United States Department of Agriculture

Economic Impacts, Costs, and Benefits of Infrastructure Investment: Lessons from the Literature

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* The views expressed are those of the authors and should not be attributed to USDA, the Economic Research Service, or the World Bank.

Motivation

- President Trump has proposed investing $200 billion of Federal funds to stimulate up to $1.5 trillion in total infrastructure investment
  - $50 billion in Federal funds for rural infrastructure
- Need for infrastructure investment appears clear:
  - ASCE (2017) estimated $4.6 trillion in investment needed by 2025 to bring infrastructure to “good condition” ($2.1 trillion investment gap)
- However, the impacts of and net returns to such investment are less clear and hotly debated in the literature

Objectives

- Review the literature on economic impacts of and rates of return to infrastructure capital stocks and investments
- Draw lessons relevant to policy debates and decisions about where to invest
- Identify gaps and opportunities for future research relevant to infrastructure investments

Scope of Review

- Review of predictive models and econometric literature, emphasizing
  - Peer-reviewed literature (mainly)
  - Literature since late 1980s
  - Studies of the U.S. and developing countries
  - Highways/roads, telecommunications, water & sewer, electricity, water resources development
  - Not limited to studies of rural infrastructure, but priority to research that includes impacts in rural areas
  - Where available, sought estimates of rates of return to infrastructure stocks or investment

Outline of Rest of Presentation

- Some key concepts
- Findings from input-output (IO) models; strengths and limitations of IO models
- Econometric productivity impact studies
- Amenity value of infrastructure
- Studies of broadband impacts in the United States
- Cost-benefit analysis of U.S. infrastructure investments
- Impacts of infrastructure investments in developing countries
- Key findings and research implications

Some Key Concepts (1)

- *Impact* – the difference between what happened *ex post* (or would happen *ex ante*) with an intervention and what would have happened without it
- *Cost* – the value of resources used in some activity if employed in their highest value alternative use
- *Benefit* – the value people would be willing to pay for something, if they could be charged for it
- *Benefit-cost ratio* (BCR) – ratio of present value of benefits to present value of costs
- *Transfers* – impacts that affect the distribution of benefits and costs but not aggregate net benefits

Some Key Concepts (2)

- *Output elasticity of capital* - the percent increase in the annual value of output resulting from a 1% increase in the value of the capital stock
- *Marginal rate of return to capital* - the increased annual value of output resulting from a $1 increase in the value of the capital stock
- The marginal rate of return to capital can be calculated by multiplying the output elasticity by the output/capital ratio
- *Internal rate of return* – the discount rate that sets the discounted benefits equal to the discounted costs

Some Key Concepts (3)

- The marginal return to public capital is not the same as the internal rate of return to Federal investment. Differences due to:
  - *Displacement* – Increases in Federal investment may reduce investment by states and local governments
    - CBO (2016) estimated that each $1.00 of increased Federal investment increases total public investment by $0.67
  - *Depreciation* – some investment is needed to offset depreciation of capital stocks
  - *Timing* – the marginal return to capital reflects the annual return on capital stocks existing at a point in time; internal rate of return accounts for timing of costs & benefits of investment
- These reasons imply IRR of Federal investment could be much lower than the marginal return to public capital

Findings from Input-Output (IO) Models

- IO models and Social Accounting Matrix models based on IO models estimate multiplier effects of an increase in spending in a sector due to demand linkages
- Employment impacts in range of 14,000 to 28,000 jobs per $1 billion invested in two national studies (Heintz et al. (2009), DeVol and Wong (2010)
- Impacts depend on the type of infrastructure considered, mainly due to imports required

Strengths and Limitations of IO Models

- Strengths
  - Fairly easy to implement
  - Provide ex ante estimates of impacts
  - Account for indirect and induced impacts of upstream activity
- Limitations
  - Don’t account for downstream impacts – e.g., impacts on firms’ productivity, costs, or profits; or on consumer welfare
  - Restrictive assumptions – constant returns to scale and fixed proportions production functions of firms, no supply constraints or input supply effects, no price responses
  - Assumptions less suited to full employment economy
  - OMB (1992) does not consider multiplier effects to be benefits

Econometric Productivity Impact Studies (1)

- Aschauer (1989) is the seminal study
  - Used national data for 1949 to 1985 to estimate aggregate production function including public capital stocks
  - **Estimated elasticity of private output to nondefense public capital of 0.39 and a marginal rate of return of 50-60%**
  - Largest impact of “core infrastructure” – highways, transit, airports, electric/gas facilities, water & sewer
  - Study criticized for large estimates of returns to public capital, methodological shortcomings
- Stimulated hundreds of studies of productivity impacts of public capital in different contexts, using different methods, for different types of capital

Econometric Productivity Impact Studies (2)

