BUILDING A STRONGER AMERICA

THE ROLE OF INFRASTRUCTURE INVESTMENT IN ECONOMIC GROWTH

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A Century Foundation Report

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This paper is part of The Century Foundation's new series, Building a Stronger America, which focuses on providing specific, concrete ideas for upgrading the nation's decaying and inadequate infrastructure. The goal of the series is both to deepen and to broaden the public's understanding of the problems we now confront, while offering proposals beyond the plans already in wide circulation. Carrying out these ideas will not only help the country to emerge from the current, severe economic downturn, but also will greatly enhance the prospects for good jobs and sustained, broadly shared prosperity decades into the future.

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The Question

The idea that infrastructure investment should have a positive effect on economic growth is intuitively appealing. Roads, electricity provision, and communications appear to be necessary for the basic functioning of an economy. It is not hard to write an economic model linking infrastructure and productivity, and indeed several such models have been written. Thus, one would expect the existence of a link between infrastructure and development to have been long established.

However, the discussion of the link between infrastructure and economic growth is far from settled. A number of prominent authors have argued that this link is weak or nonexistent, and the question as to whether infrastructure should be given preference in public investment decisions is a controversial one. This report intends to serve as a guide to literature on this link that clarifies the grounds for disagreement between different authors and the implications of existing empirical results.

Theoretically, the idea that public capital can have an effect on productivity growth and capital accumulation goes back at least as far as theoretical models developed by economists in the 1970s.[1] These economists began with the idea that the economy's income is a direct result of its private capital, public capital, and labor. All three factors affect each other, in fact.[2] Two key questions emerge from this framework. The first is, how large an effect there is on income or output to be gained by increasing the provision of public capital? The second is, how are private and public capital related? For example, to what extent will additions of public capital crowd out private capital by using the existing pool of savings?

Evidence from the United States

Empirical studies of the relationship between public investment and productivity growth were rare before the late 1980s. A series of studies by David Aschauer changed this.[3] Aschauer argued that public investment needed to be taken into account when studying economic growth, and his research found that fully 57 percent of the post-1970 U.S. productivity slowdown could be explained by the decline of infrastructure investment during the same period. This spurred talk of inadequacies in infrastructure investment as being “America’s Third Deficit.”

Aschauer’s evidence was threefold. In his first paper on this topic, he found that a measure of “core infrastructure”—which included highways, mass transit, airports, electrical and gas facilities, water, and sewers—had a highly significant effect on both labor and productivity.[4] The decline in U.S. infrastructure investment after 1970 had led, according to Aschauer’s calculations, to a decline in the productivity growth rate of 0.8 per cent a year—a very large effect.

Aschauer’s second and third papers complemented this with evidence comparing experience across states and other nations.[5] The results of these studies were consistent with the time-series evidence for the United States in Aschauer’s initial studies. Infrastructure spending was found to have a significant positive effect on productivity. The estimated returns to investment in public infrastructure were between two to five times the returns to private investment. Alicia Munnell expanded on Aschauer’s studies in two directions. Munnell refined Aschauer’s calculation by adjusting labor inputs to take account of changes in the age and sex of the labor force, and she updated the sample period.[6] In a second paper, she utilized state-level estimates of the public and private capital stock, which had been previously unavailable.[7] She also estimated the effect of public investment on private investment, to test whether the former crowded-out the latter or not. It turned out to have the opposite effect. Public investment apparently attracted more private investment, presumably by improving returns on such investment due, for example, to faster and more efficient services and transportation of goods and people. These complementarities were so large, they suggested that the provision of greater public capital led to greater private productivity and greater public investment.

The results of Aschauer and Munnell’s research generated considerable excitement and immediately spilled over into discussions in the policy arena. The U.S. Council of Mayors called for a massive increase in infrastructure spending in a 1992 report. Samuel Skinner, the transportation secretary under George H. W. Bush, and New Jersey governor James Florio made similar calls.[8]

The Clinton-Gore presidential campaign seized on this political consensus by making its $20 billion "Rebuild America" program of massive infrastructure investments the centerpiece of its economic plan.[9]

Almost simultaneously, however, a number of economists started questioning the Aschauer and Munnell results. Critics raised three basic objections. In the first place, it appeared that Aschauer and Munnell's results implied implausibly high rates of return for investment in public capital. In the second place, it was argued that the relationships they found could be spurious and merely due to coincidences in common trends. Third, increases in public capital stocks may itself have resulted from higher public investment as income rose. So, higher levels of infrastructure investment may not have been the cause, but rather the consequence of growing income.

