effects of alternative policies or external events.

The distinguishing feature of a general equilibrium model, applied or theoretical, is its closed form specification of all activities in the economic system under study. This can be contrasted with more traditional partial equilibrium analysis, where linkages to other domestic markets and agents are deliberately excluded from consideration. A large and growing body of evidence suggests that indirect effects (e.g., upstream and downstream production linkages) arising from policy changes are not only substantial, but may in some cases even outweigh direct effects. Only a model that consistently specifies economywide interactions can fully assess the implications of economic policies or business strategies. In a multi-country model like the one used in this study, indirect effects include the trade linkages between countries and regions, which themselves can have policy implications.

[9] See van der Mensbrugghe (2005) for complete model documentation.

IV. OVERVIEW OF INITIAL CONDITIONS

Infrastructure conditions across Asia are highly variegated, even between neighboring countries. As the following table indicates, Asian infrastructure expansion trends have been dramatic, but only in a few countries. This diversity is addressed in detail in ADB's flagship infrastructure study (ADB 2005); and the next section examines its growth consequences in some detail. Before presenting these results, however, it is useful to examine initial infrastructure conditions for the region.[10]

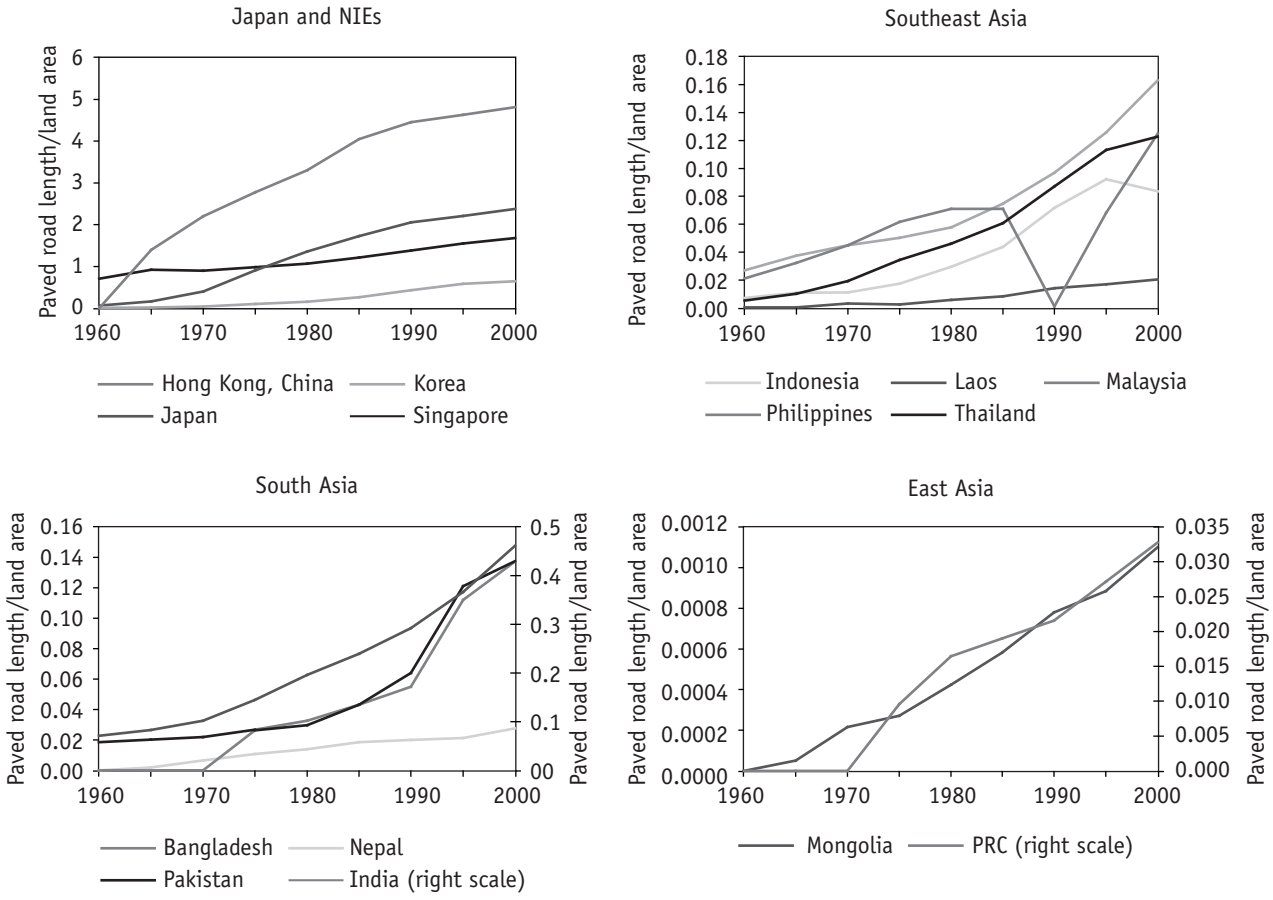
The second part of Figure 2 above indicates the variation in overall infrastructure investment flows among Asian economies. Three general groups are distinguishable: high income, high growth, and lower income. The first and second categories evince the highest regional flows to investment (including infrastructure) as a percent of GDP, while the third is understandably constrained by limited domestic resources and less ability to attract external ones (compared to the second category).

Turning from the investment flow to the stock of infrastructure, an analogous pattern is observed. The following two figures present trends in installed improved roadway over the last 45 years, expressed in two ways. The first, road length per unit of domestic national land area give an indication of national road density. This is a trend that should certainly rise for all countries striving for modernization, and indeed those with the fastest rising trends are among the most affluent (Japan and Singapore).

A few comments about Figures 2–5 are in order. Firstly, general increases are seen over time, although at very different rates. The diversity in these trends results from three factors. The first is initial conditions and early period data availability. Some countries do not report until 1970, and even then reporting is incomplete. Second, these measures do not take into account population density on a national basis. Some countries, like the PRC, have vast unpopulated areas, and their infrastructure is allocated accordingly. In the case of roads for example, the PRC has made enormous commitments to growing infrastructure, but on a national land area basis, road surface remains small compared to metropolitan (Hong Kong, China; Singapore) and more densely populated countries. Third, some per capita measures are difficult to compare between countries with dominant urban or rural populations.