- We reviewed 28 published studies that estimated the output elasticity of public capital in the U.S.
- The mean output elasticity estimated was 0.12
  - Less than 1/3 of Aschauer’s estimate
  - Similar to mean of estimates from global literature
- But there is large variation in the estimates, which range from -0.49 to 0.56
- Few studies estimated the marginal return to public capital implied by their estimates – we provide some estimates on next slide

Econometric Productivity Impact Studies (3)

Elasticity or marginal return of	Elasticity		Marginal Rate of Return	
	National Level Data	State Level Data	National Level Data	State Level Data
Total nondefense public capital	0.265*	0.033	**37%**	5%
“Core” infrastructure (transportation, water & sewer, electric & gas)	0.365*		**97%**	
Highways	0.158	0.006	67%	3%
Water and sewer		0.075*		**88%**
Other state & local (buildings, other structures, equipment)		-0.036		-67%

* Means statistically significantly different from 0 at 5% level

Econometric Productivity Impact Studies (4)

- Main findings from comparative review:
  - Output elasticities larger in studies using national level data (like Aschauer) than state level data
  - Elasticities larger for core infrastructure in general and specifically for water & sewer facilities
  - Large variations in implied marginal rates of return across infrastructure types, due to variations in output/capital ratios

Econometric Productivity Impact Studies (5)

Two studies estimated impacts on firms’ costs or profits:

- Morrison & Schwartz (1996) found that public capital reduced manufacturing firms’ costs in all U.S. regions, with **marginal rates of return in 1987 ranging from 22% in the East and North to 35% in the South**
- Vjiverberg et al. (1997) estimated the **marginal return to Federal public capital to be 59%** and the **marginal return to state and local public capital to be 14%** based on profit impacts

Econometric Productivity Impact Studies (6)

- Pereira (2000) investigated dynamic relationships among public and private investment, private employment, and output.
- **Estimated long-term rates of return (akin to IRR to public investment)**:
    - **Highways and streets – 3.4%**
    - **Conservation and development structures – 7.2%**
    - **Buildings – 8.9%**
    - **Water and sewer systems – 9.7%**
    - **Electric and gas facilities, transit systems, airports – 16.1%**

Amenity Value of Infrastructure

- None of the productivity studies accounted for consumptive amenity effects of infrastructure
- Three studies addressed this:
  - Dalenberg and Partridge (1997) - found that highways and water & sewer capital are associated with lower state level wages; interpreted as evidence that these are amenities
  - Haughwout (2002) estimated that **the BCR for increases in the public capital stock in 33 large cities was in range of 0.3 to 0.6**. Most of the benefit of infrastructure due to amenity effects rather than productivity effects.
  - Albouy and Farahani (2017) updated and extended Haughwout's approach for 55 cities, and estimated a **BCR range for increases in the public capital stock of 0.6 to 2.1**

Studies of Broadband Impacts in the U.S. (1)

- Most studies found positive impacts of broadband availability or adoption on employment level or growth
- Impacts on output, earnings, or income were mixed and often statistically insignificant across studies and contexts
- Several studies found that broadband availability was associated with lower wages or income in some contexts
- This finding is consistent with broadband being an amenity; suggests need to investigate impacts on property values as well as wages

Studies of Broadband Impacts in the U.S. (2)

- Two studies investigated impacts of broadband on rents or property values:
  - Lehr et al. (2006) found conflicting results on impact at zip code level depending on method used
  - Molnar et al. (2015) – based on data from 500,000 house sales – estimated that **access to fiber optic capability increases house values by 1.3%, that faster download speeds (from 25 mbps to 1 gbps) increase house prices by up to an additional 6%**, and that a greater number of ISP's also increase house prices
  - Considering a median house value of $200,000, a 1.3% increase in value/house = $2,600 per house. Multiplied by 83 million houses = $216 billion; large potential wealth impact

Studies of Broadband Impacts in the U.S. (3)

- Two studies investigated the impacts of USDA’s pilot and regular Broadband Loan Program (BBLP)
  - Kandilov and Renkow (2010): pilot BBLP had positive impacts on several outcomes – employment, payroll and number of establishments – but little evidence that the regular BBLP had positive impacts by 2007
  - Kandilov et al. (2017): pilot and regular BBLP had positive impacts on farm sales, expenditures, and net revenues, though the impacts of the pilot program were larger

Studies of Broadband Impacts in the U.S. (4)

- Several studies investigated heterogeneity of broadband impacts
  - Several studies found that broadband has more positive impacts where people are more educated or skilled
  - Studies reach conflicting conclusions whether broadband has more positive impacts in more rural areas

Cost-Benefit Analysis (CBA) of Infrastructure Investments in the U.S. (1)

- The U.S. Army Corps of Engineers (USACE) has used CBA for more than a century
- BCR of at least 1.0 is required for many USACE investments; some require higher BCRs (e.g., BCR of 2.5 or higher for projects justified solely on basis of economic return)
- **BCRs ranging from 1.1 to 4.5 are estimated for current USACE projects**
- The Federal Highway Administration (FHWA 2015) estimated BCRs for alternative investment scenarios. Across scenarios, the **lowest estimated BCRs range from 1.8 to 2.0 for Federal-Aid Highways; and from 1.0 to 1.7 for the National Highway System and Interstate Highways**.