The first point was made forcefully by Edward M. Gramlich.[10] He noted that the Aschauer's work implied rates of return on public investment as high as 100 percent. Public investment therefore basically would pay for itself. But if this was true, asked Gramlich, would private investors not "be clamouring to have the public sector impose taxes or float bonds to build roads, highways, and sewers to generate these high net benefits?" Gramlich argued that, if anything could be observed, it was that private investors believed the opposite: private investors were more often heard arguing that tax rates were, if anything, too high.

The second point was made by a number of critics, and paralleled a general preoccupation with the pervasiveness of spurious econometrics methodologies that arose at that point. Aschauer's statistical methods were now being widely questioned.

The third objection was raised by Douglas Holtz-Eakin, who revisited the Aschauer-Munnell results but took into account factors specific to individual states.[11] His results undermined the conclusions found by both Aschauer and Munnell. Once one controls for state-specific effects, Holtz-Eakin shows, the productivity-infrastructure link disappears, and in some cases actually turns insignificantly negative.

Thus, by the mid-1990s, the pendulum had swung back the other way. Now, critics of the position that there was a serious link between infrastructure investment and productivity had gained the upper hand. In a review article in the *National Tax Journal,* two of them argued that "the link between infrastructure and economic performance is, at the margin, *very weak***.** Thus, much of the research that followed David Aschauer's work provided little support for the hypothesis that it was the slowdown in infrastructure spending which caused the economy to perform poorly over the last 20 years."[12]

But did these criticisms really demonstrate that infrastructure had no effect on private sector productivity? Let us look at them in turn. First, there is the argument made by Gramlich that the estimated rate of return on public capital in the Aschauer and Munnell studies is implausibly high. This argument begs the question: Too high with respect to what? How large would we expect an accurate estimate of this rate of return to yield? It is practically impossible to answer this question without a well-specified political economy model that allows us to understand how public decisions regarding the provision of infrastructure and other public goods are made. One thing is clear: public choice models that can account for an under-provision of public goods are not in short supply. They go back at least to Gareth Hardin's famed work on the "tragedy of the commons."[13] In a recent analysis, for example, two researchers show that electoral competition commonly leads to an under-provision of public goods, and that the U.S. electoral system—the Electoral College—is particularly prone to this bias.[14] The reason is that, even if there are many efficient infrastructure programs in existence, politicians will often have much greater ability to target inefficient pork-barrel spending for constituents. The same reasons that make public infrastructure a pure public good—that is, it benefits many activities that range beyond state and local political constituencies—also make it extremely difficult for potential beneficiaries to organize in order to pressure for its provision. This argument echoes Mancur Olson's well-known argument about the lack of incentives for collective action to provide public goods.[15] The influential Virginia School of public choice emphasized precisely this element of public policymaking—that collective decisions commonly would yield suboptimal outcomes.[16] The crux of these arguments is that there is a distinction between socially preferred outcomes and the outcomes that one will see defended in the midst of the political process. There is certainly no scarcity of examples of unambiguously mistaken policy choices that fly in the face of any assumption that governments choose expenditure levels optimally. Yet, those who, like Gramlich, assert that the estimated rate of returns are implausibly high have in mind a political economy model in which grossly inefficient policy choices are not feasible.[17] His model, judging by the data we have, is surely no more plausible than Aschauer's implicit one.