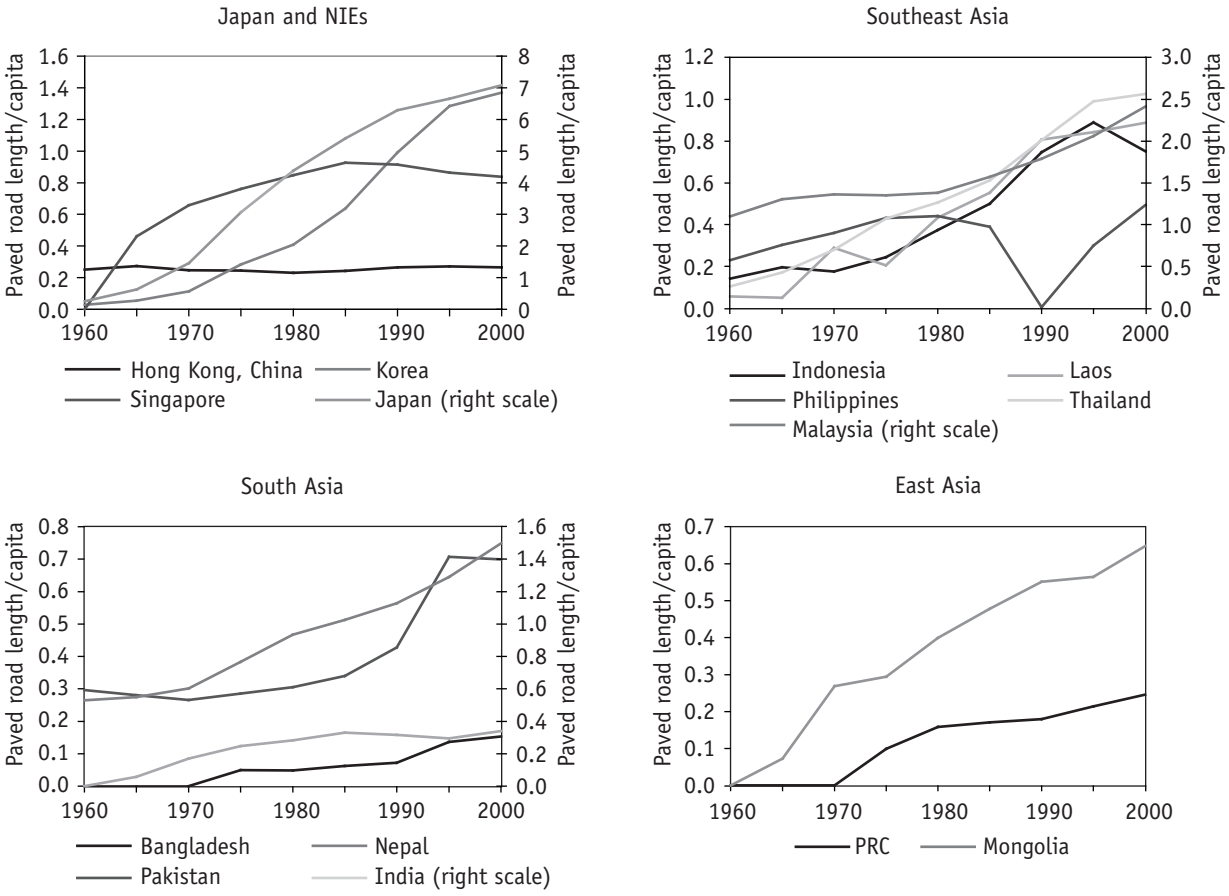
[10] For more extensive discussion of infrastructure assessment and proxies for quality and performance criteria, see for example, Estache and Goicoechea (2005).

Figure 2
Paved Road Systems and Land Area
(road length per hectare)



It is another matter, however, to compare this indicator across countries. For example, the PRC has been building roads faster (in road length terms) for the last 10 years than the US did during its "Golden Age" of transport infrastructure development in the 1950s. In spite of this, vast tracts of the PRC are and will likely remain desolate of people, markets, and transport services. For this reason, the PRC is very difficult to discern on this chart, even though its annual growth over the last two decades has been nearly double that of Korea, a much smaller country with advanced road networks and much higher per capita income. For purposes of country comparison, the stage of infrastructure development is probably more accurately reflected in a service measure, such as total road length per capita. Here Japan and Malaysia take the lead in the region, even as public transit resources are not taken into full account, of which both Hong Kong, China and Singapore are well endowed.

Figure 3
Paved Road Systems and Population
(road length per capita)



Another popular measure of modernization infrastructure is electricity capacity per capita. This is depicted in Figure 4 and the cross-country disparities are very much in line with earlier discussion about regional growth hierarchy. Electrification is an essential component of modernization, sustainable urban development, and higher productivity around the world, and this will clearly be a focal point for Asian infrastructure investment, particularly in countries that are later starters.

Another popular index of modernizing infrastructure is the scope of mobile telecommunications adoption, depicted for the Asian region in Figure 5 in per capita subscriber terms. Close examination and comparison of these trends reveals this is indeed a good proxy for economic modernization, and indeed, the hierarchy of per capita income in Asia is almost perfectly reflected in this data. Urban density creates a slight bias for the city states, but otherwise mobile saturation is a nearly perfect proxy for per capita income. Having said this, however, it should be observed that different kinds of infrastructure are more appropriate to facilitate growth at different stages of development. In countries with large rural poor populations, for example, improved roads and other transport are much more growth friendly and pro-poor than large investments in modern telecommunications.

Figure 4
Electrification
(electric capacity per capita)