Impacts of Infrastructure in Developing Countries

- Certain types of infrastructure projects may lend themselves to rigorous impact evaluation methods
- This is particularly the case when infrastructure is rolled out over time and geographic space, or when certain parameters are being evaluated which can be used for then estimating rates of returns to infrastructure
- Good examples include:
  - Dinkelman (2011) on electrification in South Africa, Torero et.al (2017) and Barron & Torero (2017) on electrification in El Salvador
  - Mu and van de Walle (2011) on roads in Vietnam, Torero et.al (2017) work on roads in El Salvador
  - Jensen (2010) on cellphones for Indian fisheries

Impacts of Roads in Developing Countries

- Road investments have significant effects in many cases on a range of outcomes, including
  - Increased agricultural productivity
  - Reduced transportation costs
  - Changes in commodity prices
  - Increased nonfarm economic activity
  - Increased employment
  - Increased rural household incomes and reduced poverty
  - Increased property values
  - Increased access to health and education services; and others.
- Road development has tended to benefit men more than women; some studies have found that the impacts of road development are greater for poor people

Impacts of Electricity in Developing Countries

- Rural electrification found to have positive impacts on rural people's economic activity, income, and welfare in many cases
- Impacts identified include:
  - Household time savings, allowing households to work more hours by increasing their access to markets (Bernard and Torero 2011)
  - Increased investment in education among school-age children
  - Increased participation by women in income-generating activities; increased probability of operating a home business (Torero et al. 2017)
  - Reduced indoor air pollution, which reduced the incidence of acute respiratory infections among children and lowered exposure to pollutants among adult household members (Barron and Torero 2017)

Impacts of Water & Sanitation in Developing Countries

- The health impacts of water and sanitation programs have been well studied
- However, very few studies have measured other important outcomes, such as: education, gender and social inclusion, and income and consumption
- The evidence on effects on income and consumption is limited, and very few studies have looked at the effect on productivity or labor market outcomes; no discernible effects have been found on these outcomes to date

Key Findings (1)

U.S. literature

- Many studies find that infrastructure investments in the U.S. have positive productivity impacts, though there is large variation across studies
- Larger productivity impacts and marginal returns to public capital found in studies based on national data than studies based on state data – possibly due to spillover impacts, but limited support from studies that investigated this
- Larger productivity impacts and marginal returns found for core infrastructure in general and water & sewer in particular
- Range of marginal returns to public capital from 97% for core infrastructure and 88% for water & sewer to 0 or negative for highways and other types

Key Findings (2)

- One study investigated dynamic relationships of public investment with private investment, employment and output, found long term rates of return to public investments ranging from 3% (for highways and streets) to 16% (for electric & gas facilities, transit systems and airports)
- Two studies considered amenity as well as productivity impacts. The first estimated the BCR to be in the range of 0.3 to 0.6 in 33 cities; the more recent study estimated BCR in the range of 0.6 to 2.1 in 55 cities. (BCRs in such city-focused studies don’t account for spillover impacts on nearby regions).

Key Findings (3)

- Several studies investigated impacts of broadband in the U.S.; most found broadband to have positive impacts on employment; more mixed impacts on wages or income. Impacts vary by degree of rurality, education levels, and other factors.
- Estimated BCRs for current USACE projects range from 1.1 to 4.5; minimum BCRs for FHWA projects range from 1.0 to 2.0

Developing country literature

- Beneficial impacts of roads, electricity, and cell phones found on a range of outcomes in developing countries. But such impacts are not always found across the nearly 200 studies reviewed; e.g., economic impacts of water and sanitation not found.

Implications for Future Research (1)

- More research is needed to estimate costs, benefits, and rates of return to different types of infrastructure investments in different contexts
- Studies of productivity impacts of infrastructure could be more useful if they estimated the marginal return to infrastructure implied by their data and elasticity estimates
- More research is needed on other impacts of infrastructure besides productivity, such as amenity values
- Research drawing on rigorous *ex post* impact assessments to validate and improve cost-benefit analysis could be valuable. Distinguishing transfers from impacts that affect aggregate net benefits is likely to be a challenge.

Implications for Future Research (2)

- Rigorous impact evaluation of infrastructure investments is also challenging because of nonrandom placement of infrastructure, the difficulty of identifying a suitable comparison group, length of time to experience impacts, etc.
- Impacts estimated in econometric studies are sensitive to the context of the study, the data and econometric models used. More research is needed demonstrating which data and models produce the most reliable estimates.

Thank you. Questions?

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