The second objection, that Aschauer's results are due to spurious correlations, is certainly correct: it is by now broadly recognized that one has little to learn from the statistical methodologies Aschauer depended upon. At best, Aschauer's findings can be characterized as one data point: the coincidence of an increase in infrastructure spending and increasing productivity in a time series. There is a problem with the objection to Aschauer, however. It is not clear that much information can be extracted from relatively short time series utilized by Aschauer's critics to claim contrasting results. Suppose that there is a link between infrastructure and productivity, but that it has an uncertain and variable timing, which certainly seems plausible. It could take time for firms to learn how to take advantage of infrastructure improvements, for example; such timing may depend on the precise type of project and the sectors that it affects. Estimating this complex relationship would require a correct specification of the relevant relationships, which is much more than what we may be able to achieve with existing data. In this case, a prolonged period of infrastructure improvements should be followed by a trend of growing productivity; a collapse of infrastructure spending, if maintained over time, would lead to a decline in productivity. But given the longer lags and more uncertain timing of the benefits, one should not be surprised if the analyses done by some critics of Aschauer[18]—which simply test whether increases in infrastructure provision lead to increases in productivity in the same year—yields insignificant results. The criticism is correct in throwing doubt on the inferences that can be drawn from Aschauer and Munnell's results, but they do not establish that the data is inconsistent with or necessarily undermines the hypothesis of a large effect of infrastructure spending on productivity. In fact, there may simply be no adequate way to draw valid inferences from this data given the small number of observations available and the complex underlying economic structure in the real world.

In principle, the hypothesis of a long-run relationship between infrastructure and productivity could be appropriately dealt with by using other sophisticated techniques. One of these requires searching for what is known as a co-integration relationship. But even when such estimates find little relationship between infrastructure investment and productivity, they also have weaknesses and simply are not sufficiently powerful to rule out the possibilities.

Most of the more sophisticated tests have been relatively short-term. As sample length is increased, some of these statistical tests in have fact found evidence for a relationship between infrastructure investment and productivity.[19] It could be simply that the tests so far performed have simply not covered a long enough period.

The third objection, based on the finding that existing correlations disappear when one controls for state-level factors, could be much more serious. Except again such relationships are typically difficult to find when such specific variables are included. This has turned out to be the case in many studies that compare national economic performance.[20]

What does seem to bear fruit is to try to focus more directly on the possible channels by which infrastructure investment may raise productivity. John G. Fernald undertook one of the most careful attempts to do this.[21] He starts out from a simple observation: if infrastructure were a significant force behind productivity growth, then we would expect the link between productivity growth and public capital to be greater for industries that use roads intensively. If the building of infrastructure were simply a reaction to income growth, or if both were caused by a third, unknown factor, there would be no correlation between the intensity of road use for an industry when infrastructure investment increased and rising productivity. Indeed, Fernald finds just this. When growth in the stock of roads increases, productivity increases disproportionately in industries that intensively use vehicles. Fernald's estimates indicate that the growth of infrastructure provision in the United States from 1953 to 1973 had an average annual rate of return of 104 percent, quite in line with Aschauer's original estimate. However, Fernald also finds that the rate of return decreased dramatically after 1973. He also finds that after 1973, there was still a quantitatively and statistically significant positive effect of roads on manufacturing productivity. But the effect of infrastructure investment in non-manufacturing productivity turned negative (albeit not significantly so) in the post-1973 period.

The most logical interpretation of Fernald's results appears to be related to the construction of the vast interstate highway network in the 1950s and 1960s. This network was largely completed by 1973, after which the productivity effect of further road building was likely to be negligible. Fernald's results also would explain the reason why some studies found no effect of infrastructure capital on productivity using cross-state data. The data used was only available for the post-1970 period, when the interstate highway system was by and large completed.[22]

An important implication of Fernald's results is that governments in less-developed economies in which a network of national roads is lacking may accrue substantial gains from undertaking such a project. The fact that the United States now has very low returns from infrastructure investment at the margin, according to Fernald, may be a reflection of the fact that it has invested a lot in the past, with substantial realized payoffs already. But it is also possible that after years of neglect, new infrastructure investment in the U.S. may have a higher pay-off. From the standpoint of a poor country that does not have a national highway system, the relevant elasticity estimates would be the pre-1973 estimates, and the lack of such a system may be an important reason for its inability to converge to the level of income of rich countries.[23]