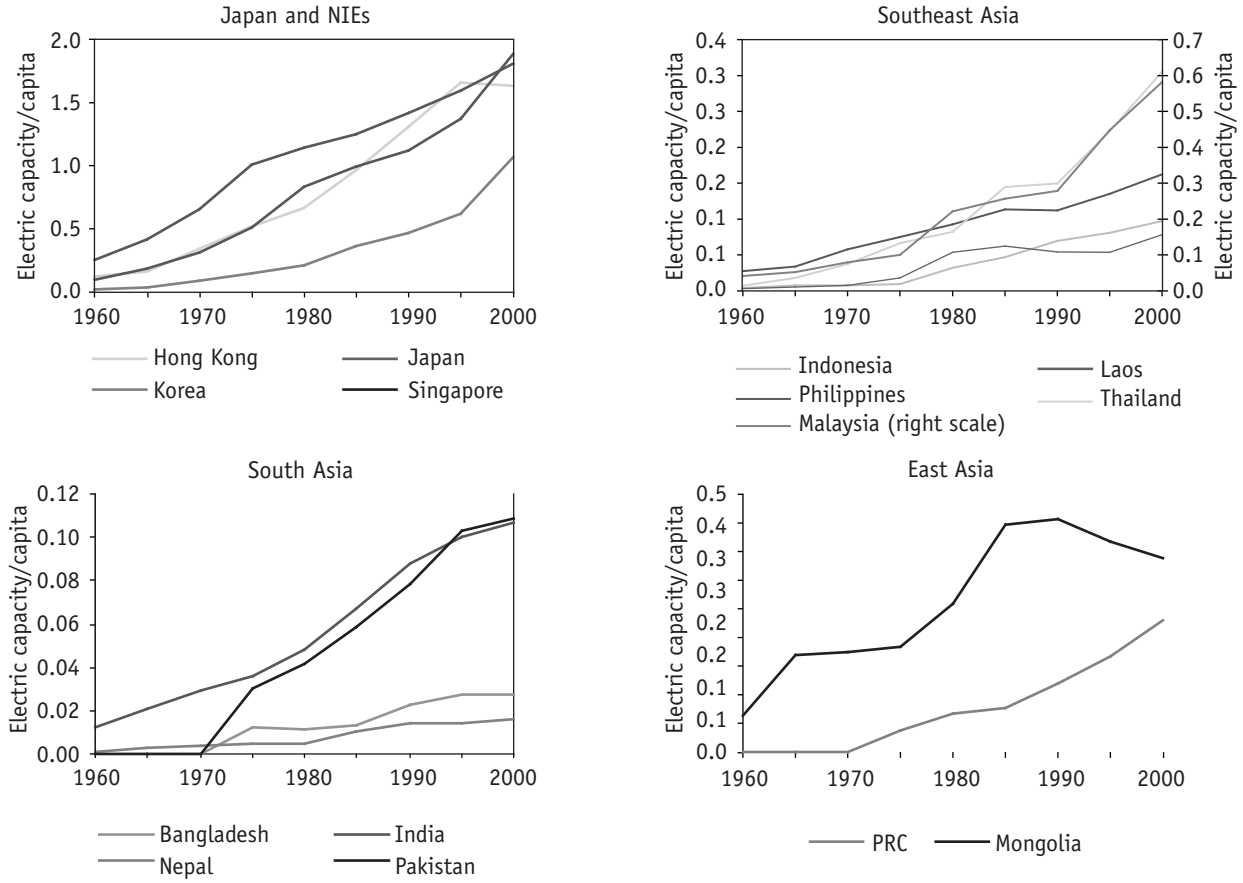


Figure 6 makes clear how domestic income and savings constrain infrastructure development. Lower-income Asian countries are caught in a low-investment trap, where both domestic private and public resources are insufficient to support rapid emergence from their less developed status. These countries might be considered fortunate in one respect, however. The developing countries are members of the Asian region, which currently enjoys the world's highest average savings rates and unprecedented stocks and inflows of external savings. In its infrastructure needs report, ADB (2005) emphasizes that external partnership can play an essential role in overcoming these constraints. Table 1 and Figure 7 show clearly why this makes sense. Table 1 presents data on incomes, aid levels, and aid sources for a variety of East Asian and Pacific economies, while Figure 7 shows trends in private (investment) and public (aid) foreign capital inflows to Asian countries. Both trends support a single conclusion, that people live in a world of complementarity where equitable growth is concerned, domestic and external partnership and public private partnership are necessary, yet neither is likely to be sufficient, if the comprehensive growth needs for effective Asian economic integration are to be met.

Figure 5
Mobile Telephony
(mobile users per thousand population)

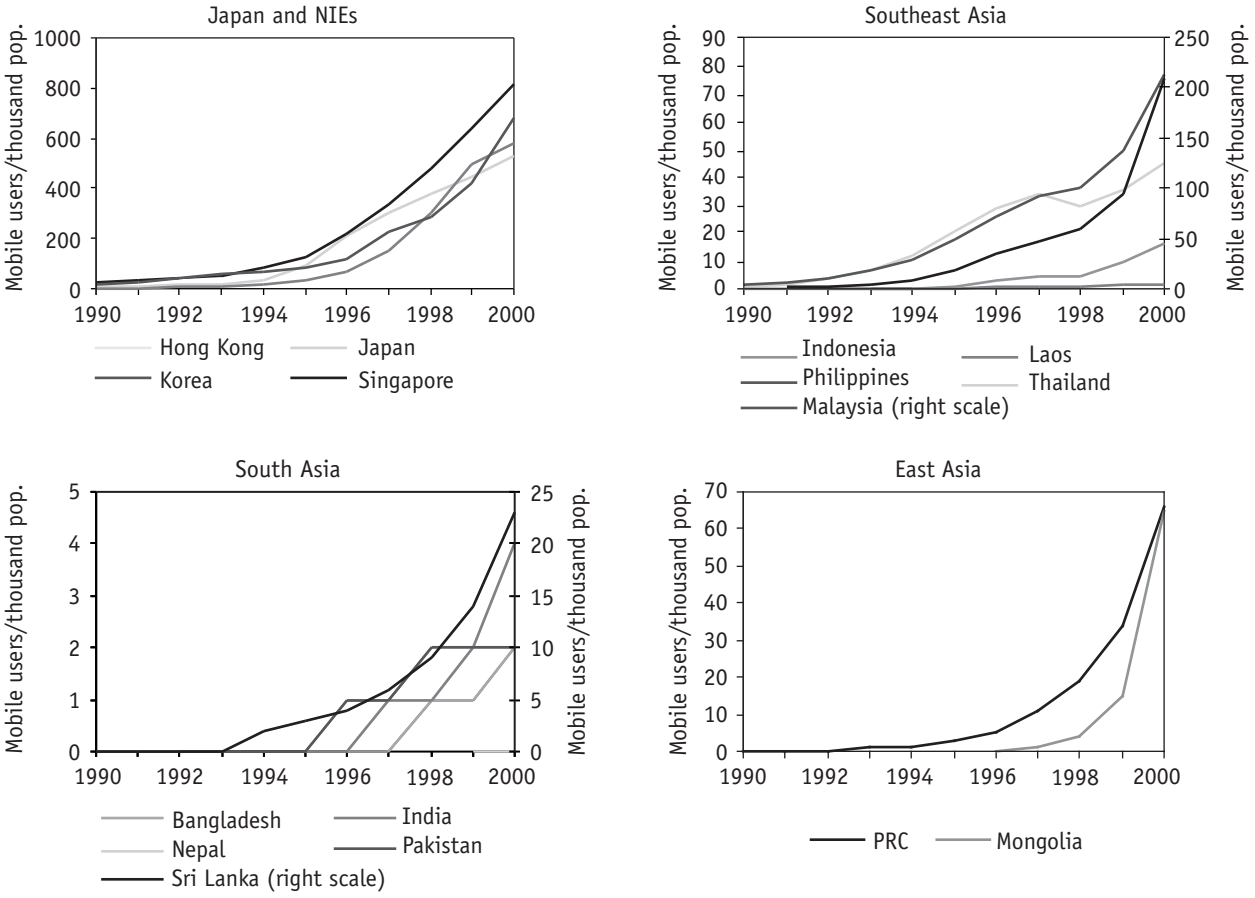


Figure 6
Income and Infrastructure

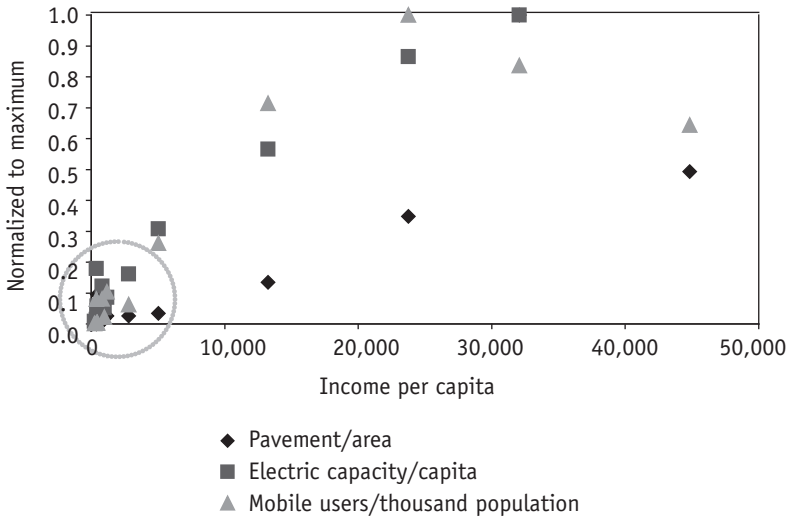
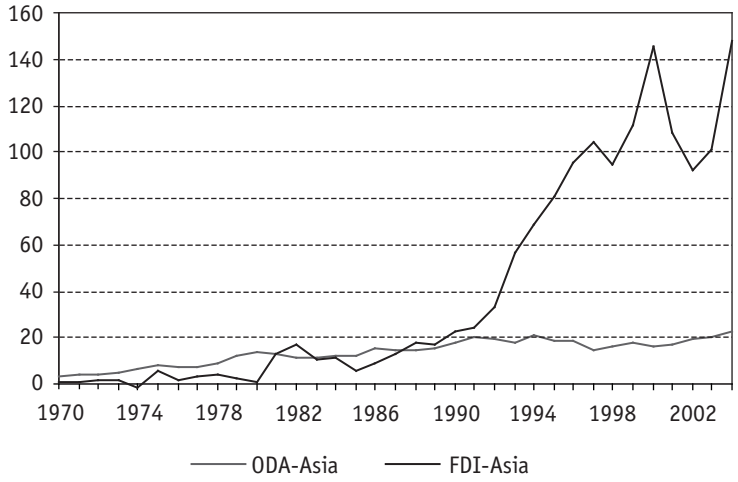


Figure 7
Asian Inbound Aid and FDI
(billions of US dollars)



ODA means official development assistance. FDI means foreign direct investment.
Sources: OECD aid statistics (OECD 2006???) and FDI statistics (UNCTAD 2006???).

Table 1
Aid Dependency in East Asia and the Pacific, 2004

	Income per capita (US$)	Aid per capita (US$)	Aid as percentage of:	
			National income	Gross investment
Malaysia	4,520	11.6	0.3	1.1
Thailand	2,490	0.0	0.0	0.0
PRC	1,500	1.3	0.1	0.2
Philippines	1,200	5.7	0.5	3.0
Indonesia	1,130	0.4	0.0	0.1
Mongolia	600	104.1	16.4	44.3
Papua New Guinea	550	46.1	7.6	...
Viet Nam	540	22.3	4.1	11.4
Lao PDR	400	46.5	11.3	62.3
Cambodia	350	34.7	10.3	38.0
East Asia and Pacific Average[1]	1,417	3.7	0.3	0.7

... means ????_____

[1] For low- and middle-income countries.
Source: *World Development Indicators* online database (World Bank 2006).

V. SCENARIO ANALYSIS

As indicated in the discussion of Section II above, the basic approach is to examine the effects of infrastructure investments from three different economic perspectives: macroeconomic (Keynesian), margins/prices (Ricardian), and productivity (neoclassical). Each approach uses different estimation strategies, and sheds light on different contributions infrastructure can make to the Asian regional economies. The general assumptions underlying the following scenarios are summarized in Box 2 below.

Box 2
Scenario Summary

Keynesian Experiments
- Asian economies with below-average baseline infrastructure accelerate investment
- New investment needs are met by a combination of higher domestic saving and external capital inflows

Ricardian Experiments
- Productivity growth in the trade and distribution sectors is assumed to occur as a result of the accelerated Keynesian investment prescribed above
- A variety of different elasticities of sector total factor productivity growth with respect of investment are considered (0, 0.5, 1.0, 2.0, 4.0)

Neoclassical Experiments
- Productivity growth in all sectors is assumed to occur as a result of the accelerated investment prescribed above

A. Macroeconomic Experiments (Keynesian)

This category of effects focuses on fiscal commitments and aggregation demand and employment linkages. At the national level, a standard macroeconomic model can capture much of this process, but for the entire region, a multicountry framework and a general equilibrium model that more fully captures the myriad of spillover benefits that follow from general investment projects like infrastructure are needed.

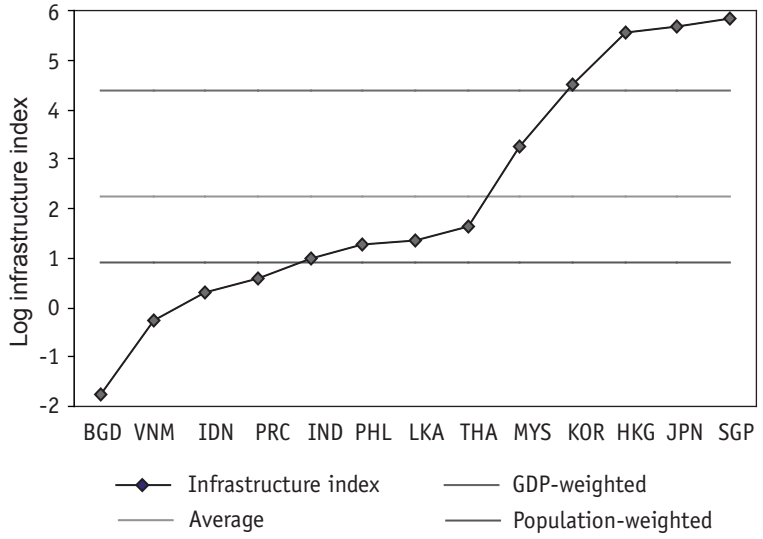
To assess the potential contribution from this kind of aggregate demand stimulus, the starting point is the position set forth in the ADB flagship report: that less developed Asian economies need to attain higher annual rates of infrastructure investment over the long term. In particular, the report suggests that a useful focal point for this investment level over the next decade would be 6.3 percent of GDP. Many economies in the region were below this level and some significantly so, and it can be expected that stepping up their commitments would accelerate growth domestically.

Empirical estimation of Asia's unmet and prospective infrastructure needs was undertaken by the ADB flagship report and is also the subject of an extensive, diverse, and interesting research and policy literature. For the present study, individual national needs for countries that are significantly below their infrastructure need in terms of baseline investment and foregone growth potential are identified. From this perspective, the path-breaking work of Calderón and Servén (2003 a and b)

provides important guidance and data. Although their main contribution was an appraisal of Latin American infrastructure needs, they assembled a global database and estimated historical national indices for infrastructure quantity and quality. These data include many Asian economies, and this subset is used to infer national infrastructure needs and the investment requirements to meet them.

More specifically, Calderón and Servén (2003 a and b) construct a synthetic index of infrastructure from the capital stocks in essential transport, distribution, and communication sectors. Figure 8 below describes the Calderón-Servén index (CSI) for 13 Asian economies in the last year of their sample, 1995.[11] Also included are mean values computed with weights for GDP, population, and as a simple average.

Figure 8
Aggregate National Indexes of Infrastructure Resources, 1995



Note: See Table A2 for definition of country-specific fixed effect variables.
Sources: Calderón and Servén (2005).

Clearly, there are wide disparities across the region, reflecting the same considerations emphasized in Sections II and IV above. To the Calderón-Servén database, national data on investment and capital formation are added to estimate the implied cost of moving countries below mean CSI values to the mean. The regression details are given in the Appendix to this paper, and the following Table 2 summarizes the estimates of the percentage increase in baseline investment that would be needed to move below-mean countries up to the mean. Depending upon which averaging method is thought to represent a reasonable Asian standard for infrastructure availability, these estimates represent the corresponding unmet investment requirement for each country below that standard. For the sake of discussion, the lower (population weighted) standard is adopted as the target for the scenarios that follow.[12]

[11] The index and country abbreviations in the figure are discussed in the Appendix.

[12] For reference, the population weighted standard yields additional investment needs of $157 billion per year, compared to the ADB flagship estimate of $200 billion for Asia's unmet growth needs. For the simple average and GDP-weighted standards, the shortfalls are $816 billion and $2 trillion, respectively.

Table 2
Estimated Changes in Baseline Aggregate Investment, by Type of Target Mean (percent)

	GDP WEIGHTED	SIMPLE AVERAGE	POPULATION WEIGHTED
Bangladesh	613	397	267
Viet Nam	464	249	118
Indonesia	407	191	60
PRC	378	162	31
India	341	125	
Philippines	312	96	
Sri Lanka	302	87	
Thailand	276	60	
Malaysia	114		
Korea			
Hong Kong, China			
Japan			
Singapore			

In particular, for the counterfactual experiments reported here, it is assumed that economies with above average infrastructure levels (Korea, Singapore, etc.) maintain their investment at baseline levels. Asian economies that are below average, by contrast, increase their investment along a logistic trend to reach a steady state exceeding baseline levels by the above percentages by 2015. It is assumed that these investments are financed by a combination of higher domestic saving and external capital inflows, which of course implies requirements for a favorable investment climate that might be difficult to fulfill.