Another paper worth mentioning is one by Etsuro Shioji.[24] This paper estimates conditional convergence growth regressions á la Robert J. Barro and Xavier Sala-i-Martin[25] on a panel of U.S. regions. The key distinction between his approach and that of Holtz-Eakin is that Shioji uses growth as the dependent variable and initial per capita income and the public capital stock as right-hand-side variables. The convergence approach, however, allows for estimation of the effect of a public capital stocks on the steady-state level of income, thus taking into account not only its effect on productivity but also its induced effect on GDP via higher private capital accumulation, an effect that is missed by conventional production function estimates. The convergence approach also serves to reduce the effect of certain types of endogeneity bias that arise from using endogenous capital stocks and labor inputs as right-hand-side variables in the production function estimation.[26] What is interesting is that, *despite controlling for regional fixed effects*, Shioji obtains significant effects of infrastructure spending on productivity growth, with elasticity estimates of 0.08 to 0.14 for the United States. These estimates, while roughly half the values of Aschauer's original elasticity estimate of 0.24, still imply considerable rates of return for public infrastructure investments of 20–35 percent. More importantly, the validity of Holtz-Eakin's claim that the infrastructure-productivity link depends on the omission of state fixed effects appears sensitive to the choice of specification.

As this literature evolved toward a more nuanced understanding of the relationship between infrastructure and productivity growth, the very facts that Aschauer had set out to attempt to explain changed. For more than twenty years before 1995, measures of productivity grew unusally slowly. But from 1995 to 2000, the basic measure of labor productivity, output per hour of work in non-farm business, grew at an average annual rate of about 2.5 percent compared with increases of only about 1.5 per cent per year from 1973 to 1995. Many economists attributed the increase to advances in information technology as well as the greater use of information technology capital.[27] The coincidence of these increments in productivity with the massive investment in the development of the Internet, which, after all had its origin as a government project in the U.S. Department of Defense and which received a huge boost under the Clinton-Gore administration, underscores the potentially high payoffs to public infrastructure projects.[28] While it may be true that it would make little sense to build another interstate highway system, as Fernald's work suggests, that does not mean that the public sector has run out of socially productive infrastructure projects. In the words of Berkeley Lab's Tsu Loken, "The federal government has a long history of investment in the nation's infrastructure. It built canals in the 18th century, railroads in the 19th century, and interstate highways in the 20th century. Then, about 10 years ago, it began the construction of high-speed computer networks. These networks are the highways of the Information Age."[29]

Evidence from Other Economies

Although the U.S. literature is particularly extensive, many country-level studies in other developing and developed economies also have examined the link between infrastructure and development. A good example of the work for Organisation for Economic Co-operation and Development (OECD) economies is the contribution of two Spanish economists, Angel de la Fuente and Xavier Vives, who estimated regional output in Spain and found a strong significant effect of public capital investment on output.[30] Interestingly, the authors showed that, while infrastructure investment has the potential to reduce regional disparities significantly, it was not used effectively for that purpose. Another study uses a similar design for examining the role of infrastructure investments among countries in the European Union and found a significant effect of public capital investment on productivity growth.[31]

Much of the literature looking at developing countries has been concentrated on understanding the links between infrastructure investment, growth, and income inequality at the regional level. Two economists used Chinese provincial level data for the 1982–99 period to study the links between road development and regional economic growth.[32] While during this period China followed a strategy of emphasizing the building of high-quality roads, the authors find that the returns to this type of investment pale in comparison with those of low-quality roads, with estimated cost-benefit ratios that are four times as high as those of high-quality roads. But the implication is that appropriate infrastructure investments have not only the potential to generate high levels of growth but also to reduce income inequality significantly.