As one would expect in a finance experiment like this, substantial aggregate benefits result from diverting household gross income to investment, even before considering more complex growth linkages. Two main components drive these results, the first-round multiplier effect of government spending (particularly with high average savings rates in Asia), and the macro benefits of domestic and external capital accumulation (incremental capital output ratio and average wage effects). For lower-income countries, and particularly for economies where capital is tightly constrained with respect to labor (Bangladesh and Viet Nam), the effects are substantial, increasing real GDP significantly. In Viet Nam, for example, cumulative GDP over the 20-year period is 40% higher, rising steadily to 65% higher in the terminal year. During the 5-year intervals considered, growth accelerates over the investment stimulus interval and then stabilizes above baseline rates (Table 3). In Bangladesh, for example, accelerated Keynesian infrastructure stimulus adds an average of 3 percentage points to baseline annual GDP growth.

Differences in aggregate growth dividends depend on the relative commitments to accelerated infrastructure investment, and this in turn depends on initial conditions. Bangladesh was farthest behind in this sense (Figure 8), thus it experiences both the biggest percent investment stimulus

and highest Keynesian growth dividend. Viet Nam is second in this sequence, followed by Indonesia and the PRC. With more up-to-date data, the PRC might not even be in the infrastructure-deficient group by the population weighted standard, having already enjoyed much of the estimated Keynesian stimulus from voluntary acceleration of domestic investment over the period 1995–2005.

Table 3
Macroeconomic Results: Annual and Cumulative (2005–2025) Real GDP
(Percent changes from Baseline)

	2010	2015	2020	2025	CUMULATIVE
Bangladesh	5	26	53	74	47
PRC	1	6	11	15	10
Indonesia	2	15	32	46	28
Viet Nam	3	21	44	65	40

These macroeconomic results clearly bear out the importance of the Asian infrastructure initiative (ADB 2005) advanced jointly by ADB, Japan Bank for International Cooperation, and the World Bank. While higher-income countries in the region have the means to meet their own infrastructure requirements, the overall regional gains from further integration will depend for all economies on the capacity of less developed Asian economies to facilitate trade and domestic commerce. The dual challenges of more sustainable and inclusive regional growth can be significantly advanced by accelerated infrastructure investment in these economies.

B. Margin/Price Experiments (Ricardian)

In what the present paper has termed the Ricardian context, infrastructure is seen as reducing transport, trade, and other distribution margins to facilitate broader market participation. As has already been emphasized, this aspect of public investment is particularly appealing because it facilitates individual private agency and promotes self-directed poverty alleviation. Given the remoteness of marginalized communities in some parts of Asia, such indirect commitments can be much more cost-effective than targeted transfer schemes or more direct interventions for poverty reduction.

If one were to assess such policies without a CGE framework, however, many indirect effects could be omitted because of the complex behavioral and structural linkages between reducing trade costs and growth. The survey of the economic literature indicates there are three main ways in which these effects are propagated. First, by reducing commercial margins, infrastructure can narrow the gap between producer and purchaser prices in the domestic economy. The direct effect of this is to benefit domestic agents, particularly those in proximity to improved infrastructure. Indirect effects extend well beyond this however, as narrower margins between producer and purchaser prices increase the scope of profitable commerce and investment, enlarging the domestic market.

A second category of indirect benefits relates to international trade. As border prices come closer to import purchaser prices and to export producer prices, this means net price reductions for the former and increases for the latter. In both cases, terms of trade improve and trade is

facilitated, expanding both domestic absorption and supply to export markets. Finally, a third effect of falling margins relates to domestic returns to scale. Trade and transport margins are an important component of marginal cost, and reducing these will shift the minimum efficient scale of production to higher output levels, allowing firms that increase supply and domestic employment while realizing greater scale economies.

The CGE experiments conducted here are designed to model margin reduction by increasing total factor productivity (TFP) in the sectors that provide distribution services, i.e., trade, transport, and communication. Productivity growth in these sectors arising from infrastructure improvements will translate directly into reduced costs for the services provided by these sectors, thereby making market access less expensive for all. In this set of experiments, the spirit (if not the letter) of an extensive literature is followed, linking infrastructure and productivity of distribution services (e.g., in Aschauer 1989). Aschauer found with US data that an additional dollar invested in public capital yields a much higher economic payoff than another dollar of private capital. Significantly, the main driver of his conclusion was a high temporal correlation between productivity and the stock of public infrastructure. As discussed in Section II above, his results were controversial and propagated an extensive literature.

For the paper's purposes, in the absence of any independent evidence estimating the direct infrastructure-margin cost effect, general inferences from productivity studies are used. All those surveys acknowledge the agency of infrastructure on margins, and all studies agree on the underlying productivity relationship, i.e., that the infrastructure–GDP linkage is positive, but in elasticity terms this effect varies across the literature by two orders of magnitude (from about 10% to 0.1%). However, the vast majority of these studies relied on data for OECD economies, and those estimates that exist for developing countries are higher and more uniform, suggesting a natural diminishing returns relationship. For the present study, the important thing is to use a calibrated simulation model to estimate the economic potential of reduced distribution margins. Individual infrastructure investments and local conditions affecting them will vary, but policymakers need to know how the economy as a whole can respond to improved market access.

For this reason, the following experiments are based on indicative productivity gains that can be seen to span a set of reasonable expectations. This experiment is coupled to the last, with the same logistic profile of accelerated infrastructure investment. In addition, it is assumed that productivity in the distribution sectors increases with four alternative elasticity values epsilon=(0.5, 1.0, 2.0, 4.0) with respect to changes in sectoral investment. Thus a 1% increase in infrastructure investment would increase distribution service productivity by epsilon percent. Note that the first column in these results (Tables 4 and 5), for epsilon=0, corresponds to the Keynesian experiment of the previous subsection.

Aggregate results in Table 4 clearly demonstrate the potential of reduced market access costs to stimulate economic growth and development. To the extent that infrastructure can lower these costs for all market participants, the benefits will be greater the larger the investment relative to the initial stock of infrastructure. For this reason, the poorer countries, with lower levels of initial stocks and concomitantly high internal trade margins, are the greatest relative beneficiaries in the base case (Epsilon=0) and all others. These are precisely the economies identified for accelerated investment by the flagship report, including Bangladesh, Indonesia, Sri Lanka, and Viet Nam. Had it also been targeted for accelerated investment, the Philippines would probably have been in the same category. Note in this set of experiments, however, that the gains are not restricted to these

economies alone. This is because it is assumed that trade and transport productivity effects occur in all countries experiencing new investment, not just those with accelerating investment. There is no productivity growth in the baseline. Taking account of that, even relatively mature economies like Japan can increase cumulative GDP (for 2005–2025) but up to 4 percent.

Table 4
Annualized Growth Rate of Real GDP
(percentage point premium over baseline)

	2010	2015	2020	2025	AVERAGE
Bangladesh	1.0	4.0	4.1	2.9	3.0
PRC	0.3	1.0	1.0	0.7	0.7
Indonesia	0.5	2.5	2.9	2.1	2.0
Viet Nam	0.6	3.5	3.9	2.8	2.7

Table 5
Margin/Price Results:
Cumulative Real GDP, 2006–2025
(percent changes from baseline trend)

	EPSILON				
	0.0	0.5	1.0	2.0	4.0
Bangladesh	47	52	56	65	94
PRC	10	11	12	14	20
Hong Kong, China	0	2	3	6	14
Indonesia	28	29	29	31	35
India	0	1	3	5	12
Japan	0	1	1	2	5
Korea, Rep. of	0	1	1	3	6
Sri Lanka	0	2	4	8	26
Malaysia	0	2	3	5	14
Philippines	–1	0	0	1	3
Singapore	1	2	2	4	8
Thailand	0	1	1	3	6
Taipei,China	0	1	2	4	9
Viet Nam	40	41	42	43	48

Figure 9
Cumulative Real GDP, 2006–2025
(percent change from baseline trend)

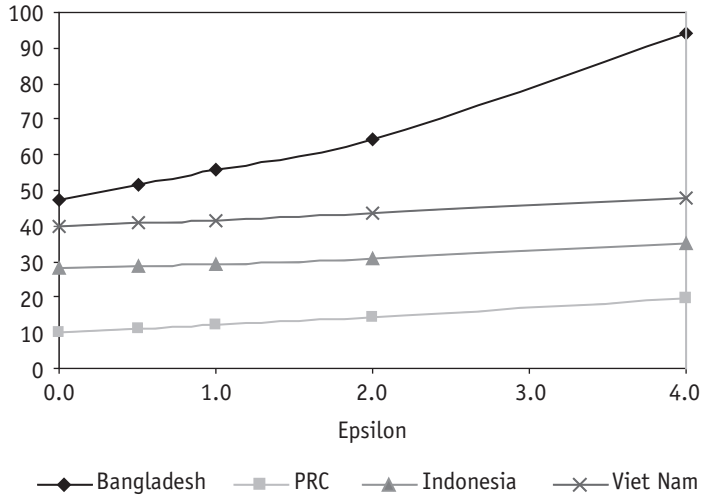
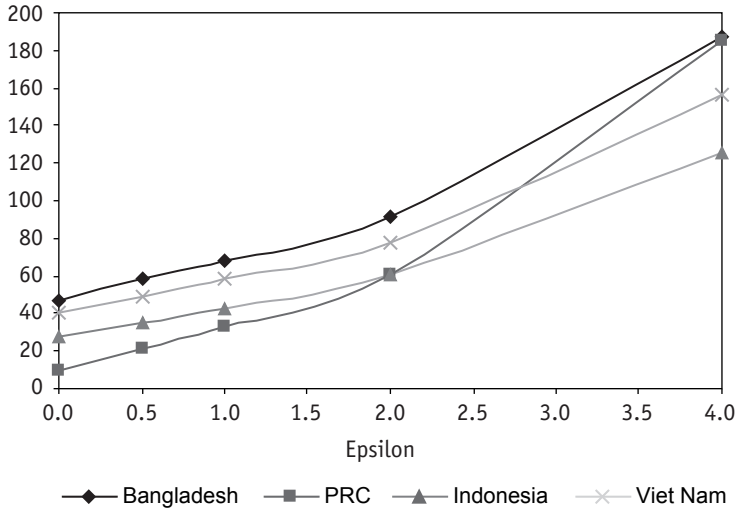


Figure 10
Cumulative Real GDP, 2006–2025
(percent change from baseline trend)



For the poorer economies with accelerated investment, annual real GDP growth rates increase substantially (Table 4), including near doubling in Bangladesh and 50% increases in Viet Nam and Sri Lanka.

C. Endogenous Growth Effects (Neoclassical)

One of the most important insights to emerge from neoclassical studies of trade and development is the notion of endogenous growth effects. Already explained above, this term refers to a wide array of economic factors that have the potential to accelerate growth, are endemic to the economic environment, and are activated by individual incentives arising from either markets or policy interventions. For example, endogenous growth factors include such things as human capital formation (the individual pursuit of education/training), technology transfer from FDI or direct external assistance, inter-industry or intra-industry spillovers, positive network externalities, etc.

Obviously, the diversity of these factors and the complexity of their economic agency make them difficult to study empirically. However, they are believed to be among the most potent stimuli for economic growth and modernization, and as such cannot be ignored. On the contrary, endogenous growth factors like technology transfer and high-skill job creation are among the most sought after elements in multilateral trade and investment negotiations, both public and private. Finally, infrastructure investment is considered to be one of the most important enabling policies to promote endogenous growth processes. For all these reasons, the links between infrastructure and growth through this channel need to be better udnerstood.

As in the previous experiments, productivity is used as a proxy variable for endogenous growth factors. This is appropriate in the present context since productivity (individually and for all factors) is one of the most common metrics for assessing the capacity of an economy for accelerating growth by internal (endogenous) means. To get a tangible sense of how these factors can contribute to growth in the context of Asian regional integration, an extension of the previous two scenarios is considered. In particular, infrastructure trends are assumed to follow those of the first two experiments, but that productivity dividends from infrastructure are more widely distributed across the economy. This extensive productivity view is universally supported in the empirical literature, although its exact magnitude is still a subject of empirical study.

More specifically, in the work discussed at the beginning of this section, Calderón and Servén (2005) construct a synthetic index of infrastructure from the capital stocks in essential transport, distribution, and communication sectors. After extensive econometric specification testing, they obtain results showing that the productivity impact of infrastructure stock on growth is positive, significant, and varies inversely with prior level of the stock. In other words, economies with smaller initial stocks are more growth-sensitive to the same absolute and relative quantity of new infrastructure investment. In particular, these authors find that investments that achieve 5-year movements of two standard deviations in the initial sample distribution of infrastructure stocks would add 1.7–3.1% to the growth rate of bottom quartile economies. The present experiments proxy a low-end 2.0% growth dividend with TFP growth of the same amount in all sectors, assuming this arises from the patterns of investment acceleration used in the last two scenarios. In other words, the growth dividend is not uniform, but depends on the movement of each economy with respect to the initial distribution of infrastructure. Lower-income countries that "catch up" with higher rates of investment will enjoy higher dividends (up to a maximum of 2 percentage points higher real GDP growth). Of course, compounding TFP growth can make average or cumulative growth rates much higher.

In this context then, infrastructure improvements not only lower transaction costs, but also increase individual and TFP. For example, a worker who can drive to work on an improved road saves money and time, increasing both purchasing power and productivity. The experiment reported next assumes the same scenario as the previous sections, but applies infrastructure-induced productivity growth to all sectors in each economy. As in the previous section, the main empirical guidance for this experiment is the exhaustive Latin American survey by Calderón and Servén (2003 a and b; 2005), who explicitly estimate the composite growth and implied TFP effects of infrastructure across an extensive and diverse panel data set. This recent study establishes a nearly definitive standard for econometric estimation in this area, and the results are extended to the Asian context in the absence of anything approaching this statistical quality in the region.

For macroeconomic results in Table 6, the results are predictably higher than in the case where productivity growth is confined to distribution sectors. In the empirical literature on infrastructure and productivity, there is a clear consensus that productivity gains from extensive public goods infrastructure are widely dispersed across economic activities. The extent of this is an empirical question, but a spectrum of productivity (aggregate investment) elasticities is examined as in the previous experiments. Even in this case, doubling GDP growth rates ~~(Table 7)~~ is possible for the economies with lowest prior infrastructure stocks. Other economies in the region are assumed to experience the same productivity benefits from their baseline investment commitments, and their growth premia remind us of the importance of capital accumulation in the dynamic Asian development story.

Among the accelerated investment countries, an interesting case is provided by the PRC's "overtaking" of Bangladesh at higher elasticity levels. The reason for this convergence lies in the PRC's high baseline investment levels. In addition to assuming investment acceleration to close the infrastructure gap, it is assumed in these scenarios that productivity benefits accrue from baseline investment trends. Because of its very high baseline saving-investment rate, the PRC's growth accelerates rapidly when productivity benefits accompany this. Indeed, the PRC places high in the Asian "league table" of growth economies.