In particular, appropriate infrastructure investments appear to have a significant effect on the well-being of the poor. One study in the Lao People's Democratic Republic found that, of the 9.5 percent decline in the incidence of rural poverty between 1997 and 2003, about 13 percent could be explained by improvements in the access to roads of rural households.[33] Using rare data on the value of farmland and distance to agricultural markets from Nepal's 1995–96 Living Standards Survey, another study finds that providing road access generates significant economic gains to poor households.[34]

A number of in-depth development case studies also have emphasized the role of infrastructure. Lack of basic infrastructure, for example, plays a prominent role in the hypothesis of Jeffrey Sachs and his colleagues that African economies are trapped in a low-income rut—a low-income "equilibrium"—that markets reinforce.[35] The authors point to the fact that, in the majority of villages in countries such as Ghana and Malawi, the distance to the nearest pickup point for motorized transport is two kilometers, while for more than a tenth of villages it is ten kilometers. Under these conditions, it is very difficult for a large part of the population to become integrated into any type of market activities. These studies have suggested that a large influx of foreign aid to help defray the costs of large infrastructure investments would help these countries' economies to achieve sustainable high-income levels that would, from then on, allow their own economies to pay for the maintenance of these networks.

Historical studies also have pointed to the relevance of infrastructure in the rapid development of U.S. industry during the nineteenth century. The role of railroads and canals in explaining the high economic growth in the United States has been explored in a vast empirical literature going back to the seminal contributions of Douglass C. North and Robert Fogel.[36] Similar results are found from transport improvements in Brazil and Mexico, where economic growth improved significantly after the building of railroad networks.[37] Railroad development occurred much later in Latin American countries than in the United States, helping to explain why Latin America fell significantly behind the United States in terms of economic performance during the nineteenth century.

Cross-National Evidence

In contrast to the U.S. research literature, studies of infrastructure and growth across countries tend to find positive rates of return to infrastructure investment, no matter the research methodology used. Rather, debate among researchers has centered not on whether there are positive effects, but the magnitude of the return and the wisdom of investing in infrastructure vis-à-vis other investment options that may be faced by the government. The first and most common reference in this literature is a paper by William Easterly and Sergio Rebelo.[38] The aim of the Easterly and Rebelo's analysis was to give a picture of the relationship between fiscal policy and growth, and it is often cited for its unexpected finding that higher tax rates are not systematically associated with higher growth rates. At the same time, Easterly and Rebelo found that public transport and communication investment was positively correlated with growth. The coefficient was very high and remained positive and significant in instrumental variables estimation (with an estimated elasticity of 0.16). The authors were somewhat puzzled by this high coefficient, but cited other World Bank studies that often found similarly high rates of return for specific transport and communications projects.

Discussion

I have surveyed some of the key empirical contributions to the study of the growth-infrastructure link. There are bodies of other research that I have not summarized fully because of their technicalities. Some suggest that infrastructure investment may be too high in certain countries, for example. But on balance, the research is either far from conclusive or suggests that infrastructure investment does improve rates of growth. Granted, at first glance, this literature generates considerable confusion, with contradictory results emerging out of many studies and with radically different positions being voiced in the policy debate. However, a closer look at this literature finds that it is possible to make some sense out of it.

Essentially, as discussed, there are two sources of negative results in the literature. On the one hand, there are the negative results on U.S. time series and cross-section data that grew out of the criticism of Aschauer's original claims. While many of these criticisms are technically right, we also have seen that at best they show that the time series and cross-region data of the United States is inconclusive. However, most country studies in Europe as well as in developing countries, and the overwhelming majority of cross-national studies, find a significant role for infrastructure in the explanation of economic growth.

In my view, the fact that the positive relationship which emerges in many of the statistical studies across nations can be ignored only by developing new measures that suggest infrastructure investment is mostly a function of growth, not a cause. But studies that explore these issues find little evidence of this, including one I did with Jose Pineda.[39] There also could be other variables that affect these outcomes, but I have yet to see that argument made well.

Ultimately, the reading of the evidence must also rely on our basic understanding of the world and a fair bit of common sense. If it were true that public infrastructure were unproductive, one should be able to imagine a world with substantially lower levels of public infrastructure (for example, the United States without an interstate highway system) and argue that private capital would yield the same returns as it does now. Personally, I find that kind of world very hard to imagine.

Claiming that infrastructure has a positive effect on economic growth is very different from saying that infrastructure investment must be increased, however. Given the objectives of policymakers, there is likely to be both an optimal level of government spending and an optimal distribution of that spending among different categories which include spending on education, health, security, and general public services. The answer to the question of whether there is overinvestment in infrastructure is certainly country-specific, and will depend on the society's priorities as well as the social returns to different types of expenditures. That said, much of the literature has suggested very high rates of return to infrastructure investment, suggesting that in many instances the answer is likely to require an increase in infrastructure investment. Understanding the nature of the political constrains on public investment and the reason why many government budgets seem biased towards current expenditures is a promising area for future research.