Table 6
Margin/Price Results Annualized Growth Rate of Real GDP
(percentage point premium over baseline)

	EPSILON				
	0.0	**0.5**	**1.0**	**2.0**	**4.0**
Bangladesh	3.0	3.2	3.4	3.7	4.9
PRC	0.7	0.8	0.9	1.0	1.2
Hong Kong, China	0.0	0.1	0.2	0.3	0.8
Indonesia	2.0	2.0	2.1	2.1	2.3
India	0.0	0.1	0.2	0.3	0.8
Japan	0.0	0.0	0.1	0.1	0.3
Korea, Rep. of	0.0	0.1	0.1	0.2	0.4
Sri Lanka	0.0	0.1	0.3	0.6	1.7
Malaysia	0.0	0.1	0.2	0.4	0.9
Philippines	–0.1	0.0	0.0	0.0	0.2
Singapore	0.1	0.1	0.2	0.3	0.5
Thailand	0.0	0.1	0.1	0.2	0.4
Taipei,China	0.0	0.1	0.2	0.3	0.6
Viet Nam	2.7	2.7	2.8	2.8	3.0

Table 7
Endogenous Growth Results: Cumulative Real GDP, 2006-2025
(percent changes from baseline trend)

	EPSILON				
	0.0	**0.5**	**1.0**	**2.0**	**4.0**
PRC	10	21	33	61	185
Hong Kong, China	0	3	6	13	33
Indonesia	28	35	43	61	126
India	0	7	15	32	101
Japan	0	2	4	7	19
Korea, Rep. of	0	4	8	17	46
Sri Lanka	0	5	11	23	71
Malaysia	0	8	17	36	111
Philippines	–1	2	5	12	36
Singapore	1	5	8	16	42
Thailand	0	4	8	17	49
Taipei,China	0	4	9	18	49
Viet Nam	40	49	58	78	156

Table 8
Endogenous Growth Results: Annual Real GDP Growth Rates, 2006–2025

	EPSILON				
	0.0	**0.5**	**1.0**	**2.0**	**4.0**
Bangladesh	3.0	3.4	3.9	4.7	7.3
PRC	0.7	1.4	2.0	3.2	6.9
Hong Kong, China	0.0	0.2	0.4	0.8	1.8
Indonesia	2.0	2.4	2.8	3.5	5.8
India	0.0	0.5	1.0	1.9	4.7
Japan	0.0	0.1	0.3	0.5	1.3
Korea, Rep. of	0.0	0.3	0.5	1.1	2.6
Sri Lanka	0.0	0.3	0.7	1.4	3.6
Malaysia	0.0	0.6	1.1	2.1	5.1
Philippines	–0.1	0.1	0.3	0.7	2.0
Singapore	0.1	0.3	0.6	1.0	2.3
Thailand	0.0	0.3	0.6	1.1	2.8
Taipei,China	0.0	0.3	0.6	1.1	2.7
Viet Nam	2.7	3.0	3.4	4.1	6.4

These endogenous growth results are not at all hypothetical in qualitative terms, as can be made apparent with an important example of Asian regional development, supply networks. One of the more dramatic modern manifestations of reduced trade costs and productivity growth is the regional and global decomposition of supply chains. Foreign direct investment and contractual linkages are distributing production tasks, employment, and income around the world for a myriad of reasons. These include factor price differences, local and regional market access, and simple diversification strategies, but in all cases, the result is an ever-growing web of regional trade linkages. This trend has been greatly facilitated in the Asian region by infrastructure investment, which reduces network management and integration costs and sharpens the differentials between costs and prices in different locales. As this process evolves, the emergence of mature industries where there once was only a primary product or component producer (see Box 3) is seen. Each time this happens, the individual locality migrates up the value added ladder and local resources command higher premia in the global marketplace. In this way, supply chain decomposition and the infrastructure that makes it possible contributes to ever wider networks of value creation, and more stable and equitable regional growth.

Box 3
A Regional Example: Bamboo Capitalism

- Network externalities in local production and finance allow complete markets to sprout from nodes in a global root system of intermediate supply.
- This culminating aspect of global supply chain decomposition has created a diverse and vibrant population of independent local industries around the East Asian region.
- Many emergent enterprises are still bound to their roots by ownership or component supply contracts.
- Increasingly, however, they arise as independent suppliers of finished products with their own brands, technologies, and marketing. This trend is an important driver for the dynamics of global competitiveness and innovation.

In East Asia, this process has advanced very quickly and pervasively, facilitated by both western FDI and a "stepladder effect" where more advanced Asian economies reallocate production to less advanced ones. In the process of distributing supply chains, foreign investors in the region create new nodes of production in different localities, and another indirect phenomenon emerges. Bamboo capitalism describes a process where fully autonomous enterprises and markets sprout from these nodes in the "root system" of global intermediate supply. This process is long established in the tiger economies and can be seen to emerge now in the PRC (even across the PRC) and other emerging Asian economies. The result is replication of industries and markets at an exponential rate. Infrastructure, whether publicly or privately financed, is a prerequisite for effective participation in this regional production sharing.

VI. INFRASTRUCTURE DEVELOPMENT GOALS

One of the most important contributions infrastructure can make to economic progress is improving the living standards of the poor. Improved living standards can take many forms, from increased market access to better quality of and access to essential public goods. As part of its broad-based commitment to advancing infrastructure's contribution to Asian regional integration and growth, ADB has placed high priority on poverty alleviation. In this paper, the many facets of infrastructure's contribution to economic growth have been discussed. This section proposes a concrete set of development goals that explicitly recognize these contributions (compare, e.g., Canning 1998). Formally, these objectives are called the Infrastructure Development Goals (IDGs) to evoke their close relationship with the UN's more general Millennium Development Goals (MDGs) that assess progress in global living standards. While the infrastructure goals are of independent interest, their conformity with the MDGs recognizes the usefulness of the latter in the international development dialogue, and is also intended to emphasize the integral contribution of infrastructure to improving the livelihoods of the majority of the world's poor.

In its 2005 report, *Connecting East Asia: A New Framework for Infrastructure* (ADB 2005), ADB emphasized the importance of infrastructure's contribution to the MDGs. Here that linkage is made more explicit by setting forth eight IDGs that can be used to measure the performance and progress of public and private development participation in poor countries. The goals cover direct economic contributions from infrastructure, but also include a variety of other welfare criteria associated with economic activity, education, health, environment, and sustainability. Establishing specific, transparent standards and metrics to measure infrastructure's contribution to improved standards of living, as well as a policy dialogue to support this process, can support more effective development strategies for development and emerging economy growth policy.

The following eight IDGs are proposed for use in publicly and privately financed evaluation (Box 4).

Box 4
Infrastructure Development Goals

Goal 1: Eradicate Infrastructure Poverty. Halve, between 1990 and 2015, the proportion of people who lack access to basic infrastructure services.

Goal 2: Achieve Universal Access to Primary Education. Ensure that, by 2015, children everywhere, boys and girls alike, have local access to full-time primary educational resources.

Goal 3: Improve Access to Information and Communication Technology. Reduce by three-quarters, by 2015, the number of households without local and affordable access to telecommunication and digital information services.

Goal 4: Improve Electrification. Reduce by two-thirds the number of households without access to in-home electricity.

Goal 5: Improve Market Access. Promote investment in transport infrastructure that can reduce average domestic seller and worker travel times by two-thirds, preferably by 2015.

Goal 6: Improve Public Health Access. Promote more extensive investment in public health resources, increasing local access for urban and rural populations generally and for the poor in particular. Reduce by three-quarters, preferably by 2015, the average combined travel and queuing time for access to licensed health care services.

Goal 7: Promote Environmental Sustainability. Integrate the principles of sustainable development into infrastructure policies and programs, and reverse the losses of environmental resources.

Reduce by three-quarters, by 2015, the proportion of people without sustainable access to safe drinking water.

Reduce by three-quarters, by 2015, the proportion of people without sustainable access to sanitation services.

Goal 8: Develop a global partnership for Infrastructure. Establish the institutional framework needed to facilitate coherent multilateral approaches to infrastructure development, including regional policy coordination, financial market integration, and standards and technology sharing.

VII. CONCLUDING REMARKS

Infrastructure can play a significant role in promoting regional integration and with it more rapid and sustained growth in Asia. Using a global CGE model, infrastructure is found to be a potent catalyst for wider economic participation, both within and between Asian economies, and that it can promote private, individual agency as a means of poverty alleviation and more rapid growth among the poorest regional economies. The basic approach elucidates the role of infrastructure as a demand stimulus, a means of reducing trade costs, and as an agent of productivity growth. In the first case, significant economywide multiplier effects accelerate growth, particularly in less developed regional economies whose initial conditions require faster investment rates to upgrade their infrastructure.

A series of simulations focusing on trade cost reduction indicate that infrastructure investment can facilitate domestic market access and regional integration, sharply increasing economic growth, but its effects vary significantly between economies. Two types of countries are most likely to gain: those with very high prior domestic margins, and those with high prior levels of external

trade dependence. Investment in domestic infrastructure is especially important for less open low-income countries. In these cases, external partnerships could be an important source of investment leverage to overcome domestic savings constraints, and the results indicate these initiatives would be rewarded with superior regional growth rates and improvements in regional equity via economic convergence. Multilateral strategies of this kind are indeed essential to make regional growth and integration opportunities more inclusive. The estimates reinforce the importance of infrastructure to overcoming bottlenecks to growth, particularly in terms of broader regional market participation. These general conclusions could be refined with more intensive local empirical work, but they are unlikely to be contradicted.

Finally, appealing to an extensive theoretical literature on endogenous growth effects, but a fairly narrow basis of prior empirical work, indicative results are given about how infrastructure-induced productivity growth can stimulate regional integration and convergence. These results need refinement with more localized data on the infrastructure–growth–productivity nexus. Despite this caveat, however, these results can faithfully illustrate infrastructure's potential as a catalyst for growth and regional poverty alleviation, and believe that qualitative results obtained here will also prove robust to more localized calibration.

Extensions of the present work could shed much new light on the more detailed effects of infrastructure commitments at every stage, including financial/fiscal sourcing, domestic, bilateral, and multilateral project implementation, and a myriad of downstream assessments including economic facilitation (as studied here), productivity spillovers and other growth externalities, income growth, and distributional outcomes. Given the importance of these issues to development in general and ADB's mission in particular; and in recognition of the capacity of GE models to account for these complex effects, the present approach can support a broad agenda of policy research with more detailed empirical study.

As a final observation, it is worth noting that the current experiments have not addressed trade policy directly. To clearly identify the role of infrastructure in domestic economic growth, the experiments are not compounded with scenarios, for example, for regional or global trade liberalization. This would be a natural extension of the present work, and would in all likelihood demonstrate strong complementarity between Asian regional policy agendas for economic integration, trade, and investment.

APPENDIX

REGRESSION RESULTS FOR ASIAN INFRASTRUCTURE NEEDS

Calderón and Servén (2005) report estimates for an index of infrastructure availability obtained for a global database of over 100 countries covering the period 1960–1995. The index was constructed to measure availability of three categories of infrastructure: telecommunications, electric power, and road/rail networks.[13] The three variables are stocks measured with respect to population (L) or total national surface area (A) as follows:

$$CSI_{it} = 0.6159 \ln\left(\frac{Z_1}{L}\right)_{it} + 0.6075 \ln\left(\frac{Z_2}{L}\right)_{it} + 0.5015 \ln\left(\frac{Z_3}{A}\right)_{it}$$

this variable is depicted in Figure 8 discussed earlier and provided the basis for the following regression estimates of unmet investment needs (Table A1):

Table A1
Regression Results for Infrastructure Investment Requirements

Source	SS	df	MS		Number of obs =	85
					F(13, 72) =	183.93
Model	740.238122	13	56.941394		Prob > F =	0.0000
Residual	22.2897486	72	.309579841		R-squared =	0.9708
					Adj R-squared =	0.9655
Total	762.527871	85	8.97091612		Root MSE =	.5564

linv	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
CSI	1.125155	.0349089	32.23	0.000	1.055566	1.194745
bgd	3.928857	.2292571	17.14	0.000	3.471841	4.385873
idn	4.349985	.2208816	19.69	0.000	3.909665	4.790304
kor	.2854137	.223805	1.28	0.206	–.1607334	.7315608
lka	.2580208	.2104293	1.23	0.224	–.1614623	.677504
mys	.0844627	.2142628	0.39	0.695	–.3426624	.5115878
phl	1.839141	.2104679	8.74	0.000	1.419581	2.258701
tha	2.838656	.2114507	13.42	0.000	2.417137	3.260175
prc	6.404122	.2345318	27.31	0.000	5.936592	6.871653
hkg	-2.797971	.3680138	–7.60	0.000	–3.531593	–2.064349
sgp	-3.870027	.2649475	–14.61	0.000	-4.39819	–3.341864
ind	4.160417	.2115945	19.66	0.000	3.738611	4.582223
pak	2.726337	.2288788	11.91	0.000	2.270075	3.182598

The results are based on a 13 country Asian subsample of the Calderón and Servén database, consisting of 85 observations pooled in 5-year intervals from 1960 to 1995. Some countries were not reporting until the 1970s and the last decade has been very important to infrastructure development in the PRC and a few other

[13] See Calderón and Servén (2005) for details about the dataset, indicator definitions, and their own extensive estimation of infrastructure productivity effects.

rapidly emerging economies. Nonetheless, the results are very robust in terms of overall goodness of fit and individual significance of the main explanatory variable (CSI) and the country dummies (defined in Table A2). Japan is the omitted country, so levels of infrastructure density are defined with respect to this economy (i.e., Hong Kong, China and Singapore above and the rest below the Japanese intercept; see Figure 8).

These results indicate that infrastructure development in Asia is highly correlated with overall investment; indeed in the 5-year intervals, an elasticity of just over unity between aggregate capital formation and the Calderón and Servén indicator is seen. The strength of this relationship will vary between countries, but it indicates that high rates of domestic capital formation in Asia contribute strongly to the national commons of productive infrastructure.

TABLE A2
VARIABLE DEFINITIONS

Dependent Variable
linv – Logarithm of aggregate domestic investment

Independent Variable
CSI – Calderón and Servén Index of infrastructure availability

Country-specific Fixed Effect Variables
bgd – Bangladesh
idn – Indonesia
ind – India
jpn – Japan
kor – Korea
lka – Sri Lanka
mys – Malaysia
pak – Pakistan
phl – Philippines
prc – People's Republic of China
hkg – Hong Kong, China
sgp – Singapore
tha – Thailand
twn – Taipei,China
vnm– Viet Nam

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