Notes

1. K. J. Arrow and Mordecai Kurz, *Public Investment, the Rate of Return and Optimal Fiscal Policy* (Baltimore, Md.: Johns Hopkins University Press, 1970); Seititsu Ogura and Gary Yohe, "The Complementarity of Public and Private Capital and the Optimal Rate of Return," *Quarterly Journal of Economics* 91, no. 4 (1977): 651–62.

2. Previous to the work of these authors, the common assumption had been that public capital and private capital were either substitutes for each other or that their effects were independent of each other. See the discussion in Ogura and Yohe, "The Complementarity of Public and Private Capital and the Optimal Rate of Return." More technically, the commonly used specification is Y = F(G,K,L) with *L* denoting aggregate employment. See, for example, R. J. Barro, "Government Spending in a Simple Model of Endogenous Growth," *Journal of Political Economy* 98 (1990), 103–25.

3. D. A. Aschauer, Does Public Capital Crowd Out Private Capital? *Journal of Monetary Economics* 24, no. 2 (1989): 171–88; D. A. Aschauer, "Is Public Expenditure Productive? *Journal of Monetary Economics* 23 (1989): 177–200; D. A. Aschauer, *Public Investment and Private Sector Growth* (Washington, D.C.: Economic Policy Institute, 1990).

4. To be precise, multi-factor productivity, the output of the economy that cannot be attributed simply to inputs of capital and labor. See Aschauer, "Does Public Capital Crowd Out Private Capital?"

5. Aschauer, "Is Public Expenditure Productive?" D. A. Aschauer, "Public Investment and Productivity Growth in the Group of Seven," *Economic Perspectives* 13, no. 5 (1989): 17–25.

6. A. H. Munnell, "Why Has Productivity Growth Declined? Productivity and Public Investment," *New England Economic Review* (January/February 1990): 3–22.

7. A. H. Munnell, "How Does Public Infrastructure Affect Regional Economic Performance?" *New England Economic Review* (September/October 1990).

8. See the discussion in A. H. Munnell, "Infrastructure Investment and Economic Growth," *Journal of Economic Perspectives* 6, no. 4 (1992): 189–98.

9. Bill Clinton and Al Gore, *Putting People First: How We Can All Change America* (New York: Times Books, 1992).

10. E. M. Gramlich, "Infrastructure Investment: A Review Essay," *Journal of Economic Literature* 32 (September 1994): 1176–96.

11. Douglas Holtz-Eakin, "Public Sector Capital and the Productivity Puzzle," *Review of Economics and Statistics* 76 (1994): 12–21.

12. Charles R. Hulten and Robert M. Schwab, "Infrastructure Spending: Where Do We Go from Here?" *National Tax Journal* 46, no. 3 (1993): 271 (emphasis in original).

13. Gareth Hardin, "The Tragedy of the Commons," *Science* 162 (1968): 1243–48.

14. Alessandro Lizzeri and Nicola Pesico, "The Provision of Public Goods under Alternative Electoral Incentives," *American Economic Review* 91, no. 1 (2001): 225–39.

15. Mancur Olson, *The Logic of Collective Action* (Cambridge, Mass.: Harvard University Press, 1971).

16. For a review, see Dennis Mueller, *Public Choice* (Cambridge, U.K.: Cambridge University Press, 2004). .

17. Gramlich, "Infrastructure Investment."

18. In particular, see Charles R. Hulten, and Robert M. Schwab, *Is There Too Little Public Capital? Infrastructure and Economic Growth* (Washington, D.C.: American Enterprise Institute for Public Policy Research, 1991).

19. Pierre Perron and Robert J. Shiller, "Testing the Random Walk Hypothesis: Power vs. Frequency of Observation," Discussion Paper no. CFDP732, Cowles Foundation for Research in Economics, Yale University, New Haven, Connecticut, 1984. C. S. Hakkio and Mark Rush, "Cointegration: How Short Is the Long Run? *Journal of International Money and Finance* 10 (1991): 571–81.

20. Francesco Caselli, Gerardo Esquivel, and Fernando Lefort, "Reopening the Convergence Debate: A New Look at Cross-Country Growth Empirics," *Journal of Economic Growth* 1, no. 3 (1999): 363–89.

21. J. G. Fernald, "Roads to Prosperity? Assessing the Link between Public Capital and Productivity," *American Economic Review* 89, no. 3 (1999): 619–38.

22. Holtz-Eakin, "Public Sector Capital and the Productivity Puzzle."

23. Fernald's results also underscore the existence of nonlinearities in the production function. Aschauer finds that allowing for this nonlinearity radically changes the results: whereby linear estimates of production functions at the cross-state levels deliver an infrastructure effect that disappears when state-effects are introduced, the nonlinear effect is robust to the introduction of state-effects and suggests that permanent changes in public capital are associated with permanent changes in economic growth. See D. A. Aschauer, "Do States Optimize? Public Capital and Economic Growth," *The Annals of Regional Science* 34 (1999): 343–63.

24. Etsuro Shioji, "Public Capital and Economic Growth: A Convergence Approach," *Journal of Economic Growth* 6 (2001): 205–27.

25. Robert J. Barro and Xavier Sala-i-Martin, *Economic Growth* (Cambridge, Mass.: MIT Press, 1991).

26. Both approaches are still subject to simultaneity bias arising from endogeneity of the pubic capital stock.

27. Stephen D. Oliner and Daniel E. Sichel, "Information Technology and Productivity: Where Are We Now and Where Are We Going? *Journal of Policy Modeling* 25, no. 5 (July 2003): 477–503.

28. A. S. Blinder, *The Internet and the New Economy,* Policy Brief 60 (Washington, D.C.: Brookings Institution, 2000).

29. Jeffery Kahn, "Building and Rescuing the Information Superhighway," *LBL Research Review* (1993), http://www.lbl.gov/Science-Articles/Archive/information-superhighway.html, accessed November 20, 2005.

30. A. de la Fuente and X. Vives, "Infrastructure and Education as Instruments of Economic Policy: Evidence from Spain," *Economic Policy* 20 (April 1995).

31. C. Gil, P. Pascual, and M. Rapún, "Structural Change, Infrastructure and Convergence in the Regions of the European Union," *European Urban and Regional Studies* 9, no. 2 (2002): 115–135.

32. S. Fan and C. Chan-Kang, *Road Development, Economic Growth and Poverty Reduction in China,* Discussion Paper (Washington, D.C.: International Food Policy Research Institute, 2004).

33. P. Warr, *Road Development and Poverty Reduction: The Case of Lao PDR,* Research Paper Series no. 64 (Manila, Philippines: Asian Development Bank Institute, 2005).

34. H. G. Jacoby, "Access to Markets and the Benefits of Rural Roads," *Economic Journal* 100 (July 2000): 717–37.

35. Jeffrey D. Sachs et al., "Ending Africa's Poverty Trap," *Brookings Papers on Economic Activity* 1 (2004): 117–240.

36. Douglass C. North, *The Economic Growth of the United States, 1790–1860* (Englewood Cliffs, N.J.: Prentice-Hall, 1961); Robert Fogel, *Railroads and American Economic Growth: Essays in Econometric History* (Baltimore, Md.: Johns Hopkins University Press, 1964).

37. W. Summerhill, "Transport Improvement and Economic Growth in Brazil and Mexico," in *How Latin American Fell Behind: Essays on the Economic Histories of Brazil and Mexico, 1800–1914,* S. Haber, ed. (Stanford: Stanford University Press, 1997).

38. William Easterly and Sergio Rebelo, "Fiscal Policy and Economic Growth: An Empirical Investigation," *Journal of Monetary Economics* 32 (December 1993): 417–58.

39. José Pineda and Francisco Rodríguez, "Public Investment in Infrastructure and Productivity Growth: Evidence from the Venezuelan Manufacturing Sector," Wesleyan University Economics Department, Middletown, Connecticut, 2005. About the Author

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